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42nd European Conference on Visual Perception (ECVP) 2019 Leuven

Welcome Address

We are very pleased to introduce to you the yearly issue of Perception with the abstracts of all presentations at the European Conference of Visual Perception (ECVP). The 42nd edition of ECVP was held in Leuven (Belgium), from Sunday August 25 till Thursday August 29, 2019, and consisted of 2 keynotes, 15 symposia, 33 regular talk sessions, and 8 poster sessions. In total, the program contained 273 talks and 415 posters, enough for 4 full days.

In addition, we had a series of 12 splendid tutorials focused on hot topics, techniques and research skills, we had a historical exhibition (highlighting the long and strong tradition in experimental perception research in Leuven) and a "Phenomenal Vision Night" – both open to the broader public as well. These additional components are not visible in the present set of abstracts, but you can find more information about them on the ECVP 2019 website: https://kuleuvencongres.be/ecvp2019.

We believe that this year's program contained a good mix of traditional ECVP ingredients in terms of content and approach, which were spiced up with some local Leuven flavors (perhaps some more neurophysiology, modeling, and clinical work than usual).

We have been able to put this together with the financial support from our sponsors, with the advice and help of extensive scientific and organizational committees, with the professional assistance by the Conference and Event Office of KU Leuven, and the peer reviews from 140 willing colleagues (all mentioned on the website).

In any event, we hope you find it useful to have access to this compilation of short descriptions of all the research findings and insights presented at ECVP in Leuven this year.

Johan Wagemans, on behalf of the scientific and organizing committees of ECVP 2019

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Keynotes

Perception Lecture: Sunday, August 25, 2019

A Broader Vision of Object Recognition

Marlene Behrmann
Carnegie Mellon University, Pittsburgh, PA, USA

The recognition of objects, including faces, common objects, and words, is typically assumed to be under the purview of the ventral cortical visual system. Decades of empirical studies using neuroimaging as well as single-unit recording in awake behaving nonhuman primates have supported this conclusion. I will describe recent studies from my laboratory that examine the nature of these ventral neural representations including investigations that permit the reconstruction of the images displayed to the observer using functional magnetic resonance imaging data acquired from ventral cortex. I will then go on to argue that signals associated with object recognition extend beyond ventral cortex and that representations in the dorsal visual pathway are also tuned to represent shape and identity properties of objects. I will describe studies using functional magnetic resonance imaging and psychophysics in both normal and brain-damaged individuals that support the role of dorsal regions in the recognition of visual objects. Finally, I will explore the plasticity of these object representations in individuals with cortical resections to ventral or dorsal regions. I will suggest that objects are widely represented in the brain, that neural maps are mutable, and that the challenge is now to understand the necessity and sufficiency of these representations.

Rank Prize Lecture: Wednesday, August 28, 2019

Shedding the Bright Light of Information Processing on the Black Box of Brain Activity (and Deep Networks)

Philippe Schyns
University of Glasgow, UK

We can now measure brain activity very well, in space, in time and at different levels of granularity. However, what we really want to know is not brain activity per se, but the processing of information that this activity reflects. To bridge this brain-activity-to-information explanatory gap, we need to reconsider brain imaging from the foundations of psychology. Developing from the methodologies of psychophysics and visual cognition, I will present a new data-driven framework that delivers information processing from brain activity and thereby better realizes the promise of brain imaging (and deep networks).

Symposia

Symposium 1: Monday, August 26, 2019

Neural and Clinical Markers of Face Processing (Invited Leuven ECVP Symposium)

Disorders of Human Face Recognition and Their Value in Fundamental and Clinical Research

Bruno Rossion
CNRS UMR 7039, Universite de Lorraine, Nancy, France

The human species has a unique ability to recognize individuals from their faces, calling upon the most complex mechanisms of perception and memory. Clinical disorders are at the root of our understanding of these mechanisms and their neural basis. This is very well illustrated by the variety of clinical populations experiencing difficulties at individual face recognition as presented in this symposium: autism spectrum disorder, neurodegenerative disorders, impairments of face recognition of developmental origin, and posterior stroke. From a clinical research perspective, difficulties at individual face recognition can therefore have a high diagnostic value, whether they occur in isolation or are part of more general cognitive impairments. From a fundamental research perspective, however, the study of rare single classical cases of prosopagnosia—a sudden neurological inability to specifically recognize individual faces occurring in a neurotypically developed face recognition system—remains invaluable. Systematic observations of such patients as well as of cases of transient prosopagnosia following intracerebral electrical stimulation inspire and constrain our understanding of the critical right lateralized cortical face network subtending human face recognition.

Probing the Origins of the Face Inversion Effect With an Extraordinary Participant

Lucia Garrido[1], Tirta Susilo[2], Constantin Rezlescu[3] and Bradley Duchaine[4]
[1]Brunel University London, UK
[2]Victoria University of Wellington, New Zealand
[3]University College London, UK
[4]Dartmouth College, Hanover, NH, USA

We describe the case of Claudio, who is a man with a congenital condition (arthrogryposis multiplex congenita) that has affected multiple joints of his body. As a result of his condition, Claudio's head is rotated backward so that it nearly rests against his back. Therefore, like most people, Claudio has lifelong experience of viewing upright faces but, unlike most people, his own face orientation does not match upright faces (at least, most of the time). This extraordinary case has allowed us to probe the origins of the face inversion effect: Does it result from phylogenetic factors or from experience? We tested Claudio on a number of face detection and face identity perception tasks. All tasks showed reliable inversion effects in controls, in that almost all participants were better at detecting or matching upright faces compared with inverted faces. In contrast, for a large number of these tasks, Claudio's performance with upright and inverted faces was comparable. In addition, Claudio's performance on tasks with upright faces was much worse than controls'. These results suggest that the face inversion effect results from a combination of experience and phylogenetic factors.

Understanding Face Processing in Autism Spectrum Disorders With Fast Periodic Visual Stimulation Electroencephalography

Bart Boets[1], Stephanie Van der Donck[1], Sofie Vettori[1], Milena Dzhelyova[2], Corentin Jacques[1], Jean Steyaert[1] and Bruno Rossion[3]
[1]KU Leuven, Belgium
[2]UC Louvain, Belgium
[3]Université de Lorraine, Nancy, France

Humans are social beings par excellence. Efficient face processing, such as recognizing face identity and interpreting facial expression, plays a major role in social communication. Individuals with autism spectrum disorder (ASD) are characterized by impairments in social communication and interaction, including difficulties in face processing. Yet, it remains challenging to assess these daily life difficulties in an experimental laboratory environment. Here, we propose a new neuroimaging approach to quantify the individual sensitivity for subtle and implicit sociocommunicative cues by means of fast periodic visual stimulation electroencephalography (EEG). We present data on 25 school-aged boys with ASD, as compared with 25 well-matched typically developing boys, on a series of fast periodic visual stimulation EEG experiments assessing social preference, facial identity processing, and facial expression processing. Results indicate that this extremely versatile EEG technique reliably differentiates between children of both groups. We will discuss the basic principles of this innovative approach as well as the potential clinical applications for early assessment and detection of sociocommunicative impairments in ASD and beyond.

Recognition of Facial Identity in Subjects at Risk for Neurodegeneration

Jan Van den Stock, Daphne Stam, Joke De Vocht, Philip Van Damme and Mathieu Vandenbulcke
KU Leuven, Belgium

Recognition of facial identity and emotion typically proceeds effortlessly and fast in healthy subjects. Functional brain imaging studies in normal subjects have revealed dedicated areas to process faces and their many dimensions such as identity and emotion. Clinical studies in patients with brain damage in areas that are associated with face processing can provide insight into the nature of the role of these regions. We combined behavioral assessment with brain imaging in subjects at risk for neurodegeneration. A sample of presymptomatic carriers of the C9orf72 mutation, causing amyotrophic lateral sclerosis and frontotemporal dementia and matched controls underwent structural brain MRI and performed psychophysical tasks targeting identity and emotion processing. The neuroimaging results revealed a clear reduction of gray matter volume in the bilateral thalamus (primarily in the pulvinar nucleus) in the C9orf72 group. The behavioral results revealed deficits in the C9orf72-sample in recognition of facial identity and facial emotion. Impaired facial identity recognition in this sample was correlated with regional gray matter volume in the anterior cerebellum and temporal pole. The findings add to knowledge on face recognition and indicate that structural brain characteristics of nonatrophic regions are associated with face processing deficits in neurodegeneration, even at the presymptomatic level.

Face Recognition Deficits in Posterior Stroke—Are There Hemispheric Differences?

Randi Starrfelt
University of Copenhagen, Denmark

Severe and selective problems with face recognition (prosopagnosia) can occur following injury to posterior cerebral areas and are typically associated with right lateralized or bilateral lesions. Milder and less selective deficits have been reported following damage to either hemisphere. We have investigated face processing in a large sample ($N = 65$) of patients with stroke in the posterior cerebral artery recruited based on lesion anatomy rather than symptomatology. Patient performance is compared with controls ($N = 48$) in a case series design. We tested different aspects of face processing using several tests and experimental paradigms: delayed matching, surprise recognition, Cambridge Face Memory Test, famous face familiarity, recognition, and naming. We also included a questionnaire about face recognition ability following stroke. We find that deficits in face recognition may follow left and right unilateral as well as bilateral posterior cerebral artery stroke. A few patients show consistent, severe deficits across face tests, and this can occur following left, right, or bilateral stroke. No patients in our sample show consistent, severe, and selective deficits in face recognition (a conservative definition of prosopagnosia). Rather, they also show deficits in object recognition and reading, although in some patients, these additional deficits are much less severe than their problems with faces.

Symposium 2

Comparing Deep Nets and Primate Vision: The Need of Recurrent Processing to Fill the Gap (Invited Leuven ECVP Symposium)

Feedforward and Feedback Interactions for Perception and Learning in Deep Cortical Networks

Pieter Roelfsema
Netherlands Institute for Neuroscience, Amsterdam, the Netherlands

Most scientists believe that early visual cortex is responsible for the analysis of simple features, while cognitive processes take place in higher cortical areas. However, there are findings that implicate early visual cortex in visual cognition—in tasks where subjects reason about what they see. Are these cognitive effects in early visual cortex an epiphenomenon or are they functionally relevant for mental operations? I will discuss new evidence supporting the hypothesis that the modulation of activity in early visual areas has a causal role in cognition. I will discuss how figure-ground perception emerges in an interaction between lower and higher brain regions, with a special role for feedback connections and specific classes of interneurons. I will next address how feedback connections guide learning. It is not yet well understood how a neuron in the sensory or association cortex optimizes the strength of its synapses to improve the performance of the entire network. I will argue that this "credit-assignment problem" is solved in the brain when feedback from motor cortex gates plasticity in upstream cortical areas. Feedback connections thereby create the conditions for biologically plausible rules for deep learning in the brain.

The Role of Recurrent Computations During Pattern Completion

Bill Lotter
CHB/HMS, Harvard University, Boston, MA, USA

During everyday vision, we routinely need to make inferences from partial information when objects are partially visible due to occlusion or poor illumination. The ability to perform pattern completion in these circumstances is a fundamental aspect of visual cognition. I will present behavioral, physiological, and computational observations that strongly suggest that pattern completion is unlikely to be instantiated through purely feedforward processing. The evidence comes from behavioral experiments showing that pattern completion requires additional processing time, that pattern completion is disrupted by backward masking, in addition to neural recordings showing that physiological responses along the ventral stream also show delays during recognition of occluded objects. Furthermore, state-of-the-art bottom-up models struggle to recognize heavily occluded objects. Finally, I will provide proof-of-principle computational models including recurrent connectivity that are consistent with recent neurophysiological recordings and neuroanatomy and are able to perform pattern completion. I will argue that recurrent computations play a critical role in the ability to complete patterns and make inferences from partial information.

Object Recognition in Man and Machine

Felix A. Wichmann
University of Tübingen, Germany

Convolutional neural networks (CNNs) have been proposed as computational models for (rapid) human object recognition and the (feedforward-component) of the primate ventral stream. The usefulness of CNNs as such models obviously depends on the degree of similarity they share with human visual processing. In my talk, I will discuss two major differences we have found between human vision and current feedforward CNNs: first, distortion robustness—unlike the human visual system, typical feedforward CNNs fail to cope with novel, previously unseen distortions and second, texture bias—unlike humans, and contrary to widespread belief, standard CNNs primarily recognise objects by texture rather than by object shape. Both differences between humans and CNNs can be diminished; however, we created a suitable data set which induces a human-like shape bias in standard, feedforward CNNs during training. The shape-bias of the CNN was accompanied by emerging human-level distortion robustness. Taken together, our experiments highlight how key differences between human and machine vision can be harnessed to improve CNN robustness by inducing a human-like bias. I will discuss the remaining behavioural differences between CNNs and humans in object recognition in terms of architectural and training discrepancies.

Symposium 3

Big Data in Vision Science

The Importance of Large-Scale Vision Science in Psychology, Neuroscience, and Computer Science

Martin N. Hebart[1], Charles Y. Zheng[2], Adam H. Dickter[1], Alexis Kidder[1], Wan Y. Kwok[1], Anna Corriveau[1], Caitlin Van Wicklin[1], Francisco Pereira[2] and Chris I. Baker[1]
[1]Laboratory of Brain and Cognition, National Institute of Mental Health, Bethesda, MD, USA
[2]Section on Functional Imaging Methods, National Institute of Mental Health, Bethesda, MD, USA

In vision science, experimenters are often faced with a difficult trade-off between the degree of experimental control and the choice of naturalistic stimuli and tasks that more closely reflect our everyday interactions with a visual world. Recent developments in large-scale vision-science promise a shift of this balance toward larger stimulus spaces, more complex tasks, and naturalistic environments. In this talk, I will lay out different approaches where large-scale vision science can improve the generality of research findings while maintaining similar levels of experimental control. After an overview of different applications, I will exemplify this strategy using research recently conducted in our own laboratory. First, I will present the large-scale object concept and object image database THINGS that contains more than 26,000 natural images of 1,854 object concepts sampled to be representative of our use of concepts in the American English language. Second, I will present results from a large-scale online crowdsourcing experiment of around 1.5 million trials that allows us to identify key dimensions that shape our mental representational space of objects. I will conclude with an outlook onto ongoing collaborative neuroscientific and computational research that promises large-scale multimodal neuroimaging data sets of object perception made available to the public.

A Large Single-Participant Functional Magnetic Resonance Imaging Data Set for Probing Brain Responses to Naturalistic Stimuli in Space and Time

K. Seeliger[1], R. P. Sommers[2], U. Güçlü[1], S. E. Bosch[1] and M. A. J. van Gerven[1]

[1]Donders Institute for Brain, Cognition and Behaviour, Nijmegan, the Netherlands
[2]Max Planck Institute for Psycholinguistics, Nijmegan, the Netherlands

Fine-grained steps in the neural processing of visual and auditory input cannot be studied at the group level but only in individual brains. Representations from convolutional neural networks have been used as explanatory models for these stimulus-induced hierarchical brain activations. However, none of the functional magnetic resonance imaging data sets that are currently available has adequate amounts of data for sufficiently sampling their representations. We have recorded a large functional magnetic resonance imaging data set in a single participant exposed to spatiotemporal and auditory naturalistic stimuli, acquiring approximately 120.000 whole-brain volumes (23 hours) of single-presentation data and 26 repetitions of a smaller resampled set (11 minutes). The data have been recorded with fixation over a period of 6 months.

Testing the Navigation Skills of 3.7 Million Participants With a Video Game

Antoine Coutrot[1], Ricardo Silva[2], Ed Manley[3], Will de Cothi[4], Saber Sami[5], Véronique D. Bohbot[6], Jan M. Wiener[7], Christoph Hölscher[8], Ruth C. Dalton[9], Michael Hornberger[5] and Hugo J. Spiers[4]
[1]CNRS, LS2N, University of Nantes, France
[2]Department of Statistical Science and CSML, University College London, UK
[3]Centre for Advanced Spatial Analysis, University College London, UK
[4]Department of Experimental Psychology, Institute of Behavioural Neuroscience, University College London, UK
[5]Norwich Medical School, University of East Anglia, Norwich, UK
[6]Douglas Mental Health University Institute, Department of Psychiatry, McGill University, Montreal, Quebec, Canada
[7]Department of Psychology, Ageing and Dementia Research Centre, Bournemouth University, Poole, UK
[8]ETH Zürich, Swiss Federal Institute of Technology, Zürich, Switzerland
[9]Department of Architecture and Built Environment, Northumbria University, Newcastle upon Tyne, UK

When scientists need to record signals from human participants such as their eye movements or their brain activity, they need to ask them to physically come to a research facility. This process is costly and time-consuming. As a consequence, the human sample size in a typical neuroscience paper is below 100, and the cohort often consists in students from the local university. Here, we argue that video games can be a useful and cost-effective solution to drastically increase the sample size and diversity of human-based experiments. We developed Sea Hero Quest, a mobile gaming app that records users' spatial exploration strategies. The game has been downloaded 3.7 million times in every country in the world. We are using these data to create the world's largest benchmark of how humans navigate, which will then go on to become a critical diagnostic tool for dementia in the future.

Effects of Face Familiarity in Humans and Deep Neural Networks

Katharina Dobs, Ian A. Palmer, Joanne Yuan, Yalda Mohsenzadeh, Aude Oliva and Nancy Kanwisher
Massachusetts Institute of Technology, Cambridge, MA, USA

The recognition of familiar faces is a crucial aspect of human social life. Recent evidence suggests that familiar faces are processed more robustly and efficiently than unfamiliar faces, but the neural mechanisms underlying this effect remain unknown. In a recent magnetoencephalography study, we found that identity and gender, but not age, representations are enhanced for familiar faces very early during processing, suggesting that familiarity affects face perception by altering feedforward face processing. Here, we tested this hypothesis by asking whether familiarity enhancements emerge in purely feedforward deep neural networks trained on face identity. We trained two deep neural networks on two distinct large-scale sets of face images and extracted activations to left-out images of trained ("familiar") or untrained ("unfamiliar") identities, respectively. Using representational similarity analysis, we found that gender and identity, but not age, information is significantly enhanced for familiar versus unfamiliar faces in the penultimate layer of these networks ($p < .05$; bootstrap test). Together, these findings suggest that the strong behavioral familiarity effect may be implemented via a feedforward mechanism in the brain and further show that many specific properties of human face perception emerge spontaneously from a model optimized for face identification.

Idiosyncratic Brain and Behavioral Representations

Ian Charest[1,2], Daniel Lindh[1,3,4], Kimron Shapiro[1,2] and Ilja Sligte[3,4]
[1]School of Psychology, University of Birmingham, UK
[2]Center for Human Brain Health, University of Birmingham, UK
[3]Brain and Cognition, Department of Psychology, University of Amsterdam, the Netherlands
[4]Amsterdam Brain and Cognition, University of Amsterdam, the Netherlands

The ability to consciously recognize objects is crucial for adaptive behavior and survival. Yet, how our conscious experience of the world emerges in our brain remains unknown. In addition, individual differences are omnipresent in psychophysical experiments manipulating conscious access, yet they remain poorly understood. Using representational similarity analysis (RSA), we previously showed that individually unique brain representations predict idiosyncrasies in behavior, suggesting a tight link between representational geometries measured with functional magnetic resonance imaging and behavior. Here, we asked whether individual differences in representational geometries could explain differences in conscious access. Participants each completed 3,840 trials of an attentional blink paradigm, in four separate sessions. In each trial, two targets were embedded in a rapid serial visual presentation of distractor masks. Two functional magnetic resonance imaging sessions were collected in the same participants to characterize template brain representations for these natural object targets. Using RSA, we show that target–target similarity in visual ventral stream activity patterns explains large amounts of attentional blink variance across trials and objects. Importantly, we show that individuals with distinct pattern representations in the temporo-parietal junction are better equipped to survive the blink. Together, these results shed light on the neurocognitive mechanisms behind conscious access in object recognition.

Symposium 4

Some History of Visual Perception Research in Leuven/Louvain (Invited Leuven ECVP Symposium)

The Historical Psychological Equipment at the Laboratory of Experimental Psychology in Leuven/Louvain

Lothar Spillmann
University of Freiburg, Germany

I will introduce a few selected instruments from the collection of Professor Albert Michotte and briefly describe what one could do with them. The collection comprises instruments in the fields of visual, auditory, cutaneous, and olfactory research. I will discuss why it is important to preserve these old instruments and show them to today's students of sensory psychology. Experimental psychology started in Wundt's laboratory in Leipzig 150 years ago and spread quickly to major universities within Europe, the United States, and Asia. The new psychology wrestled away from philosophy in the direction of physiology and physics. It was marked by the advent of workshops in psychological institutes. To do an experiment one had to closely collaborate with a master fine mechanic who designed and built the equipment needed. This required much ingenuity and was quite time-consuming. However, the precision of the equipment enabled accurate threshold measurements, standardization of methods, and comparison of data. The instruments preserved in Leuven are invaluable for teaching the history of psychology. They also illustrate the important relationship between psychology, medicine, and the natural sciences that characterized the brass age of sensory psychology and raise awareness for the great achievements of the scientists at that time.

History Armand Thiéry's 19th-Century Constancy Explanation of Visual Illusions

Barbara Gillam
University of New South Wales, Sydney, Australia

Some 40 years ago, Richard Gregory popularized a view of visual illusions known as "misapplied constancy theory" in which he showed illusions such as the Ponzo in natural settings. The illusory size differences were explained by a process in which size is judged relative to surrounding context. Gregory's theory was convincing at the time and attracted a great deal of attention. However, the theory was not new. It had merely had a long quiescence. The same theory was rather common in the 19th century and may have begun with Armand Thiéry, a Belgian psychologist (also philosopher, theologian, architect, and priest). who did a PhD with Wilhelm Wundt in 1895 specifically in order to prepare himself to found an experimental psychology department at the University in Leuven/Louvain. Not only did Thiéry attribute a number of illusions to constancy processing, but he also made the point that this is not a conscious cognitive process but automatic and unconscious. His arguments and experimental evidence will be discussed in this talk.

Filling in "Les Compléments Amodaux"

Rob van Lier
Radboud University, Nijmegen, the Netherlands

Michotte and coworkers published a seminal work on amodal completion in 1964: "Le compléments amodaux des structures perceptives" (later translated as "Amodal completion of perceptual structure"). The term amodal, however, was coined in an even earlier study, published by Michotte and Burke in a two-page conference paper (1951), introducing it with the following historical line

(after describing a case of occlusion): "L'absence des qualités sensorielles (brillance, couleur) est exprimée par le terme de "donné amodal" ("The absence of sensory qualities (brightness, color) is expressed by the term amodal datum"). In this talk, I will briefly review the insights of Michotte and coworkers on amodal completion and connect with research that has been done ever since. I will touch upon a variety of paradigms, stimuli, and models that have been developed to test and predict the outcome of amodal completion. Today, Michotte's "compléments amodaux" (or "donné amodal") are still intriguing, triggering rather fundamental questions. What does it exactly mean for a shape to be amodally present and how does amodal completion relate to perception? Indeed, amodal completion remains a largely unknown process that sometimes appears to operate in a "gray-zone" between perception and cognition—still waiting to be filled in.

From Shape and Motion to Causality and Animacy: How Michotte Expanded Our Understanding of the Scope of Visual Perception

Brian Scholl
Perception & Cognition Laboratory, Yale University, New Haven, CT, USA

The goal of vision science is to understand how we see. In pursuit of this goal, though, we can ask an equally fundamental question: *What* do we see? And perhaps nobody has changed our understanding of this question's answer to a greater degree than Albert Michotte. Some of the answers to this question seem uncontroversial, and it seems clear that visual processing extracts properties such as color, shape, and motion. But Michotte expanded our understanding of the scope of perception, showing us how visual processing also extracts seemingly higher level properties such as causality and animacy. Inspired by Michotte, contemporary research continues to show how such properties are indeed *seen* in a concrete, nonmetaphorical sense. Seeing that one object caused another to move, or that one object is chasing another, seems more like perceiving a shape than proving a theorem. This presentation will review Michotte's seminal influence in these domains, showing us how perception delivers a rich interpretation of the world to the mind at large.

Symposium 5: Tuesday, August 27, 2019

The Ecological Approach of James J. Gibson: 40 Years Later

Gibson: An Ecological Approach to Binocular Vision

Barbara Gillam
University of New South Wales, Sydney, Australia

Binocular vision has over recent years been treated as "sensation" with an emphasis on mechanism and simple width disparity. However, both Helmholtz and Wheatstone emphasized ecologically significant stimuli producing vertical, curvature and spatial frequency disparity in addition to width disparity. This emphasis was resurrected by Barrand, a student of Gibson, who usefully pointed to another ubiquitous feature in binocular views of a scene; the presence of monocular regions. These had been treated as "noise" if noticed at all. It will be argued (with examples) that binocular perception uses information carried by many naturally occurring interocular differences, including monocular regions.

J. J. Gibson: His Achievement and Legacy

Ken Nakayama
University of California, Berkeley, CA, USA

My generation was captivated by the amazing findings of Barlow, Hubel, and Wiesel, who discovered the remarkable coding properties of visual neurons. By measuring psychophysical and neuronal responses to precisely measured stimulus variations (the spatial and temporal aspects of luminance, wavelength), the common goal was to explain vision most rigorously. Gibson was immune to all of these developments, pursuing his unique, brilliant, and functional approach to vision. His focus was centered on the useful optical information available for the mobile animal in mediating actions. Regarding the mainstream as too narrow and ill focused, his ecological approach opened the door to a richer domain for exploration. His views still deserve wider appreciation both as a framework for the future and as a critique of current thinking.

Optic Arrays, Retinal Images, and the Perception of the Three-Dimensional World

Brian Rogers
University of Oxford, UK

In his "Ecological Approach to Visual Perception," James Gibson famously claimed that "the retinal image is not necessary for vision." Instead, he argued that his conception of an optic array provides a much better starting point. However, many textbooks on perception start with the claim that there is a special problem of three dimensional (3D) vision because the retina is essentially a two-dimensional surface that contains only "cues" to the structure and layout of the 3D world. How important is this distinction to our understanding of 3D vision? The advantage of the optic array conception is that it allows us to distinguish between whether there is any information available and whether a particular visual system is able to use that information. For example, simple geometry shows that there is information about the 3D structure of objects and their layout by virtue of having either two spatially separated vantage points (binocular stereopsis) or a changing vantage point (motion parallax), but this does not mean that any particular species is capable of using that information. In this talk, I shall present evidence both of the richness of available information and of our ability to use that information.

J. J. Gibson's "Ground Theory of Space Perception"

H. A. Sedgwick
SUNY College of Optometry, New York, NY, USA

Gibson's ground theory of space perception is contrasted with Descartes' theory, which reduces all of space perception to the perception of distance and angular direction, relative to an abstract viewpoint. Instead, Gibson posits an embodied perceiver, grounded by gravity, in a stable layout of realistically textured, extended surfaces, and more delimited objects supported by these surfaces. Gibson's concept of optical contact ties together this spatial layout, locating each surface relative to the others and specifying the position of each object by its location relative to its surface of support. His concept of surface texture—augmented by perspective structures such as the horizon—specifies the scale of objects and extents within this layout. And his concept of geographical slant provides surfaces with environment-centered orientations that remain stable as the perceiver moves around. None of this requires Descartes' viewer-centered distance, which need not be regarded as a pervasive and fundamental characteristic of our perception of the world. Instead, viewer-centered distance may best be appreciated using Gibson's concept of affordances. Viewer-centered distances may be ad hoc perceptions, inextricably bound to the spatial–temporal affordances for the particular, sometimes skilled, visual-motor behaviors that require them.

On the Ambient Optic Array

James Todd
Ohio State University, Columbus, OH, USA

Traditional analyses of three-dimensional (3D) vision have employed projective geometry in order to describe how points and lines in 3D space are mapped onto a two-dimensional pattern of points and lines within a visual image. Gibson argued that this conception of visual stimulation is unnecessarily impoverished, and that it does not adequately capture the complex patterns of stimulation that are available in the natural environment. To provide an alternative to this traditional approach, Gibson introduced the concept of the ambient optic array in which light from luminous sources radiates throughout space and is scattered by reflective surfaces in the environment in varying amounts toward a point of observation. Although he did not extensively develop the implications of this insight during his lifetime, it has proven to be remarkably prescient. In this talk, I will describe how this new conception of visual stimulation has led to the recent explosion of research on the perception 3D shape and material properties from patterns of shading.

Information Is Where You Find It: Shape, Optic Flow, and Affordances

William Howe Warren
Brown University, Providence, RI, USA

Texts on visual perception typically begin with the following premise: Vision is an ill-posed problem, and perception is underdetermined by the input. If this were universally true, however, perception might never have evolved. James Gibson's signal contribution was his insistence that for every perceivable property of the environment, however subtle, there must be a variable of information, however complex, that uniquely corresponds to it—if only we are clever and dogged enough to find them. Research in sensory ecology is replete with species that exploit unexpected variables to guide behavior in their niches, from nematodes to narwals. Logically ill-posed problems may thus become ecologically well posed. I look at three cases in which Gibson's account of information yielded fruitful research programs. A classic ill-posed problem is perceiving three-dimensional shape with a two-dimensional retina, yet effective information for qualitative shape has been found in second-order spatial derivatives of motion, disparity, and shading fields.

Second, optic flow patterns are sufficient to perceive and control locomotion in a three-dimensional world. Third, affordances for action such as passable openings and jumpable gaps are specified by action-scaled information. In each case, asking, "What's the information?" has led to progress in vision science, neuroscience, and applications.

Symposium 6

Maximum Likelihood Difference Scaling (MLDS): Applications and Challenges

Measuring Appearance on Interval Scales: MLDS and MLCM

Laurence T. Maloney
New York University, NY, USA

Imagine viewing four gray matter surface patches differing only in albedo. All four are readily discriminable and observers would likely agree in ordering them in lightness. But let's ask a different question. Is the difference in perceived lightness between the first two patches smaller or larger than that between the latter two? We could repeat this judgment with many different quadruples of patches chosen along the albedo scale. Can we assign numbers to each item such the absolute differences in the numbers of any two items predict the perceived perceptual difference? Can we estimate an interval scale that captures the perceived differences in lightness? Maximum likelihood difference scaling (MLDS) is a recently developed method based on superthreshold judgments of perceived perceptual differences. The pattern of responses across many choices of quadruples is used to estimate an interval scale—or demonstrate experimentally that no such scale exists. I will discuss how such an interval scale based on difference judgments relates to other psychophysical judgments such as threshold estimation, Thurstonian scaling and Stevens' magnitude scaling. I will review past work using MLDS. I will also introduce maximum likelihood conjoint measurement a multidimensional extension of MLDS.

Investigating the Role of Object Features in Material Perception Using MLDS and MLCM

Sabrina Hansmann-Roth[1] and Pascal Mamassian[2]
[1]Icelandic Vision Lab, University of Iceland, Reykjavík, Iceland
[2]Laboratoire des systèmes perceptifs, École normale supérieure, Paris, France

We easily add labels to materials like smooth, rough, glossy, or matte. These labels are based on the visual appearance of the material and the visual system's estimation of the underlying physical properties. Gloss, for example, originates from specularly reflected light that reaches our eyes. Perceptually, however, gloss is a multidimensional property. It varies with the color and shape of the object but also with extrinsic scene variables like intervening media or the background behind objects. Maximum likelihood conjoint measurement (MLCM) allows us to study exactly these joint influences of multiple dimensions on a single perceptual judgment. In two studies, we quantified the strength to which extrinsic scene variables manipulate perceived gloss and lightness. By manipulating the context rather than the object, we are using MLCM to study inductive effects rather than direct effects. To obtain a perceptually linear stimulus space, all MLCM experiments preceded a maximum likelihood difference scaling (MLDS) experiment to estimate perceptual scales separately for both dimensions and assess a possible nonlinear relationship between physical and psychological dimensions. Conjoint measurements have lead us to a better understanding of the contextual effects in material perception, not just confirming their importance but also quantifying the strength of these effects.

Quantifying Visual Phenomena Using MLDS: A Tutorial Overview With the Watercolor Effect

Frederic Devinck
Univ. Rennes, Rennes, France

Several psychophysical methods have been used to quantify the physical properties responsible for visual percepts. Sometimes, perceptual effects have proven to be difficult to quantify because of their subtlety. Over the last decade, paired-comparison methods have been extended to estimate perceptual scales within a signal detection framework. One example is the maximum likelihood difference scaling procedure. This method is used for scaling a single dimension of appearance. In this tutorial overview, I review some of the various stages and key choices faced in using this approach. I describe some studies we have performed that investigate the influence of physical properties on the watercolor effect. This is a long-range filling-in phenomenon induced by a pair of distant, wavy contours of complementary chromaticities. Previous classical methods indicated large within and between variability. The use of maximum likelihood difference scaling turned out to be advantageous to measure color appearance and other subtle visual effects. This method uses a maximum likelihood criterion to estimate interval scales that best predict observers' choices. This method appears to be robust indicating how the sensitivity of the observer varies with

stimulus magnitude. I further argue that this procedure used successfully is a powerful tool to investigate the strength of visual percepts.

How to Compare Perceptual Scales Across Contexts: A Comparison of MLDS and MLCM

Guillermo Aguilar and Marianne Maertens
Technische Universität Berlin, Germany

Maximum likelihood difference scaling (MLDS) is a straightforward method to characterize a single perceptual scale. However, often we want to know whether and how the mapping between a physical and a perceptual variable changes with changes in viewing conditions. In matching, this is problematic because the context might render target and match so different that all the observer can do is a minimum difference "match." Here, we compare MLDS and maximum likelihood conjoint measurement (MLCM) in their ability to estimate scales for perceived lightness. In simulations, we adopted three different observer models: a lightness-constant, a luminance-based, and a contrast-based model. MLCM was able to correctly recover all simulated models. MLDS was successful only for the lightness-constancy case. To empirically probe the models, we used two types of stimuli: (a) variegated checkerboards supporting lightness constancy and (b) center-surround stimuli not supporting lightness constancy. The experimental data conformed to the simulation-based expectation. MLDS and MLCM estimated consistent scales for the stimulus supporting lightness constancy (a). MLDS and MLCM estimated different scales for the stimulus not supporting lightness constancy (b). Examining the assumptions underlying scale estimation in MLDS and MLCM, we will outline how the different anchoring rules lead to the observed results.

Maximum Likelihood Scaling Methods: Future Directions in Appearance Measurement

Kenneth Knoblauch
Inserm U1208, Bron, France; University of Southeastern Norway, Notodden, Norway

Maximum likelihood scaling methods, maximum likelihood difference scaling and maximum likelihood conjoint measurement, have introduced a new rigor to psychophysical measurement beyond the threshold regime. In this talk, I will review several outstanding issues that concern these methods and some new directions in which they might be taken including: (a) Are maximum likelihood scaling and threshold methods mutually consistent? I will consider some of the assumptions underlying the two types of measurements and given their differences, whether we should expect them to agree or not. (b) Can these methods be exploited with nonverbal subjects? Here, I will consider recent experiments using maximum likelihood conjoint measurement in infants and some of the pitfalls therein. (c) How can these methods be extended within a Bayesian framework? Bayesian estimation methods bring the benefit of being able to make all potential sources of variability explicit. In particular, they permit greater flexibility than mixed-effects models in fitting group data. An example graphical model will be presented for a group maximum likelihood difference scaling analysis with discussion of how to implement it.

Symposium 7

The Geometry of 3D Shape and Scene Perception (Invited Leuven ECVP Symposium)

The Geometry of Space: The Visual Angle

Nicholas Wade
University of Dundee, UK

A common thread running through the history of space perception is the visual angle. It commences with Euclid's equation of vision with visual angle and continues to computational attempts to address the mismatch between projection and perception. Great landmarks can be charted between these end points. From the 15th century, artists represented visual angles intersecting a picture plane in front of a stationary eye. Two centuries later, it was established that light entered the eye focussing an image on the retina and the eye was likened to a camera. Characteristics of the retinal projection could be related to the scene seen and cues to the missing dimension in the retinal image—depth—were sought. Thereafter, growing knowledge of the anatomy and physiology of the visual system as well as increasingly sophisticated models of it were applied to interpreting the retinal image. Statistical properties of the image as well as inferential processes feature prominently in such models.

The Invariance and Redundancy Aspects of Symmetry

Zygmunt Pizlo, Ran Duan, Doreen Hii and Peng Sun
UC Irvine, CA, USA

Symmetry is defined in math and physics as invariance under transformations. This is how Galois (1846) introduced symmetry into mathematics and how Noether (1918) used symmetry to connect it to the conservation laws in physics. Note, when an ordinary chair is reflected with respect to its symmetry plane, we get the same chair in the same three dimensional (3D) orientation and position. But, when a chair is rigidly moved from my room to yours, the situation has changed; your room has a chair but mine does not. But note that despite the changed situation, the chair remained a chair. It is invariant. These two examples of symmetry are different because the first example capitalizes on the redundancy of the object, while the second example does not. It turns out that both aspects of symmetry, invariance, and redundancy are essential in 3D shape perception. Invariance in the presence of rigid motion (a 3D rotation in particular) is critical for defining shape perception, as well as the shape, itself. Redundancy, on the other hand, is critical for recovering a 3D shape from a single two-dimensional image. This 3D recovery is accomplished by a process analogous to the operation of a least-action principle in physics.

Mental Geometry Underlying 3D Scene Inferences

Qasim Zaidi[1], Erin Koch[2] and Akihito Maruya[3]
[1]State University of New York, NY, USA
[2]California Institute of Technology, Pasadena, CA, USA

Correctly judging poses, sizes, and shapes of objects in a scene are functionally important components of scene understanding for biological and machine visual systems. A three-dimensional (3D) object seen from different views forms quite different retinal images, and in general many different 3D objects could form identical two-dimensional (2D) retinal images, so judgments based on retinal information alone are underspecified. However, the very frequent case of objects on the ground projected to retinal images is a 2D-to-2D mapping and an invertible trigonometric function. Hence, using the back-transform derived by inverting the projection function would lead to veridical inferences. We show that human observers consistently apply the optimal backtransform for pose inferences in 3D scenes and also for obliquely viewed pictures of 3D scenes. This leads to veridical estimates for 3D scenes, with a systematic fronto-parallel bias, but illusory rotation of pictured scenes with respect to the observer. For estimating relative sizes, observers' generally correct projective distortions according to the optimal backtransform, except for poses close to the line of sight. Size underestimation increases with physical length, which we show is due to an overestimation of viewing elevation. These results suggest that humans have internalized many aspects of projective geometry through evolution or learning.

Human and Machine Perception of Three-Dimensional Shape From Contour

James H. Elder[1], Yiming Qian[1], Michael Clement[2] and Srikumar Ramalingam[3]
[1]Centre for Vision Research, York University, Toronto, Canada
[2]LaBRI, Bordeaux INP, Talence, France
[3]Department of Computer Science, University of Utah, Salt Lake City, UT, USA

Recent neuroscience has revealed localized areas of the brain specialized for distinct forms of three-dimensional (3D) shape and scene encoding. I will present two specialized computational models for estimating the 3D shape of an object from a single view of its contours. Both models rely upon geometric regularities of solid objects and their transformation by perspective projection. The first model is specialized for rectilinear solid objects. The model comprises a feedforward network of modules representing progressively more global two-dimensional and 3D structure through repeated application of Gestalt principles from edges to 3D line segments, 3D junctions, and local 3D scaffolds and ultimately complete 3D rectilinear polyhedra. The model has no free parameters, requires no training, and outperforms state-of-the-art deep learning approaches. The second model is specialized for recovering the 3D rim of a solid object given only its silhouette. A sparse dictionary spanning a large training sample of 3D rims is learned and then used as a generative model to estimate the missing depth dimension of a novel object given only the two-dimensional bounding contour. The resulting sparse model outperforms recent Bayesian and deep network approaches. Unlike deep learning models, both of these models are explainable in terms of underlying geometric principles.

Critical Contours and the Apparent Geometry of Shape

Steven Zucker
Yale University, New Haven, CT, USA

Inferring shape from image shading or contours is a classical ill-posed problem. Nevertheless, we seem to solve it effortlessly, (almost) regardless of lighting and material

reflectance functions. One approach is to introduce a number of priors, such as expectations on the light source, to limit the possibilities. We propose a different solution to this conundrum: that the goal is not to infer the precise quantitative shape directly from among the infinite variety possible, but rather to first seek qualitative—topological—properties of shape that are common to all generic solutions across (almost all) lightings. This topological solution reveals a type of scaffold—a network of critical contours—over which the detailed shape can be "draped." Formally, the critical contours resemble (parts of) artists' drawings, and the draping process resembles the manner in which we "fill in" the space between the artists' strokes. The approach is mathematically well-structured and yields a basic, one-to-one relationship between generic properties of images and generic properties of surfaces. In the end, it is consistent with individual differences in shape inferences and specifies the image regions that anchor them.

Symposium 8

Why Do We Like What We See?

Two Ways to Study Beauty

Denis G. Pelli and Aenne A. Brielmann
New York University, NY, USA

The scientific study of beauty began with Fechner less than 200 years ago and has matured over the past two decades. In particular, two strands of research are yielding insight into several aspects of the experience of beauty. Stimulus-focused studies have determined key object properties that, on average, increase or decrease the attractiveness or beauty of an object, such as symmetry and curvature. Response-focused studies have started to describe the processes that underlie aesthetic pleasure and beauty and their neural correlates independent of stimulus properties. So far, research indicates that the feeling of beauty requires successful early sensory processing and that there is an especially tight, linear relation between beauty and pleasure responses.

From "Being Moved" to Moving Images

Edward A. Vessel
Max Planck Institute for Empirical Aesthetics, Frankfurt am Main, Germany

Esthetic experiences evolve over time, from fleeting first impressions to the savoring of memories long after an experience. How is it that such experiences with the external world can reach within to deeply "move" us emotionally? In previous work, we measured static "snapshots" of brain activity (functional magnetic resonance imaging), while participants viewed unchanging visual artworks. We found that when a person finds an artwork to be aesthetically "moving," parts of the brain's default-mode network (DMN), associated with inwardly directed thought, are surprisingly active even though the focus lies on the outer world—the artwork. To expand this static snapshot into an understanding of a dynamic process, we set first our measurement and then our stimulus, in motion. In one experiment, static artworks were viewed for different durations to allow separation of processes linked to external stimulation versus internal processes operating independently. For aesthetically moving paintings, the DMN "locked-on" to sensory signals, while DMN dynamics were independent of external input for low-rated artworks. In a second experiment, collection of continuous behavioral responses to videos (artistic landscape videos or dance performances) revealed that participant identity, more than movie identity, determined the amount of moment-to-moment fluctuation in reported enjoyment.

Accounting for Taste: Why Do Individuals Differ in Their Visual Preference?

Branka Spehar
UNSW Sydney, Australia

The degree to which aesthetic preferences are universal or determined by individually or culturally specific factors is one of the most enduring questions in experimental aesthetics. While there is strong evidence for robust and seemingly universal preferences for certain image characteristics (compositional arrangements, symmetry, smooth contours, and fractal scaling among others), it is also undeniable that observers differ in their preferences for these characteristics. So far, most studies on individual differences in aesthetic preference tend to focus on the degree of agreement between individual observers across various domains. A complementary, but often neglected, issue to that of variability between individuals is whether individuals exhibit aesthetic preferences that remain constant and stable over time and generalizable across domains. In our studies, we explore potential commonalities in aesthetic preference for variations in fractal scaling characteristics within and across different sensory and physical domains. We use a range of visual, auditory, and three-dimensional tactile stimuli to investigate the equivalence of fractal-scaling variations on aesthetic preferences within and between sensory domains. Despite some superficial differences, the underlying dimensional structure mediating the preference across sensory domains is remarkably similar, suggesting

systematic patterns of preference for fractals in vision, audition, and touch.

An Embodied Approach to Understanding Visual Aesthetics

Beatriz Calvo-Merino
City. University of London, UK

Embodiment theories propose our internal body representation contributes to perceiving and assessing the external world. Here, we propose a differential embodiment contribution to low-level visual perception and higher visual judgments related to aesthetic experiences. We provide evidence from a series of studies using functional magnetic resonance imaging and electroencephalography, exploring embodied process in two groups of participants with different bodily abilities (motor experts/dancers) and nonexperts. Functional magnetic resonance imaging results show a strong contribution of primary somatosensory cortex during aesthetic judgments (as compared with visual judgments) of dance movements. The electroencephalographic study shows direct involvement of primary somatosensory cortex (measured via somatosensory-evoked potentials) in the same comparison (aesthetic vs. visual judgement task). Interestingly, the time frame of the embodied response is significantly different in expert dancers, suggesting that both our early sensory body representation and sensorimotor experience with the perceived stimuli brings additional layers to the embodied process that contributes to forming the final aesthetic percept.

Intense Beauty Requires High Pleasure

Aenne Annelie Brielmann and Denis G. Pelli
New York University, NY, USA

At the beginning of psychology, Fechner (1876) claimed that beauty is immediate pleasure, and that an object's pleasure determines its value. In our earlier work, we found that high pleasure always results in intense beauty. Here, we focus on the complementary question: Is high pleasure necessary for intense beauty? If so, the inability to experience pleasure (anhedonia) should prevent the experience of beauty. We asked 757 participants to rate how intensely they felt beauty from each image. We used 900 OASIS images along with their available valence (pleasure vs. displeasure) and arousal ratings on 1 to 7 scales. We then obtained self-reports of anhedonia (TEPS). Beauty ratings were closely related to pleasure ($r = .75$). Only images with an average pleasure rating above 4 achieved beauty averages that at least occasionally (>10%) exceeded the median beauty. Furthermore, for normally beautiful images, the beauty ratings were correlated with anhedonia ($r \sim -.3$). Looking at average beauty ratings per participant, the most anhedonic participants' averages never exceeded the overall median, while, for the remaining participants, 50% of averages did. These results indicate that beauty requires high pleasure.

Symposium 9: Wednesday, August 28, 2019

Ensemble Perception: Theory and Experiment

Five Dichotomies in the Psychophysics of Ensemble Perception

Joshua A. Solomon
City, University of London, UK

1. Whereas psychophysicists may formulate hypotheses about appearance, they can only measure performance. Bias and imprecision in psychophysical data need not necessarily reflect bias and imprecision in perception.
2. The visual system may exaggerate the differences between each item and its neighbours in an ensemble. Alternatively, the visual system may homogenize the ensemble, thereby removing any apparent difference between neighbouring items.
3. Ensemble perception may be involuntary when observers attempt to report the identities of individual items. Conversely, when asked to make a (voluntary) decision about the ensemble as a whole, observers may find it very difficult to compute statistics that are based on more than a very small number of individual items.
4. Modeling decisions about prothetic continua like size and contrast can be tricky because visual signals may be distorted before and after voluntarily computing ensemble statistics. With metathetic continua, like orientation, distortion is less problematic; physically vertical things necessarily appear close to vertical and physically horizontal things necessarily appear close to horizontal.
5. Decision processes are corrupted by noise that, like distortion, may be added to visual signals prior to and after voluntarily computing ensemble statistics.

Ensemble Perception and the Inference of the Invisible

David Whitney, Zhimin Chen and Allie Yamanashi
UC Berkeley, CA, USA

Ensemble perception—the perception of summary statistical characteristics in groups of features and objects—operates at virtually every level of visual processing. In addition to providing fast, efficient, compressed information about crowds of things, ensemble coding uniquely affords information about what is not present—that which is invisible. For example, even if there are gaps in a scene, such as occlusions or scotoma, we may be able to infer characteristics in that region based on ensemble information in the surround. Here, we tested the perceptual inference of the invisible in two different studies. In one, we measured sensitivity to liveliness (animacy) information in natural photographs and found that observers' ensemble animacy estimates were best fit by a weighted integration across different regions of the natural scene. In the second study, we found that introducing a hole or occlusion in the image does not prevent observers from inferring the contents of that region. The perceptual inference revealed an emergent representation not carried by the visible portion of the image. An intriguing possibility is that observers routinely use ensemble information to make perceptual inferences about unseen objects.

Perceptual Averaging: How to Separate Inattention From Representational Noise?

Aire Raidvee[1] and Jüri Allik[1,2]
[1]University of Tartu, Estonia
[2]Estonian Academy of Sciences, Tallinn, Estonia

When it was discovered that perceptual averaging is almost as precise as perception of each element in isolation it was heralded as a mechanism capable of circumventing the capacity limits of the visual system. The initial enthusiasm was dampened by a simulated demonstration that the observed precision can be obtained by taking into account only two to three elements, given the critical attributes are determined exactly (noiselessly). Empirical data have offered evidence in support of both global, preattentive processing (Allik et al, 2013) with no conscious access to individual items and shown (by using outliers) that perceptual averaging involves aspects of focused, object-based attention (Raidvee & Fougnie, 2017). Because noise and inattention are controlling the slope of psychometric function identically, it has been challenging to tell them apart. Here, we define the Proportion of Informative Elements (PIE) as the ratio of elements carrying task-relevant information to the total number of displayed elements. Because the representational noise is indifferent to PIE, any change in the discrimination precision must be caused by some other factor such as inattentional blindness. The latter can be detected by a unique signature in the shape of the psychometric function reflecting the amount of purely random guessing.

The Properties of Large Receptive Fields Can Explain Ensemble-Related Phenomena

Igor S. Utochkin
National Research University Higher School of Economics, Moscow, Russia

I am going to discuss three sets of well-documented findings related to ensemble perception: (a) the average feature of an ensemble appears to be better represented in overt judgments, whereas extreme features are often underrepresented and pulled toward the average, (b) the precision of averaging drops down as the physical feature range increases, and (c) outlier features likely pop-out from the rest of ensemble (if they are singletons) or form a categorically separate groups of items (if there are many such items). For an explanation, I propose a hypothetical model based on two established neural mechanisms, pooling and population coding (earlier discussed separately by Haberman & Whitney, 2012, and Hochstein, 2018). Here, a population of selectively tuned neurons with large overlapping receptive fields pool local feature signals from lower level populations with smaller receptive fields. The distribution of synaptic weights of these local signals favors greater activation in the neurons encoding the mean feature. Feature range makes more pooling neurons respond strongly, thus producing a noisy (imprecise) population code. Finally, outlier features provide additional peaks in the population code precluding their perception as a part of a single ensemble. This work is supported by Russian Science Foundation (project 18-18-00334).

The How and Why of Ensemble Perception

Shaul Hochstein
Hebrew University, Jerusalem, Israel

Mechanisms overcoming sensory system bottlenecks include selective attention, Gestalt gist perception, categorization, and ensemble encoding of set summary statistics. In categorization, we relate objects to their category, assume that they share relevant properties and disregard irrelevant characteristics. In ensemble perception, attending a set of similar objects, we represent the group without encoding individual information. We now relate these processes and suggest they depend on similar mechanisms, namely, population encoding. Just as categorization depends on prototype and

intercategory boundaries, so set perception includes mean and range. We test summary perception with a Rapid Serial Visual Presentation paradigm and find that participants perceive both mean and range extremes, automatically, implicitly, and on-the-fly. We use the same paradigm testing category representation and find participants perceive categorical characteristics better than individual elements. Categorization depends on lifetime learning of category prototypes and boundaries, so we developed novel abstract "amoeba" forms, with simple ultrametric structure that observers can learn. We find that they learn these categories on-the-fly and build representations of their progenitor (related to set "mean" or category prototype) and boundaries (related to set range and intercategory boundaries). These findings put set perception in a new light, related to object, scene, and category representation.

Symposium 10

Toward Naturalistic Paradigms in Vision Research: Coregistration of Brain Activity and Eye Movements

Toward Naturalistic Paradigms in Vision Research: Perspectives of the Coregistration of Brain Activity and Eye Movement (an Introduction to the Symposium)

Andrey Nikolaev
KU Leuven—University of Leuven, Belgium

Investigation of perceptual processes in naturalistic behavioral conditions increases in popularity as an alternative to the traditional stimulus–response paradigm. In visual neuroscience, it becomes possible with the coregistration of brain activity and eye movements. The symposium will discuss the dynamical neural mechanisms underlying perceptual and memory processes across sequential eye movements in natural viewing of objects and scenes. The symposium will focus at spatiotemporal characteristics of active perception in various behavioral tasks, such as visual search, scene recognition, and reading. The symposium will also contribute to a better understanding of the range of research questions that can be approached by the coregistration as well as methodological solutions for simultaneous recording and analysis of EEG/MEG/ECoG/LFP and eye movement. The target audience of the symposium will be visual neuroscientists and psychologists who focus at active vision, who are interested in perceptual and cognitive research in naturalistic conditions, and who wish to extend their methodological arsenal in this field. The symposium may also attract those who are interested in applied, multidisciplinary vision research.

Investigating the Role of Prediction in Trans-Saccadic Perception Using Coregistered EEG and Eye Tracking

David Melcher[1], Christoph Huber-Huber[1], Antimo Buonocore[2], Clayton Hickey[3] and Olaf Dimigen[4]
[1]University of Trento, Italy
[2]University of Tubingen, Germany
[3]University of Birmingham, UK
[4]Humboldt University, Berlin, Germany

Object recognition has traditionally been studied by flashing stimuli to the central visual field. In natural vision, however, viewers actively sample the environment with eye movements based on a lower resolution, parafoveal preview of soon-to-be-fixated objects. Using electroencephalography (EEG) coregistered with eye tracking, we investigated whether the peripheral preview licenses predictions about the postsaccadic visual input. In the first experiment, we measured the N170, a classic electrophysiological marker of the structural processing of faces, for face stimuli presented after the saccade. We contrasted conditions in which there was a face preview compared with when a phase-scrambled face image was used as the preview. A robust postsaccadic N170 was found during the more natural viewing condition but was massively reduced due to extrafoveal processing of the face target ("preview positivity": Dimigen et al. 2012). In a second experiment, the preview and postsaccadic stimulus could be either an upright or inverted face, either matched in orientation or incongruent across the saccade. Again, we found evidence for a strong effect of the preview stimulus on postsaccadic face processing, including early components. These findings constrain theories of visual stability and show that the extrafoveal preview methodology can be a useful tool to investigate visual stability.

Eye Fixation/Saccade-Related Potentials During Visual Tasks

Anne Guerin-Dugue
University Grenoble Alpes, France

In the 1970s, seminal works of Gastaut or Barlow and Ciganek combined electrooculography and electroencephalography (EEG) to gain understanding of the consequences of eye movements on EEG activity. From their work, the eye-fixation related potential estimation was developed to

provide greater insight into mechanisms related to eye movements, and the time course of the continuous cognitive processing involved in experimental tasks. This technique requires joint EEG and eye-tracking acquisition. Both event-related potentials and eye-fixation-related potentials, but also eye-saccade-related potentials can be observed to derive the cognitive processes involved and their timelines along visual tasks with greater ecological validity. Adapted methodologies mainly based on general linear models are available to temporally deconvolve overlapped potentials. Thanks to these methodologies with a focus on fixations but also on saccades, we will present results obtained for different visual tasks in the field of reading, natural scenes exploration, and emotional facial expressions decoding. Even with complex tasks as in daily life, the objective is to attempt to separately analyze intertwined cognitive processes according to the temporal dynamic of each participant across his or her eye movements to achieve the task

Applying Deconvolution and Nonlinear Modeling to Coregistered Electroencephalogram/Eye-Tracking Experiments in Vision Research

Benedikt V. Ehinger[1,2] and Olaf Dimigen[3]
[1]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands
[2]Institute of Cognitive Science, Osnabrück, Germany
[3]Humboldt University of Berlin, Germany

When combining eye tracking and EEG, two fundamental problems remain to be solved: (a) varying temporal overlap between brain responses evoked, for example, by consecutive fixations in natural viewing and (b) the numerous and often nonlinear influences of low-level stimulus properties and eye movement properties (like saccade amplitude) on the neural responses. To address these two problems, we have recently published the freely available open source "unfold" toolbox (www.unfoldtoolbox.org) which unifies the linear deconvolution framework (to disentangle overlapping potentials) with nonlinear regression (generalized additive modeling, to control for nonlinear confounds). In this talk, we will illustrate how this approach can be used to address theoretically interesting questions in vision research using data from face perception, scene viewing, and natural sentence reading. First, we will demonstrate how deconvolution can be used to account for, and analyze, overlapping brain potentials produced by involuntary (micro)saccades in a typical face recognition experiment. Then, we will disentangle multiple nonlinear influences of saccade parameters on fixation-related potentials during natural scene viewing. Finally, we will isolate the neural correlates of preview benefit in natural reading and separate them from the artifactual effects of varying fixation durations. Our approach shows a principal way to measure reliable fixation-related potentials during natural vision.

Activity of Visual Cortex Neurons Differs Between Passive Stimulation and Active Free Viewing

Junji Ito[1], Cristian Joana[1], Yukako Yamane[2,3], Pedro Maldonado[4] and Sonja Grün[1,5]
[1]Research Center Juelich, Germany
[2]Osaka University, Japan
[3]Okinawa Institute of Science and Technology, Japan
[4]University of Chile, Santiago, Chile
[5]Research Center Juelich, Germany; RWTH Aachen University, Germany

The standard paradigm for examining the neuronal activity of visual cortices has been the use of simple stimuli, such as moving bars or gratings, which are typically presented within the receptive field of the neurons of interest. In contrast to this paradigm, during natural vision, visual stimuli rarely appear suddenly in the visual field but arise as a consequence of eye movements. We conjecture that visual cortex neurons change their activity, not only as a consequence of visual inputs, but also reflecting the involvement of sensory–motor interactions, including eye movements, that are absent in the classical paradigm. Here, we quantify the neuronal responses of visual cortex neurons recorded from macaque monkeys while they freely view natural images and contrast these responses to the responses of these neurons to the sudden appearance of the same images at their presentation onset. We find that the latencies of the neuronal responses are considerably shorter during free viewing than at image onset and also the relative timing of the responses in different cortical areas/layers changes between the two conditions. Our study reveals the impact of voluntary eye movements on neuronal activity and provides hints that visual processing differs in active and passive viewing conditions.

Symposium 11

Culture and Attention: Insights From "Majority" Populations

Cultural Paradigms in Managing Attention

Barbara Rogoff
University of California Santa Cruz, CA, USA

Most research on attention has employed limited populations—mainly middle-class European or European-heritage people. Research indicates that the commonly held conclusion that skilled attention is narrowly focused is based on a specific cultural paradigm, not universal. Cultural comparative studies show skilled simultaneous attention, with no break in attention to competing events, among Guatemalan Mayan and Mexican-heritage communities. The research shows this to be rare in middle-class European American communities. Skilled simultaneous attention may be an important cultural tool for learning from observation in communities where children are included widely in family and community endeavors. This idea is supported by research showing keen attentiveness to surrounding events among Mayan and Mexican-heritage children, which was rare among middle-class European American children; they seldom paid attention to events around them that were not directed to them. The cultural differences support the idea of narrowly focused attention and broadly focused attention being distinct cultural paradigms.

Visual Attention in Children From Three Different Cultures

Moritz Köster, Shoji Itakura, Relindis Yovsi and Joscha Kärtner
Freie Universität Berlin, Germany

Cognitive processes differ markedly between children from different cultures, with best evidence for attention to visual scenes and the activities of others. Here, we assessed 144 five-year-old children from three prototypical cultural contexts (urban Germany, rural Cameroon, and urban Japan) to investigate variations in attention across a variety of tasks. Attention to the elements of a visual scene was assessed in an optical illusion task, in picture descriptions and an eye-tracking paradigm. Attention to and learning from others' activities were assessed in a parallel action task and a rule-based game. Some tasks indicated higher context-sensitive attention in urban Japan, while other findings indicated higher context-sensitive attention in urban Germany. Levels of parallel attention and learning from others' activities were lower in rural Cameroonian children compared with the urban samples. These findings substantiate that culture has a profound influence on early cognitive development, already in the preschool years. To highlight one mechanism in the development of children's attention processes, we will present two recent works on the development of visual attention pattern, indicating that context-sensitive attention is socialized via a verbal route in the parent–child interaction and that visual cortical networks align with verbal measures of context-sensitivity later in development.

The Effects of Gender and Education on Local–Global Bias in Eastern-European Roma Populations With Mixed Levels of Education and Literacy

Helen Spray and Karina J. Linnell
Goldsmiths, University of London, UK

Recent findings in African populations suggest that a global perceptual bias is not the universal characteristic of adult perception, it has been purported to be but rather is dependent on experience. We examined the effects of education, literacy, and gender on local–global bias in two low-socioeconomic status (SES) Eastern-European Roma populations. The two populations differed in overall levels of education and literacy as well as SES and other sociocultural circumstances. We found no evidence for an effect of literacy. However, results were broadly compatible with education promoting a global bias, albeit not unconditionally. In particular, there was no evidence for any effect of education on the local–global bias of women in the lowest SES Roma population: Women in this population demonstrated a local bias regardless of education or literacy, whereas men from the same population presented with a global bias. To our knowledge, this is the first documentation of a local bias in a nonclinical Western population. Our results emphasize the importance of both education and gender in determining local–global bias, while demonstrating that their effects may be interrelated and dependent on other sociocultural factors such as SES and the functional utility of education at the societal and gender level.

The Local Bias of Nonremote and Educated Populations From Rwanda

Serge Caparos[1], Karina Linnell[2] and Isabelle Blanchette[3]
[1]Université Paris 8, France
[2]Goldmsiths, University of London, UK
[3]Université du Québec à Trois-Rivières, Canada

In 1977, Navon argued that perception is biased towards the processing of global as opposed to local visual information (or the forest before the trees) and implicitly assumed this to be true across places and cultures. Previous work with normally developing participants has supported this assumption except in one extremely remote African population. Here, we explore local–global perceptual bias in normally developing African participants living much less remotely than the African population tested previously. These participants had access to modern artefacts and education but presented with a local

bias on a similarity matching Navon task, contrary to Navon's assumptions. Nevertheless, the urban and more educated amongst these participants showed a weaker local bias than the rural and less educated participants, suggesting an effect of urbanicity and education in driving differences in perceptual bias. Our findings confirm the impact of experience on perceptual bias and suggest that differences in the impact of education and urbanicity on lifestyles around the world can result in profound differences in perceptual style. In addition, they suggest that local bias is more common than previously thought; a global bias might not be universal after all.

Symposium 12: Thursday, August 29, 2019

Predictive Coding in Autism and Schizophrenia (Invited Leuven ECVP Symposium)

Introduction of the Symposium "Investigating Predictive Coding in Autism and Schizophrenia"

Laurie-Anne Sapey-Triomphe and Sander Van de Cruys
Laboratory of Experimental Psychology, Department of Brain and Cognition, Leuven Brain Institute, KU Leuven, Belgium

In recent years, several disorders or conditions have been revised within the predictive coding framework. According to that framework, the brain constantly learns priors that capture the underlying regularities of the environment. Priors play an important role in perception: they are combined with sensory information to generate percepts (perceptual inference). The relative contributions of priors and sensory evidence depend on their precision or confidence. Atypical balances between prior and sensory precisions have been proposed to account for the symptoms encountered in conditions such as autism spectrum disorder (ASD) or schizophrenia. The multiple predictive coding accounts of ASD and schizophrenia sometimes show considerable overlap in the hypothesized etiological mechanisms for the two conditions. It remains to be determined whether these conditions could be considered as primary disorders of perceptual inference. In the introduction of this symposium, we will provide some background to the predictive coding framework and how it has been applied to ASD and schizophrenia. We will raise some of the main questions that need to be answered in order to critically assess the validity and added value of these theories in ASD and schizophrenia.

Learning What to Expect in Autism

Rebecca Lawson
University of Cambridge, UK

Autism is a neurodevelopmental condition with a complex genetic basis that affects how people interact with the social and the nonsocial sensory environment. Prominent psychological theories of autism have suggested that the core cognitive difficulty concerns "context insensitivity," a perceptual bias toward small details at the expense of global processing. Predictive coding theories offer a computational account of how neural processing is contextualized via precision or sensory gain. In this talk, I will first outline predictive processing as applied to autism spectrum disorder. I will then present the findings from a number of recent studies examining differences in how autistic people process and learn about different kinds of sensory context, leading to (in)flexible perceptual decision-making in a changing world.

Preserved Integration of Sensory Input With Spatial and Temporal Context in Autism Spectrum Disorder

Floris de Lange
Radboud University, Nijmegen, the Netherlands

Autism spectrum disorder (ASD) may be marked by an altered balance between sensory input and prior expectations derived from spatial or temporal context. We examined neural activity in the visual system of ASD and typically developing (TD) adolescents, during several experiments in which sensory processing was altered by spatial or temporal context. First, we examined how the neural response in visual cortex is modulated by spatial context, in the context of a well-known visual illusion: the Kanizsa illusion. We find that early visual activity is strongly but equally modulated by this illusion in both ASD and TD groups. Second, we examined how the neural response in the early visual cortex is modulated by temporal context, by examining neural adaptation (repetition suppression) to repeated input. We find that visual cortex of both ASD and TD groups shows robust and indistinguishable adaptation. In sum, our data indicate preserved integration of sensory input with spatial and temporal context in ASD.

Predictions, Perception, and Psychosis: A Neurocomputational Account of Schizophrenia

Philipp Sterzer
Charité—Universitätsmedizin Berlin, Germany

There has been increasing interest in the underlying neurocomputational mechanisms of schizophrenia. One successful approach involves the theory of Bayesian hierarchical predictive coding, which proposes that inferences regarding the state of the world are made by combining prior beliefs with sensory signals. It has been suggested that schizophrenia is characterized by decreased precision of prior beliefs and a stronger weighting of sensory signals, leading to maladaptive inferences that result in delusions and hallucinations. However, empirical research has provided conflicting findings in this regard. Here, I propose that different levels of hierarchical predictive coding may differentially contribute to the psychopathology of schizophrenia and that such a nuanced view is needed to explain the individual differences in clinical appearance. I will present recent behavioral, neuroimaging, and computational work that investigated predictive processes in visual perception at different hierarchical levels. Results suggest that precision of priors is decreased at low levels of the predictive-coding hierarchy, while it is increased at higher hierarchical levels. This view has the potential to resolve apparent inconsistencies between previous findings, may help to understand the heterogeneity in the phenomenology of psychosis, and explain changes in symptomatology over time.

Symposium 13

Unraveling the Link Between Autism and Synesthesia

Psychophysical and Neurophysiological Markers of Subjective Sensory Sensitivity

Jamie Ward, Magda del Rio Forster, Tom Apps and Gozde Filiz
University of Sussex, Brighton, UK

Several neurodevelopmental conditions—including autism and synaesthesia—are characterised by heightened sensory sensitivity (e.g., aversion to lights and sounds). However, the underlying mechanism(s) that give rise to this remain elusive. In this presentation, results from several ongoing lines of research are reported. One hypothesis is that subjective sensory sensitivity reflects increased neural noise. This might manifest itself as greater cortical excitability (reduced phosphene thresholds in transcranial magnetic stimulation) and less consistent responses to the same physical stimuli in detection tasks. Evidence is presented that lower phosophene thresholds are correlated with increased subjective sensory sensitivity in a neurotypical sample, although this was not related to wider autistic tendencies (measured via the autism quotient). In addition to testing the neural noise hypothesis, we test using psychophysical techniques whether people with high subjective sensory sensitivity show less adaptation to visual stimuli: in effect, a failure to discount ongoing background stimulation may give rise to "sensory overload." It will also manifest itself behaviorally as, for instance, differences in visual search to targets presented on adapted-away backgrounds.

EEG Signatures of Local/Global Perception in Children With an Increased Likelihood of Synaesthesia and Children With Autism Spectrum Disorder

Tessa M. van Leeuwen[1], Myrte Druyvesteyn[1], Chelsea K. Donaldson[1], Eline van Petersen[1], Martine van Dongen-Boomsma[2], Jan Buitelaar[1,2], Sabine Hunnius[1,3] and Rob van Lier[1]
[1]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands
[2]Karakter Child and Adolescent Psychiatry University Centre, Nijmegen, the Netherlands
[3]Baby and Child Research Center, Radboud University, Nijmegen, the Netherlands

Synaesthesia, a mixing of the senses, is more common in autism spectrum disorder. These conditions may share perceptual alterations. We explore visual perception in three groups: children with autism, children with an increased likelihood of synaesthesia, and healthy control children (ages 5–6 years, preliterate). Electroencephalography (EEG) was measured during passive viewing of sinusoidal gratings of high/low spatial frequency (6.0/0.75 c/deg) at high/low luminance contrast (100%/10%). We hypothesized larger visual-evoked potentials in children with autism and children with an increased likelihood of synaesthesia for high spatial frequency (and high contrast) stimuli that specifically stimulate the parvocellular visual system. EEG data of healthy control children ($N = 21$) revealed a main effect of luminance contrast on P1 amplitudes, with higher contrast eliciting stronger responses; and main effects of spatial frequency, contrast, and their interaction for N2 amplitudes. For the N2 component, no hypothesized group differences were observed, but preliminary data from the synaesthesia and autism groups revealed larger P1 amplitudes in children with autism for high spatial frequency (detailed) stimuli than in control children, irrespective of luminance contrast. Children with increased likelihood of synesthesia showed

intermediate amplitudes. These preliminary findings are in accordance with our hypothesis of stronger parvocellular responses in both synaesthesia and autism.

Benefits and Disadvantages of Synaesthesia and Autism in Adults and Children

James Hughes and Julia Simner
University of Sussex, Brighton, UK

Synaesthesia and autism are two rare conditions that each represent unique ways of experiencing the world. Previous research has demonstrated multiple overlaps in the phenomenology of both of these conditions (e.g., sensory sensitivities) including a higher prevalence of synaesthesia in autistic populations. Over the last 4 years, research in our laboratory has focussed on how the combination of synaesthesia and autism in both children and adults is linked to a host of additional cognitive, perceptual, and behavioural traits/states. We have investigated both advantageous and disadvantageous outcomes that occur from the combination of synaesthesia and autism. First, I will discuss our findings related to the development of superior skills/talents in people who experience synaesthesia and autism together (also known as savant syndrome). I will also discuss how the specificity of these interactions can influence multiple unique outcomes (e.g., skills in different areas). Second, I will discuss our more recent work in child populations looking at disadvantageous outcomes of synaesthesia and autism. Here, I will show early data revealing associations between individual differences in sensory-sensitivities and how this is linked to anxiety and well-being in children.

The Genetic and Environmental Architecture of Synesthesia and Its Association With Autism and Other Psychiatric Conditions—A Twin Study

Mark Taylor[1], Tessa van Leeuwen[2], Ralf Kuja-Halkola[1], Sven Bölte[3,4] and Janina Neufeld[3,4]
[1]Department of Medical Epidemiology and Biostatistics at Karolinska Institutet, Stockholm, Sweden
[2]Donders Institute for Brain, Cognition and Behaviour, Centre for Cognition, Radboud University, Nijmegen, the Netherlands
[3]Karolinska Institutet, Solna, Sweden
[4]Stockholm Health Care Services, Stockholm County Council, Stockholm, Sweden

Synesthesia runs in families and co-occurs with autism spectrum disorder (ASD). However, the genetic and environmental contributions to synesthesia are unknown, and it is unclear whether it also co-occurs with other psychiatric conditions, such as attention-deficit hyperactivity disorder (ADHD). Using classic twin design, we are investigating the genetic/environmental architecture underlying synesthesia and its associations with ASD and other psychiatric conditions for the first time in a population-based twin-sample (current $N = 1{,}112$; age = 18 years). Synesthesia, autistic traits, and ADHD traits were assessed based on self-report. A preliminary univariate analysis on the 287 complete same-sex twin pairs, $N(\text{MZ}) = 128$, $N(\text{DZ} = 159)$, indicates that synesthesia is to 67% genetic (confidence interval [CI] = [52%, 75%]) and to 33% influenced by unique environment (CI [25%–45%]), while the impact of shared environmental factors is negligible (CI [0%–11%]). Furthermore, synesthesia correlated similarly with autistic traits (Spearman's $\rho = .1$, $p < .01$) and ADHD traits (Spearman's $\rho = .1$, $p < .001$) and individuals who report that they tend to get lost in details reported more synesthesia (Wilcoxon rank sum test: $W = 140{,}925$, $p < .005$). The results indicate that synesthesia is largely genetic while unique environmental factors play a smaller but also significant role. They further suggest that not only ASD but also ADHD traits as well as detail-focus are associated with synesthesia.

Symposium 14

The Spatial Character of Temporal Processes

Temporal Processes in the Visual System

Inci Ayhan
Bogazici University, Istanbul, Turkey

Adaptation, suppression, or interruption of transient signals may induce spatially specific distortions in event time. Apparent duration, for example, has been shown to be manipulated in a local region of visual field by long-term adaptation to flicker or motion. Saccadic eye movements were also revealed to distort subjective time as well as space. Recently, we introduced a new effect using a short-term adaptor and demonstrated that this brief adaptation induces a significant subjective duration compression on a subsequently presented RDK pattern only for global motion patterns drifting at 50% motion coherence but not for those drifting at 0% coherence, suggesting spatially specific sensory components of time perception mediating duration effects in the higher level motion areas. In another study, we have also demonstrated that not only domain-specific actions (i.e., eye movements) but also concurrently executed keypresses might trigger a compression in the subjective duration while performing a visual duration judgment task, providing further support for the involvement of transient

mechanisms in the timing of visual and visuo-motor events. In the first talk of our symposium, here, I will give a broad summary of these results with a specific emphasis on the involvement of motion-processing pathway in the timing of brief visual events.

Multiple Mechanisms for Judging Duration

Alan Johnston
University of Nottingham, UK

Classical theories of timing assume the presence of an amodal universal clock which could be used to judge the time of occurrence and duration of events. However, more recently, evidence has been accruing that there are multiple timing mechanisms that can exploit embedded signals arising from the natural operation of cognitive systems. Empirical evidence from two systems will be reviewed. In the first case, we will consider the evidence for spatially localized influences of adaptation to flicker or motion on the timing of visual events and how these changes might be explained. Classical studies have shown arousal to influence duration judgments, effects that were explained in terms if arousal speeding up an internal clock. In the second case, we will consider evidence that changes in arousal, measured by pupil size during an eye contact timing task, can provide a clock signal, rather than simply modifying a generic mechanism. Intervals with greater rates of increase in pupil size were judged longer. These examples suggest at least two different strategies for timing: one based on temporal prediction and one based on rates of endogenous signals.

Mechanisms of Space and Time in the Healthy and the Diseased Brain

Lorella Battelli, Grace Edwards and Federica Conto
Italian Institute of Technology, Genoa, Italy

Disruption of space and time perception caused by acquired cortical lesions after stroke can have profound consequences on daily living. For many individuals, spatial deficits such as visual neglect will resolve after the acute phase of stroke into long-lasting deficits encompassing space and time functions, with the presence of both deficits as a sign of the severity of the deficit. Typically, visual extinction in which objects and events in the contralesional space are ignored in favor of events in the ipsilesional space indicates imbalance in attention control, and it implicates a restructuring of attention networks in the brain; however, to date, there have been no detailed measurements of the state of these cortical networks in stimulation-induced recovery in the diseased and functional and behavioral response in the healthy brain. I will present data from stroke patients and healthy subjects with noninvasive brain stimulation indicating different behavioral and cortical responses depending on whether space and time are tested separately or simultaneously. I will also demonstrate how the complex inhibition and excitation dynamic across hemispheres and within areas in one hemisphere can have an impact on visuospatial functions.

Space and Time in the Visual Brain

Gianfranco Fortunato[1], Tatiana Kénel-Pierre[2], Micah Murray[2] and Domenica Bueti[1]
[1]Scuola Internazionale Superiore di Studi Avanzati, Trieste, Italy
[2]Laboratory for Investigative Neurophysiology, Department of Clinical Neurosciences, University Hospital of Lausanne, Switzerland

Performing a timed movement like dancing, playing a musical instrument, or simply walking requires for the brain the integration of both temporal and spatial information. How and where the human brain links these two types of information remain unclear. Previous studies have shown that V1 and V5/MT are both involved in the encoding of temporal information of brief visual stimuli. However, none of these studies clarify whether temporal information in visual cortex is encoded within the same circuitry encoding spatial information. Here, we tested the hypothesis that V1 and V5/MT encode time in different spatial coordinates. In two distinct experiments, we asked participants to discriminate the duration of millisecond visual intervals presented at different retinotopic and spatiotopic (head-centered) positions, while 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 a worsening of temporal discrimination after paired-pulse transcranial magnetic stimulation over both V1 and V5/MT compared with control conditions (i.e., vertex and contralateral V1). More specifically, the effects were hemifield-specific in V5/MT and retinotopic-specific in V1. These results show, for the first time, the existence of a functional link between representation of time and space in visual cortices.

Symposium 15

The Vision of Taste. How Visual Perception Can Change Our Sensory Experience of Food

The Vision of Taste: How Visual Perception Can Change Our Sensory Experience of Food—An Introduction and Multidisciplinary Review to the Symposium "Food and Visual Perception"

Francesca Di Cicco, Maarten Wijntjes and Sylvia Pont
Delft University of Technology, the Netherlands

Food industries are designing healthy products with reduced content of fat, sugar, and sodium that are still sensory appealing. Replacing fat or sugar molecules alters the physical and chemical structure of food, having a negative effect on texture parameters such as viscosity or creaminess, and thereby on taste. Texture properties are assessed primarily visually, setting expectations of palatability and affecting the food choice and intake. Researchers have also been looking into color, size, and shape of food plus external aspects like labels and packaging design, plating, or the best lighting conditions for the "tasty look." So, even if the recipe and ingredients are kept constant, taste and flavor perception can be influenced by visual modifications to the food (presentation). Therefore, interesting insights may be derived from art and how painters have been rendering food in a way meant to "whet the appetite." With a multidisciplinary approach, we can better understand what affects consumers' perception and thus acceptance, for innovation and design of healthy food. I will present a review on this topic, illustrated with concrete examples of the effects of vision on taste, including novel results on freshness perception of fruits.

Do Not Judge New Foods by Their Appearance! How Visual and Oral Sensory Cues Affect Sensory Perception and Liking of Novel, Heterogeneous Foods

Marco Santagiuliana, Vani Bhaskaran, Elke Scholten, Betina Piqueras Fiszman and Markus Stieger
Wageningen University, the Netherlands

This study investigated how exteroceptive and interoceptive cues influence sensory perception and liking of novel, heterogeneous foods. Twelve heterogeneous cheeses were prepared by adding bell pepper pieces to homogeneous processed cheese matrices. Consumers evaluated cheeses in three conditions. In the first condition, subjects tasted cheeses and rated them on sensory properties and liking while being blindfolded (interoceptive condition). In the second condition, participants evaluated expected sensory properties and liking of cheeses presented as pictures together with product descriptions (exteroceptive condition). In the third condition, consumers tasted and evaluated cheeses, while visual cues and product descriptions were provided (combined condition). Hardness and concentration of bell pepper pieces predominantly determined variations in sensory perception in interoceptive and combined conditions, whereas bell pepper size or concentration influenced expected sensory properties in the exteroceptive condition. Both visual and oral sensory cues influence texture and flavour perception of heterogeneous cheeses. Consumers' liking was not influenced by the cheese's exteroceptive cues during the combined condition. In contrast, interoceptive cues as hardness played a large role in determining variations in consumer's hedonic responses. We conclude that for novel, heterogeneous foods liking after consumption is determined by textural product properties and depends on confirmation of consumers' sensory expectations.

Beyond Expectations: The Responses of the Autonomic Nervous System to Visual Food Cues

Luz Verastegui-Tena, Hans van Trijp and Betina Piqueras Fiszman
Wageningen University and Research, the Netherlands

Eye appeal is half the meal. Visual cues carry essential information for product identification setting up expectations about foods. But how strongly does that visual information manifest in our most visceral reactions? Seventy-five participants tasted four drinks (three of them were the same) and were shown their supposedly main ingredient (pleasant, neutral, or unpleasant) either before or after tasting. Heart rate and skin conductance were measured during the whole procedure. The results showed that autonomic nervous system (ANS) responses followed a similar pattern when images were presented before or after tasting. Heart rate decreased for all images, with the largest decrease found for the pleasant and unpleasant food images. Skin conductance increased, with the largest increase found for unpleasant food image. To test if the effects were related to the perception of images alone, a second study was done in which 40 participants saw the same images. In conclusion, the ANS

responses of the first study are a result of sensory processing and defense mechanisms part of the creation and (dis)confirmation of expectations and highlights that the context of use influences the patterns and magnitude of the ANS responses to food cues.

The Yummy and the Brush

Jeroen Stumpel
Utrecht University, the Netherlands

Our visual system can finely distinguish between different surface properties as an indication of the possible presence of nutrients. The highlight (a dot-like specular reflection from smooth and convex surfaces) plays an essential role in the perception of material. A berry, for instance, that is swollen and smooth is more likely to be ripe than a rough and wrinkled one. In a coevolutionary process, fruits that are dependent on other species for the spreading of their seeds may even enhance the optical conditions for highlights, signal ripeness more strongly. Highlights to render surface properties also entered the pictorial world. Although not restricted to food, the pictorial highlight was of great importance precisely for edibles. In 17th century still life painting, for instance, it was an outspoken artistic ambition to make food look savory, which sometimes lead to stunning results. A large part of this painterly craft consisted in the arranging and fine-tuning of various forms of highlights. This study discusses highlights and attractiveness related to food perception within the history of art, including the very painting process itself, because this, too, may be admired in aesthetic terms akin to those for food appreciation, such as "creamy," "nice," "succulent," or saturated.

Talk Sessions

Monday, August 26, 2019

Talk Session 1

Motion Processing

The Loss Function of Perception Is Adjustable

Tianyuan Teng[1,2], Sheng Li[3,4] and Hang Zhang[2,3,4]
[1]Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, China
[2]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China
[3]Beijing Key Laboratory of Behavior and Mental Health, School of Psychological and Cognitive Sciences, China
[4]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, China

Human perception is well modeled by Bayesian inference, where loss function is a necessary component that determines the optimal readout from the posterior. Although often assumed to be quadratic, its functional form has rarely been empirically tested. Here, we investigated a random-dot motion estimation task to infer the loss function of perception and whether it is modifiable. Each dot's moving direction was sampled from a skewed mixture of two Gaussian distributions. L2 (quadratic) and L0 ($hit = 0$, $otherwise = 1$) loss functions, respectively, predict the perceptual readout of the mean and mode. In Experiment 1 ($N = 15$), we found the motion direction estimated by participants had a consistent deviation from the mean and biased toward the mode, with the bias increasing almost linearly with the mode-to-mean distance, which suggests a loss function between L2 and L0. In Experiment 2 ($N = 6$), we tested whether this default loss function can be modified by feedback that designates the mode as the correct answer. After extensive training, participants' estimation bias increased by approximately 125% in the trained direction and, surprisingly, increased by approximately 50% in the untrained direction as well, which implies the loss function can adapt to the external definition of loss.

Discriminating the Direction of Motion

Chie Takahashi[1], Marina Danilova[1,2] and John Mollon[1]
[1]University of Cambridge, UK
[2]I. P. Pavlov Institute, St. Petersburg, Russia

The discrimination of some visual attributes (e.g., luminance) deteriorates rapidly as the stimuli—the discriminanda—are separated in space; but in the case of other attributes (e.g., spatial frequency), differential thresholds are the same, or are very similar, whether the discriminanda are adjacent or are separated by 10° and fall in opposite hemifields. Here, we ask what should be expected for discrimination of the directions of two arrays of random dots moving at 4° per second and exposed briefly for 180 milliseconds. If the discrimination of adjacent arrays depended on a shear signal at their shared boundary (analogous to a local contrast signal in luminance discrimination), we might expect performance to deteriorate rapidly as the arrays were separated. The experimental data do exhibit a motion analog of the oblique effect (discrimination was optimal for directions close to vertical.) However, the change in threshold with spatial separation of the two arrays is small. How is this human ability to be explained? Should we postulate a battery of dedicated comparator neurons for every possible pair of

local regions in the field, or is direction represented at the site of comparison by a more abstract code?
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Octopuses Perceive Second-Order Motion: Evidence for Convergent Evolution of Visual Systems

Marvin Rainer Maechler[1], Marie-Luise Kieseler[1], Jade Smith[1], Mark Taylor[1], Shae Wolfe[1], Sylvia Hipp[1], Alexandra Simpson[1], Scarlett Souter[1], Jean Fang[1], Matthew Goff[1], David Edelman[1], Marcus Missal[1] and Peter Ulric Tse
Dartmouth College, Hanover, NH, USA

The ability to detect camouflaged prey and predators is important for survival. One plausible candidate mechanism for counteracting camouflage in the environment is second-order motion perception, which requires more sophisticated processing than first-order motion perception. We conditioned octopus bimaculoides to approach the side of a screen containing a second-order motion stimulus: a patch of visual noise moving over a background of similar visual noise. Stimuli were presented on a tank wall, which served as a projection screen. The screen was split in half by another smaller wall orthogonal to the screen, dividing a part of the tank into two compartments, inside one of which the target stimulus was presented. After conditioning, the animals would select the target by entering the correct compartment almost perfectly. Octopuses are a notable model organism with complex cognitive faculties, some of which are reminiscent of mammalian intelligence. Yet, cephalopod and mammalian brains have evolved independently for more than 500 million years. Their last common ancestor possessed only rudimentary light sensing organs and a primitive visual system. Convergent evolution of such systems strongly suggests that the trait in question—second-order motion perception—is an optimal solution for a common problem.

Different Motion Integration Mechanisms for Cortical and Subcortical Visual Motion Processing Pathways in Mice

Richard van Wezel, Wenjun Zhang, Zahra Rezvani and Laurens Kirkels
Donders Insitute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands

In recent years, mice have become an important animal model for studies on visual processing. We designed a new method to behaviorally quantify mice visual motion processing by measuring reflexive opto-locomotor responses. Mice were placed head-fixed on an air-floating ball at the center of a large dome on the inside of which we projected moving random-dot patterns for 2 seconds. Rightward or leftward moving random-dot patterns caused the mice to change their running direction, which we quantified. When we covered the right or left eye we found a strong bias at first (subcortical processing), but after a few hundred milliseconds, this bias disappeared and behavior was similar to responses to motion under binocular conditions (cortical processing). Furthermore, under conditions with transparently presented motion patterns in two different motion directions, the mice follow the average motion direction the first few 10 milliseconds and after that one of the two motion directions is selected. From these behavioral measurements, we conclude that visual motion is averaged in the subcortical pathway, while it is segregated in the cortical pathway of mice.

A Structurally Simple Model Explains MT Transients Under Variable Stimulus and Behavioral Conditions

Chen Xiao[1], Bohnenkamp Lisa[1], Wegener Detlef[2] and Udo Ernst[1]
[1]Department of Theoretical Physics, University of Bremen, Germany
[2]Institute for Brain Research, University of Bremen, Germany

Natural, cluttered visual scenes often contain rapidly changing information. For successful behavior, it is crucial to process and evaluate such changes as quickly as possible. In monkey area middle temporal (MT), it was shown that motion-selective neurons represent sudden speed changes in fast transient responses. Both spatial and non-spatial visual attention modulate the transient's latencies, which in turn closely correlate with reaction time. We investigate the underlying computational mechanisms by a structurally simple model providing divisive inhibition to MT neurons, to quantitatively reproduce the time course of transient responses under passive viewing conditions. Mathematical analysis of the circuit explains hallmark effects of transient activations, identifying the relevant parameters determining response latency, peak response, and sustained activation. Analysis of the model also predicts a consistent increase in the transient's rise time for a corresponding positive input change under conditions of attention, matching the experimental observation of shorter latencies for this case. Interestingly, the model also predicts faster decay times for negative transients for attended speed decrements, which indeed were found in previously unpublished MT data. Thus, the model

provides a unique framework for a mechanistic explanation and mathematical understanding of MT response dynamics under very different sensory and behavioral conditions.

Multimodal Representation of Visual and Auditory Motion Directions in hMT+/V5

Mohamed Rezk[1], Stephanie Cattoir[2], Ceren Battal[1,2], Valeria Occelli[2], Stefania Mattioni[1,2] and Olivier Collignon[1,2]
[1]Institut de recherche en sciences psychologiques, Universite catholique de Louvain, Belgium
[2]Center for Mind/Brain Sciences, University of Trento, Italy

The human middle temporal area hMT+/V5 is known to code for visual motion directions. Despite being traditionally considered as purely visual, recent studies suggested that hMT+/V5 could also code for auditory motion. However, the nature of this cross-modal response in hMT+/V5 remains unsolved. In this study, we used functional magnetic resonance imaging (fMRI) to comprehensively investigate the representational format of visual and auditory motion directions in hMT+/V5. Using multivariate pattern analysis, we demonstrate that visual and auditory motion direction can be reliably decoded inside individually localized hMT+/V5. Moreover, we could predict the motion directions in one modality by training the classifier on patterns from the other modality. Such successful cross-modal decoding indicates the presence of shared motion information across the different modalities. Previous studies used successful cross-modal decoding as a proxy for abstracted representation in a brain region. However, relying on series of complementary multivariate analysis, we unambiguously show that brain responses underlying auditory and visual motion direction in hMT+/V5 are highly dissimilar. Our results demonstrate that hMT+/V5 is a multimodal region that contains motion information from different modalities. However, while shared information exists across modalities, hMT+/V5 maintains highly separate response geometries for each modality.

Separable Mechanisms for the Processing of Real and Illusory Motion?

Sunčica Zdravković[1,2] and Ian M. Thornton[3]
[1]Department of Psychology, University of Novi Sad, Serbia
[2]Laboratory for Experimental Psychology, University of Belgrade, Serbia
[3]Department of Cognitive Science, University of Malta, Msida, Malta

Recently, we used visual search to show that the onset of illusory motion "pops-out" (Thornton, Zdravković, 2018). Here, in three experiments, we use additional reaction time tasks to contrast the processing of illusory and real motion. In Experiment 1, four experienced observers performed a nulling task to determine individual speed estimates of illusory motion. These ranged from 1.8° to 2.4° of angular rotation/s. In a subsequent search task, both illusory and speed-matched real motion targets popped-out, but illusory targets gave rise to consistently faster responses. In Experiment 2, we replicated this illusion advantage with naive participants. Below 2 deg/s, the addition of illusory motion gave a detection advantage compared with both motion-neutral and implied motion control stimuli. In Experiment 3, we used a conflict task, where the direction of illusory or implied motion was either congruent or incongruent with the direction of physical rotation, which varied between 2 deg/s and 5 deg/s. This manipulation had no effect on implied motion stimuli but gave rise to clear costs and benefits for the illusory motion stimuli. Our findings suggest that some stages of illusory motion processing may be separable from those used to process real motion stimuli, possibly involving more rapid retino-collicular rather than retino-thalamic pathways (Beltramo & Scanziani, 2019).

A Visual Model of Collective Motion in Human Crowds

William H. Warren and Gregory C. Dachner
Brown University, Providence, RI, USA

Collective motion in human crowds emerges from local interactions between individual pedestrians. Previously, we found that an individual in a crowd aligns their velocity vector with a weighted average of their neighbors' velocities, where the weight decays with distance (Rio, Dachner, & Warren, PRSB, 2018; Warren, CDPS, 2018). Here, we explain this "alignment rule" based solely on visual information. When following behind a neighbor, the follower controls speed by canceling the neighbor's optical expansion (Bai & Warren, VSS, 2018) and heading by canceling the neighbor's angular velocity. When walking beside a neighbor, these relations reverse: Speed is controlled by canceling angular velocity and heading by canceling optical expansion. These two variables trade off as sinusoidal functions of eccentricity (Dachner & Warren, VSS, 2018). We use this visual model to simulate the trajectories of participants walking in virtual (12 neighbors) and real (20 neighbors) crowds. The model accounts for the data with root mean square errors (.04–.05 m/s, 1.5°–2.0°) the distance decay as a consequence of comparable to those of our previous velocity-alignment model. Moreover, the model explains Euclid's law of perspective, without an explicit distance term. The visual model thus provides a better explanation of collective motion.

Talk Session 2

Crowding

The Role of Cortical Distance in the Perceptual Outcomes of Crowding

John A. Greenwood, Katarina Jerotic, Joseph E. Danter and Rhiannon J. Finnie
University College London, UK

Peripheral vision is disrupted by crowding, which typically causes target and flanker objects to appear more alike (assimilation). Conversely, simultaneous contrast effects can also increase target–flanker dissimilarity (repulsion). The trade-off between these effects has been attributed to cortical distance: Assimilation occurs when elements are close within retinotopic maps, while more distant flankers induce repulsion. We tested this proposal by psychophysically manipulating cortical (vs. physical) distance. Observers judged the orientation of a target Gabor. First, we placed a flanker in either the ipsilateral or contralateral hemifield (manipulating cortical distance by projecting elements to the same or different hemispheres). Although crowding was observed, flanker location had no effect, contrary to prior studies. Second, because cortical magnification is highest along the radial dimension from fixation, target–flanker distances are lower for radially positioned versus iso-eccentric flankers. Accordingly, errors were predominantly assimilative with radial flankers and repulsive with iso-eccentric flankers. Finally, because the representation of the upper visual field is compressed, target–flanker cortical distances would be reduced relative to the lower field. Again, assimilation was greater in the upper versus lower field. Altogether, our results suggest that cortical distance can alter the perceptual outcomes of crowding, though factors including flanker number and collinearity must also be considered.

Visual Crowding Does Not Scale With Eccentricity for Densely Cluttered Displays

Erik van der Burg[1], Adam Reynolds[1], John Cass[2] and Chris Olivers[1]
[1]Vrije Universiteit Amsterdam, the Netherlands
[2]Western Sydney University, Australia

Visual crowding refers to the inability to identify an object in peripheral vision when it is surrounded by nearby clutter. Bouma (1970) demonstrated that identification errors are likely when distractors are located nearby the target within a radius equal to approximately half the target eccentricity. The general consensus is that crowding scales with eccentricity. Recent work has indicated that crowding may function differently in dense displays. Using an evolutionary algorithm, we investigated whether critical spacing scales with eccentricity (4.8° and 7.2°) for dense displays. Participants reported the orientation of a nearly vertical target among 512 horizontal and vertical distractor elements. We generated initially random distractor arrays and those supporting highest accuracy were selected ("survival of the fittest") and combined to create new displays. Performance improved over generations, predominantly driven by the emergence of horizontal flankers within 0.6° of the near-vertical target, but with no evidence of interference beyond this radius. Interestingly, eccentricity did not affect the outcome in dense displays, although we found evidence that crowding scales with eccentricity when the target was surrounded by just four distractors. The results indicate that what we know from the literature using simplistic displays does not necessarily generalise to more complex displays.

Shrinking Bouma's Window: Visual Crowding in Dense Displays

Alban Bornet[1], Adrien Doerig[1], Gregory Francis[2], Michael H. Herzog[1] and Erik Van der Burg[3]
[1]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne, Switzerland
[2]Department of Psychological Sciences, Purdue University, West Lafayette, IN, USA
[3]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, the Netherlands

In crowding, perception of a target deteriorates in the presence of nearby flankers. In the traditional feedforward framework of vision, only elements within Bouma's window interfere with the target and adding more elements always leads to stronger crowding. Crowding is usually studied with sparse displays that involve only a few flankers, as too many flankers lead to a combinatorial explosion of display configurations. To deal with these challenges, Van der Burg et al. (2017) proposed a paradigm to measure crowding in dense displays using genetic algorithms. In their study, displays were selected and combined over several generations to maximize human performance. Van der Burg et al. found that only the target's nearest neighbours affect performance in their displays. Here, we used the same paradigm, but the displays were selected according to the performance of visual crowding models. We found that all models based on the traditional framework of vision tested so far produce results in which all elements within Bouma's window affect performance in dense displays, contrary to human behavior. The only model that explains the results of Van der Burg et al. has a dedicated grouping process. We conclude that a grouping stage is crucial to understand visual processing.

Basic Gestalt Laws Cannot Explain Uncrowding

Oh-hyeon Choung[1], Einat Rashal[1,2] and Michael H. Herzog[1]
[1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne, Switzerland
[2]Department of Experimental Psychology, University of Ghent, Belgium

Visual crowding is the inability to perceive elements within clutter. Traditional crowding models, such as pooling, predict that performance deteriorates when flankers are added. However, this prediction has been disproved. For example, performance was found to deteriorate when a Vernier was surrounded by a single square but also to improve when more squares were added. This phenomenon is termed "uncrowding." Previous studies showed that it is not the number of flankers that matters for uncrowding but the configuration. To understand how a configuration leads to crowding or uncrowding, we presented a Vernier surrounded by a square in the center of the screen. To that we added squares and stars that constructed different configurations according to the Gestalt laws of symmetry, closure, and good continuation. We did not find any evidence that the Gestalt laws we tested play an important role in crowding. To test for low-level factors, we also used a pixel-wise clustering method (k-means algorithm). However, we could not find evidence for the involvement of low-level factors either. We conclude that neither Gestalt laws nor basic processing can explain crowding and uncrowding. Likely, more complex aspects of display matter.

Capsule Networks Explain Complex Spatial Processing

Adrien Doerig, Lynn Schmittwilken and Michael Herzog
École Polytechnique Fédérale de Lausanne, Switzerland

Classically, visual processing is described as a cascade of local feedforward computations. This view has received striking support from the success of convolutional neural networks (CNNs). However, CNNs only roughly mimic human vision. For example, CNNs do not take the global spatial configuration of visual elements into account and thus fail at simple tasks such as explaining crowding and uncrowding. In crowding, the perception of a target deteriorates in the presence of neighboring elements. Classically, adding flanking elements is thought to always decreases performance. However, adding flankers even far away from the target can improve performance, depending on the global configuration (uncrowding). We showed previously that no classic model of crowding, including CNNs, can explain uncrowding. Here, we show that capsule networks, a type of deep network combining CNNs and object segmentation, explain both crowding and uncrowding. We trained capsule networks to recognize targets and groups of shapes. There were no crowding/uncrowding stimuli in the training set. When we subsequently tested the network on crowding/uncrowding stimuli, both crowding and uncrowding occurred. We show theoretically how crowding and uncrowding naturally emerge from neural dynamics in capsule networks. These powerful recurrent models offer a new framework to understand previously unexplained experimental results.

Attentional Limits in Crowding Are Asymmetric

Koen Rummens[1] and Bilge Sayim[1,2]
[1]University of Bern, Switzerland
[2]CNRS, UMR 9193, SCALab, Sciences Cognitives et Sciences Affectives, Univ. Lille, France

Crowding impedes the recognition of a target surrounded by objects. Previous studies showed reduced crowding for the central target of a trigram when its location was cued. Here, with spatial probability as attentional cue, we investigated how letter identification at all positions within a trigram was affected by attention. Participants reported the left, central, or right letter of a three-letter string in a crowding paradigm. The target letter position varied in probability (100%, 80%, 50%, or 33%; equal percentages for the two remaining positions) and was indicated by a postcue. As expected, overall accuracy was better for the inward and outward compared with the central letter. Interestingly, higher target probability improved performance compared with lower probability only for the outward letter. Target probability did neither affect inward nor central letter performance. Our results indicated an inward–outward asymmetry of attention when identifying crowded objects: Outward performance was strongly limited by attention, while inward performance and central performance were mainly constrained by crowding effects independent of attentional cueing. We suggest that attention and crowding limit crowded target identification differently depending on the target location within clusters of objects.

Crowding Reduces Numerosity Estimates for Large Numbers

Miao Li[1,2], Bert Reynvoet[2,3] and Bilge Sayim[1,4]
[1]CNRS, CHU Lille, UMR 9193—SCALab—Sciences Cognitives et Sciences Affectives, Univ. Lille, France
[2]Faculty of Psychology and Educational Sciences, KU Leuven, Belgium

[3]Brain and Cognition, Faculty of Psychology and Educational Sciences, KU Leuven, Belgium
[4]Institute of Psychology, University of Bern, Bern, Switzerland

Crowding, that is, the deleterious influence of clutter on target perception, was proposed to play a crucial role in numerosity estimation (NE). For example, eccentricity and spacing were shown to modulate performance in NE similarly as in crowding, however, dependence on these factors is not unique to crowding. Here, we used one of the key characteristics of crowding, its radial-tangential anisotropy (i.e., that radially arranged flankers crowd more than tangentially arranged flankers), to investigate the role of crowding in NE. We varied crowding by letting target discs either fall (crowding condition) or not fall (no-crowding condition) into neighboring crowding zones, while keeping other stimulus properties, such as average eccentricity, spacing, and convex hull the same in the two conditions. Participants were presented with displays consisting of discs across five numerosity ranges (21–25, 31–35, 41–45, 49–53, and 53–57). The task was to estimate the number of discs. Underestimation occurred in both the crowding and no-crowding condition with large but not with small numerosities. Importantly, underestimation was stronger in the crowding than in the no-crowding condition, indicating that crowding decreased the perceived number of discs compared with the no-crowding condition. Our findings show that crowding plays a critical role in NE with large numbers.

Less Brain Activity Is More When Reading Fine Print

Derek Arnold[1], Eleanor Moses[1], Wiremu Hohaia[1] and Melveyn Goodale[2]
[1]The University of Queensland, Brisbane, Australia
[2]Western University, London, Ontario, Canada

Human sensitivity to visual inputs often scales with the magnitude of responses in the brain. Here, we demonstrate an exception. Using electroencephalography to measure brain activity, we find that ability to read fine print is inversely scaled with the magnitude of responses recorded by a cluster of occipital-parietal sensors, encompassing a time window from ~140 to 160 milliseconds after word onsets. Moreover, we find that this relationship holds when people adapt to flicker prior to reading text—which improves reading acuity. Our data suggest that large early neural responses to fine print are associated with blur perception, which prevents text from being resolved, whereas smaller responses are associated with less blur, and better acuity. Our data also suggest that flicker adaptation can encourage smaller responses to input and thus better acuity. Overall, our data suggest that smaller responses to input can predict greater sensitivity when task success relies on the acuity of human vision.

Talk Session 3

Visuo-Vestibular, Visuo-Motor, Visuo-Haptic

Muscular Responsiveness as Measurement of the Influence of Visual Input in Motor Cortical Excitability

David Zeugin and Silvio Ionta
Sensory-Motor Lab, Department of Ophthalmology, University of Lausanne, Jules Gonin Eye Hospital-Fondation Asile des Aveugles, Switzerland

In nonhuman primates, ablating the visual cortex leads to structural aberrations in motor areas, suggesting that visual input influences neural development in motor regions. In humans, evidence about the equivalent connectivity is more uncertain. To fill this gap, we used transcranial magnetic stimulation (TMS) to study the effects of inhibiting the primary visual cortex (V1) on the baseline activity in the primary motor cortex (M1). First, with repetitive TMS, we inhibited activity either in V1 or vertex (control). Then, we applied a single-pulse TMS on M1 to assess cortico-spinal excitability via motor-evoked potentials (MEPs). We measured the MEPs' amplitude (AMP), cortical silent period (CSP), and area (Area), recorded before (Pre) and after (POST) the inhibition protocols (V1, control). In contrast to the control condition, only when V1 was TMS-inhibited the MEPs' Area was smaller in the POST- than the Pre-session. Such difference was not found for AMP and CSP. As Area is the ratio between AMP and CSP, it provides a more comprehensive index of the corticospinal outcome. The present results indicate that inhibition of V1 has a direct and timely consequence on the baseline activity in M1.

Voluntary Action Modulates Visually Evoked Cortical Responses in Primary Visual Cortex: An Integrated Ultra-High Field fMRI and EEG Study

Alessandro Benedetto[1], Paola Binda[1], Tam Ho[1], Mauro Costagli[2], Michela Tosetti[2] and Maria Concetta Morrone[1,2]
[1]Department of Translational Research on New Technologies in Medicines and Surgery, University of Pisa, Italy
[2]IRCCS Stella Maris, Calambrone, Pisa, Italy

In previous studies, we have shown that voluntary actions can induce long-lasting theta behavioral oscillations. These oscillations have been observed for several visual

functions, including temporal order judgments, orientation, and contrast discrimination. To study how behavioral oscillations are related to endogenous neural oscillations, we investigated the spatiotemporal characteristics of the visual response around the time of a voluntary action in an ultra-high-field (7T) functional magnetic resonance imaging (fMRI) experiment, and in an electroencephalography (EEG) experiment. Participants ($N = 13$ and 18, for Experiments 1 and 2, respectively) discriminated the spatial frequency of two very brief gratings, presented randomly in the upper or lower visual field after a free self-paced button-press. The stimulus was displayed randomly with either 70-millisecond or 150-millisecond delay from button-press, corresponding to the first minimum/maximum of the sensitivity oscillation. Stimuli presented at 150 milliseconds evoked a stronger V1 BOLD response than stimuli presented at 70 milliseconds (i.e., the predicted peak/through of the excitability cycle, respectively). Consistently, the occipital visual-evoked potential to the 150-millisecond stimulus had higher amplitude respect to the 70-millisecond stimulus. These results suggest an early visuo-motor interaction, at the level of V1. The rhythmic modulation points to a synchronization between vision and action, shaping vision by alternatively suppressing and enhancing visual processing.

Visual-Vestibular Conflict Detection Is Modulated by Motor Signals

Paul MacNeilage, Savannah Halow and James Liu
University of Nevada, Reno, NV, USA

Head movement relative to the stationary environment gives rise to congruent vestibular and visual optic flow signals. The resulting percept of a stationary visual environment depends on mechanisms that compare visual and vestibular signals to evaluate their congruence. Here, we investigate the efficiency of these mechanisms and how it depends on fixation behavior as well as on the active versus passive nature of the head movement. Sensitivity to conflict was measured by modifying the gain on visual motion relative to head movement on individual trials and asking subjects to report whether the gain was too low or too high. We measured the range of gains that are compatible with perception of a stationary visual environment, referred to by Wallach as the Range of Immobility. Experiments were conducted using a head-mounted display capable of rendering visual scene motion contingent on head motion, with fixation behavior monitored by an embedded eye tracker. The experimental design included combinations of active or passive head movement together with head-fixed or scene-fixed fixation. Performance was better during active than passive head movement and better during scene-fixed than head-fixed fixation. These findings quantify how visual–vestibular conflict detection is modulated by eye and neck motor signals.

Veridical and Perceived Location Compete for Visuomotor Control

Marjan Persuh[1], Fatemeh Alhabib[2] and Robert Melara[2]
[1]Borough of Manhattan Community College, The City University of New York, NY, USA
[2]The City College of New York, The City University of New York, NY, USA

We examined the contributions of veridical and perceived location to response priming, using a flash-lag illusion. Participants made speeded responses to the location of the target disk presented above or below the static bars. In the first experiment, we kept the physical location of the prime disk constant, the disk and moving bars were presented at the same location. Responses to the target disk were consistently biased by the prime disk, demonstrating that rapid motor responses were primed by the illusory perception of the prime location. In the second experiment, we estimated the size of illusion for each participant and then presented the prime disk either above or below the moving bars so that perceived location was in alignment with the moving bars. Motor responses were moderated by the prime disk, showing that visuomotor system used veridical prime location. In the third experiment, we pitted veridical and perceived location against each other so that veridical location and perceived location of the prime were on the opposite sides of the moving bars. With this setup, motor responses were not influenced by primes. Our experiments demonstrate that our visuomotor systems use veridical as well as perceived location to guide behavior.

The Role of Visuo-Haptic Position and Size Signals When Grasping Handheld Objects in Visual Periphery

Ivan Camponogara and Robert Volcic
New York University Abu Dhabi, United Arab Emirates

Visually guided reach-to-grasp actions are often also assisted by haptic information from the hand contralateral to the one performing the action (e.g., reaching for the lid while holding a jar). Here, we investigated the role of visual and haptic object information in multisensory grasping by modifying the quality of visual information. Participants ($n = 18$) grasped objects of different sizes in central or peripheral vision (40° eccentricity) either with or without additional haptic information or with haptic information

only. We replicated our previous finding that in central vision multisensory information leads to more efficient actions than unisensory information. In addition, we found that when objects were only peripherally seen, participants' grasping movements were slow and almost insensitive to changes in object size. In contrast, the simultaneous availability of peripheral vision and haptics led to faster movements and smaller grip apertures than in the peripheral vision or haptics only conditions. Importantly, scaling to object size was only partially restored, being not much better than in the haptic condition and worse than in central vision. Our findings suggest that in multisensory grasping the integration of visual and haptic information about object position is prioritized over integration of object's size information.

Hand Pose Selection in Visually Guided Grasping

Guido Maiello, Marcel Schepko, Lina K. Klein, Vivian C. Paulun and Roland W. Fleming
JLU Giessen, Germany

To grasp an object, one must decide which hand pose to employ: A delicate precision grip will be suitable for picking up a thin needle but not a heavy bowl. We rely on vision to identify objects and the properties that determine how we should grasp them, yet how visual features are combined to select the hand pose for grasping is unknown. We asked human participants to grasp objects varying in size, shape, and material while wearing a data glove. We recorded the hand pose (the angular bend of each finger) selected by participants to grasp the objects. We performed principal component analysis on the glove data. As our fingers do not move independently, dimensionality could be reduced and five principal components were sufficient to explain 95% of the variance in hand pose. A support vector machine classifier applied to the principal components could classify object identity above chance, suggesting distinct and repeatable hand poses for different objects. Object size was easily decodable, object shape and material only partially. Clustering analysis on the glove data identified the set of distinct hand poses participants employed to grasp the stimuli. Together, these findings provide important constraints on models of visually guided multidigit grasping.

Asymmetric Effect of Distractor Graspable Objects on Lateralized Readiness Potentials of Successive Actual Grasp

Stefano Uccelli[1], Veronica Pisu[1], Letizia Palumbo[2], Neil Harrison[2] and Nicola Bruno[1]
[1]University of Parma, Italy
[2]Liverpool Hope University, UK

Suppose you see a first object (distractor) and then have to grasp a second object (test). Will your grasp depend on the initial distractor? Previous results suggest that it will (ECVP, 2018). Using electroencephalography in a grasping task, we replicated our earlier observations and extended them to response-locked lateralized readiness potentials (R-LRP). We show that (a) R-LRP onset for tests occurs earlier for pentapod relative to pincer grips; (b) R-LRP amplitude reduces, and R-LRP amplitude peaks later, before grasping tests associated to grips that are incongruent with those of distractors, in comparison to congruent; and (c) the latter effect is asymmetric: It is strong before performing a pincer grip after a distractor eliciting a pentapod grip, but negligible before performing a pentapod grip after a distractor eliciting a pincer grip. These results (a) are consistent with the notion that seeing a graspable object automatically elicits a motor representation, (b) confirm that preparatory motor processes are affected by temporal context, and (c) suggest that a key parameter of motion preparation is precision.

Systematic Adaptation of Exploration Forces for Different Exploration Lengths

Aaron C. Zoeller and Knut Drewing
Justus-Liebig-Universität Gießen, Germany

Humans can more efficiently interact with their surroundings when they optimize their perception. For haptic softness perception it was shown that humans tune their exploration behavior to the task. To gather sensory information about softness humans typically indent the object's surface multiple times with their fingers: It was shown that when expecting smaller differences between the softness of two objects, humans use higher peak forces in the initial indentation. Thus, they increase their differential sensitivity, which is suitable for smaller differences. Here we investigated what happens when exploration length is constrained. In free exploration sufficient sensory information can be gathered through successive indentations. However, with a limited number of indentations, also information input is limited. We hypothesize that for shorter explorations humans should compensate by executing higher initial peak forces. In an experiment, eight participants performed a two-interval forced-choice task

discriminating the softness of two rubber stimuli. In different blocks, participants performed either one or five indentations per stimulus. Initial peak forces were higher when indenting stimuli only once as compared with five times. No difference in the percentage correct responses was found. We conclude that humans can trade off different ways to gather sufficient sensory information for a perceptual task.

Talk Session 4

Visual Impairments

A Comparison Between the Visuoperceptual Abilities of Children With Cerebral Visual Impairment and Children at Risk for Visual-Perceptual Problems But Without a Diagnosis

Nofar Ben Itzhak[1], Inge Franki[1], Johan Wagemans[2] and Els Ortibus[1]
[1]Department of Development and Regeneration, University of Leuven, Belgium
[2]Department of Brain & Cognition, Leuven Brain Institute, University of Leuven, Belgium

The aim was to examine which visuoperceptual tests distinguish between children with cerebral visual impairment (CVI) and children referred for visual-perceptual problems but without diagnosis (no-CVI). Records of 630 children visiting the CVI clinic and the Centre for Developmental Disabilities in Leuven (2008–2018) were systematically reviewed: Children who completed at least one of the following visuoperceptual test batteries: L94 ($N = 196$), Visual-Motor-Integration (VMI) Beery ($N = 255$), Test of Visual Perceptual Skills (TVPS, $N = 180$), or motion tests ($N = 106$) were included. Mann–Whitney U tests indicated that all subtest scores on the L94 ($p < .0001$ to $< .05$; effect sizes 0.59–0.15) and the VMI-Beery ($p < .01$ to $< .05$; effect sizes 0.18–0.15) were significantly lower in CVI compared with no-CVI. Only some subtests from the motion tests (form-from-motion) and the TVPS (visual-spatial-relationships and visual-discrimination) were significantly lower in CVI compared with no-CVI ($p < .01$; effect size 0.31, and $p < .01$; effect sizes 0.18 and 0.14, respectively). Children with CVI showed more deficits in object recognition (L94), visual-motor-integration (VMI-Beery), form-from-motion (motion tests), and visual-spatial-relationships and visual-discrimination (TVPS) compared with no-CVI, suggesting that these tests distinguish more between the groups. Motion-coherence, motion-speed, and biological-motion (motion subtests), visual-form-constancy, visual-memory, visual-sequential-memory, form-constancy, and visual-figure-ground (TVPS) scores were similarly impaired in both groups.

Multisensory Adaptation of Serious Games for Visually Impaired Children to Learn Geometrical and Arithmetical Concepts

Luigi F. Cuturi[1], Giulia Cappagli[1,2], Elena Cocchi[3], Carla Gilio[3], Nicolò Balzarotti[4], Gabriel Baud-Bovy[4], Erica Volta[5], Gualtiero Volpe[5] and Monica Gori[1]
[1]Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Genoa, Italy
[2]Fondazione Istituto Neurologico Nazionale C. Mondino, Pavia, Italy
[3]David Chiossone Institute, Genoa, Italy
[4]Robotics Brain and Cognitive Sciences, Istituto Italiano di Tecnologia, Genoa, Italy
[5]InfoMus Lab, University of Genoa, Genoa, Italy

Learning geometrical and arithmetical concepts can be challenging in case of visual impairment, especially when it emerges early in life. To provide an inclusive teaching tool, we assessed the efficacy of three new multisensory serious games for geometrical and arithmetical learning. To this aim, a group of low vision and blind children underwent tests for the evaluation of perceptual haptic number line, the two-dimensional/three-dimensional haptic perception of shapes and proprioceptive spatial updating skills. The training consisted of one of the three games: two games aimed at teaching Cartesian coordinates in virtual reality via adapted visual and acoustic properties for low vision children or haptic and auditory exploration for blind children; the third game focused on angle discrimination via auditory and adapted visual feedback of body movements. Our results indicate that visually impaired children show improvements especially for the sensory modality trained by the games, for example, when children were tested on the haptic number line and trained in a haptic virtual environment. Perceptual improvements assessed in this study constitute the first step for the validation of the serious games and provide useful insights for the development of novel multisensory teaching approach in the case of visual impairment.

Eye Movements in the Formally Blind

Paul Zerr[1,2], Jose Ossandon[1], Idris Shareef[3], Stefan Van der Stigchel[2], Ramesh Kekunnaya[3] and Brigitte Röder[1]

[1]Biological Psychology and Neuropsychology, Hamburg University, Germany
[2]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[3]Child Sight Institute, Jasti V Ramanamma Children's Eye Care Center, LV Prasad Eye Institute, Hyderabad, India

Sensitive periods have been identified for several human visual system functions, such as global motion perception and face perception. This study investigated whether sensitive periods exist in the development of human oculomotor control. Goal-directed eye movements are crucial for efficient visual perception. Eye movements in individuals born with total bilateral cataracts were compared with sight-restored late blind individuals, individuals with pathological nystagmus, and controls with typical vision. Congenital cataract reversal individuals (CC) regained the ability to make systematic, purposeful gaze shifts, even after decades of blindness. The typical strong nystagmus of CC individuals caused distorted eye movement trajectories, but measures of latency and accuracy were as expected from their prevailing nystagmus, that is, not worse than in individuals with pathological nystagmus due to other reasons than a period of blindness. By contrast, saccade velocity was lower in CC individuals than in any of the control groups. This first study on basic characteristics of oculomotor control in CC individuals demonstrated a remarkable recovery of goal-directed gaze shifts despite some remaining impairments in oculomotor control. Thus, the severe higher visual function impairments observed in this group cannot be fully explained by the lack of basic goal directed eye movements.

Learning Face Perception Without Vision: Rebound Learning Effect and Hemispheric Differences in Blind and Sighted

Lora Likova, Ming Mei, Kris Mineff and Spero Nicholas

Smith-Kettlewell Eye Research Institute, San Francisco, CA, USA

To address the longstanding questions of whether the blind-from-birth have an innate face-schema, what plasticity mechanisms underlie nonvisual face learning, and whether there are interhemispheric face processing differences in the blind, we used a unique nonvisual drawing-based training in congenitally blind (CB), late-blind (LB), and blindfolded-sighted (BF) groups of adults. The 5-day 1-hour training taught participants to haptically explore, recognize, and memorize raised-line images and draw them from memory. FMRI (Siemens 3T) was run before and after training. Tactile-face perception activated the occipito-temporal cortex in all groups. However, the training led to a strong left-hemispheric reorganization in the blind, in contrast to right-hemispheric in BF. This is the first finding of interhemispheric differences in nonvisual face processing. Remarkably, this learning-based change was positive in CB and BF but negative in LB. The lateralization and inversed-sign learning effects were specific to faces but absent in nonface categories (small objects, houses). Importantly, a short training enabled good tactile-face perception and even face-empathy in CB, implies a preexisting face-schema. A rebound learning model and a neuro-Bayesian economy principle are proposed to explain multidimensional learning effects. The results provide new insights into the Nature-vs-Nurture interplay in rapid brain plasticity and neurorehabilitation.

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Early Blindness Triggers an Imbalance Between Temporal and Occipital Regions Coding for Auditory Motion Directions

Ceren Battal[1,2], Mohamed Rezk[1,2], Stefania Mattioni[1,2], Roberto Bottini[2], Giorgia Bertonati[2], Valeria Occelli[2], Stefano Targher[2] and Olivier Collignon[1,2]

[1]Institute for Research in Psychology, Institute of Neuroscience, Université catholique de Louvain, Belgium
[2]Center of Mind/Brain Sciences, University of Trento, Italy

A region in the middle occipito-temporal cortex (hMT+/V5), classically considered as purely visual, enhances its response tuning to moving sounds in case of congenital blindness. However, whether hMT+/V5 contains information about sound directions and whether the impact of this crossmodal reorganization of hMT+/V5 on the regions typically dedicated to auditory motion, like the Planum Temporale (PT), remains equivocal. We used functional magnetic resonance imaging to characterize the brain activity of sighted and congenital blind individuals listening to left, right, up, and down moving and static sounds. Whole-brain univariate analysis revealed preferential auditory motion response in both sighted and blind participants in a dorsal fronto-temporo-parietal network including PT, and in the most anterior portion of hMT+/V5. Blind participants showed additional auditory motion response in the more posterior region of hMT+/V5. Multivariate pattern analysis revealed auditory motion direction information in independently localized PT and hMT+/V5 in blind and sighted participants. However, decoding accuracies in the blind were higher in hMT+/V5 and lower in PT when compared with the sighted.

Together, these results suggest that congenital blindness triggers a network-level reorganization that enhances the recruitment of occipital areas in conjunction with a release in the computational workload of temporal regions typically dedicated to spatial hearing.

Categorical Representation From Sound and Sight in the Occipito-Temporal Cortex of Sighted and Blind

Stefania Mattioni[1], Mohamed Rezk[1], Karen E. CuculizaMendoza[2], Ceren Battal[1], Roberto Bottini[2], Markus J. van Ackeren[2], Nikolaas N. Oosterhof[2] and Olivier Collignon[1]
[1]UCLouvain, Belgium
[2]Cimec, Trento, Italy

The Ventral Occipito-Temporal Cortex (VOTC) shows robust category selective response to visual information. How is this functional organization tributary of visual input or even visual experience? To address these questions, we used functional magnetic resonance imaging to characterize the brain responses to eight categories (4 *living*, 4 *nonliving*) presented acoustically in sighted and early blind individuals and visually in a separate sighted group. Using a combination of decoding and representational similarity analyses, we observed that VOTC reliably encodes sounds categories in the sighted and blind groups using a structure strikingly similar to the one found in vision. Blind people, however, showed higher decoding of auditory categories in VOTC. In addition, the correlation between the representational structure of visual and auditory categories was almost double in the blind ($r = .66$) when compared with the sighted ($r = .35$) group. Crucially, we also show that VOTC represents the semantic but not the acoustic relations between auditory categories in both groups. Our results suggest that early visual deprivation triggers an extension of the intrinsic categorical organization of VOTC that is partially independent from vision.

Talk Session 5

Disparity, Parallax, Stereo, Vergence

The First Stereoscopic Image Pair?

Kenneth Brecher
Boston University, MA, USA

The initial understanding of the perception of depth from stereo image pairs began with the 1838 report by Charles Wheatsone. To illustrate the phenomenon, he drew examples of stereoscopic image pairs. David Brewster disputed Wheatstone's priority. Brewster asserted that Wheatstone's discovery was preceded by Italian artist Jacopo Chimenti. His evidence? A pair of images by the artist produced around 1600. Were there earlier stereo image pair art works? A report in 2013 proposed that the Mona Lisa on display at the Louvre in Paris and a second version of the painting on display at the Prado Museum in Spain form a stereo pair. Are there any other early artistic stereo pairs? Here, I propose that another painting may provide an early example of a stereo pair. The painting is at the Tate Museum in London. It is entitled "The Cholmondeley Ladies," painted by an unknown artist circa 1600 to 1610. Parts of the painting viewed cross-eyed seem to offer a greater sense of depth than the monocular clues alone provide. The entire painting and individual parts will be presented here. I will also demonstrate my recently devised "Dichopter" smartphone viewer to allow for easy evaluation of the images.

Judging Eye Height Above a Ground Plane Surface Using Information From Disparity, Motion Parallax, and Perspective Transformations

Brian Rogers[1] and Alla Cherniavskaia[2]
[1]University of Oxford, UK
[2]Saint Petersburg State University, Russian Federaion

Helmholtz (1910) provided evidence that the corresponding vertical meridia of the two eyes are extorted by $\sim 2^{\circ}$, with the consequence that these meridia would be stimulated by features lying on a ground plane surface located at eye height below the eyes. But is there anything special about these particular extorted meridia? Geometry shows that corresponding features on ground plane surfaces at any height below the eyes will stimulate extorted meridia and the degree of extortion specifies the height of the observer's eyes above the plane. The same is true of the orientation changes during motion parallax

transformations. A two-alternative forced choice procedure was used to measure thresholds for discriminating pairs of large-field images ($40^\circ \times 30^\circ$) of natural scenes that differed only in terms of their specified eye height above the ground plane. There were four viewing conditions: (a) monocular, stationary; (b) monocular + observer motion parallax; (c) binocular, stationary; and (d) binocular + observer motion parallax. Thresholds were highest in (a) and lowest in (d) (<2% of eye height), for all specified ground plane heights. However, stationary, monocular observers were still able to discriminate different ground plane heights, suggesting that observers were using perspective information. This was confirmed using random-dot patterns instead of natural scenes.

Border-Ownership-Dependent Tilt Aftereffect for Shape Defined by Binocular Disparity and Motion Parallax

Reuben Rideaux[1] and William Harrison[1,2]
[1]University of Cambridge, UK
[2]University of Queensland, Brisbane, Australia

Discerning objects from their surrounds (i.e., figure-ground segmentation) is a fundamental task of the brain. Neurophysiological work has revealed a class of cells in the visual cortex that may be ideally suited to support this neural computation: border-ownership cells. These orientation-tuned cells appear to respond conditionally to object borders. A behavioural correlate supporting the existence of these cells in humans was demonstrated using two-dimensional luminance defined objects. However, objects in our natural visual environments are often signalled by complex cues, for example, motion and depth order. Thus, for border-ownership systems to effectively support figure-ground segmentation, they must have access to information from multiple depth cues with strict depth order selectivity. Here, we measure border-ownership-dependent tilt aftereffects after adapting to figures defined by either motion parallax or binocular disparity. We find that both depth cues produce a tilt aftereffect that is selective for figure-ground depth order. Furthermore, we find the effects of adaptation are transferable between cues, suggesting that these systems may combine depth cues to reduce uncertainty. These results suggest that border-ownership mechanisms have strict depth order selectivity and access to multiple depth cues that are jointly encoded, providing compelling psychophysical support for their role in figure-ground segmentation.

Correlated Neuronal Activity in Populations of Visual Cortical Neurons Limits the Encoding and Discrimination of Stereoscopic Depth

Andrew John Parker and Jackson Earl Tulonen Smith
Oxford University, UK

Limits on the encoding and discrimination of sensory information arise not just from the variability of neuronal firing but also the structure of correlated firing within task-relevant neurons. We made simultaneous recordings of visual cortical neurons while macaque monkeys performed a binocular depth discrimination task. Animals fixated a small point while an array of four dynamic, random-dot stereograms was displayed. Initially, all stereograms had identical depth, but at the trial's end one pattern changed, presenting a detection task for the animal. Utah array electrodes with 64 channels were implanted in two visual areas, yielding 195 neuron recordings for analysis in V1 and 232 in V4. We measured the pairwise interactions between neurons, based on R (signal)—correlation between the stimulus-driven responses—and R (noise)—the degree of common fluctuation in neuronal firing. In both V1 and V4, R (noise) declined as the receptive fields were more spatially separated, but R (noise) increased with R (signal). Theoretical analysis suggests that sensory encoding and discrimination in the neuronal population should be limited by the product of the differentials of the neuronal tuning curves. We show that this prediction is upheld for both V1 and V4 over a range of temporal integration limits.

Depth From Stereo With and Without Using Any Oculomotor Information

Tadamasa Sawada
Higher School of Economics, Moscow, Russia

Our perception of depth is quite reliable under natural three-dimensional viewing conditions, and it is widely believed that binocular disparity serves an important role in the perception of depth. It is assumed that depth perception, based on disparity, requires knowing the relative orientation of the eyes. Depth perception, based on disparity, has usually been studied in the laboratory with very simple, unnatural visual stimuli. These experiments showed that depth perception was slow, unreliable, and systematically distorted. These results conflict with our everyday life experience where depth perception is fast, reliable, and stable. This conflict was addressed by developing a computational model, which does not use any oculomotor information, whatsoever, to recover depth from a stereo-pair of retinal images. This recovery is based entirely on the geometry of the optics of the eyes.

Note that when degenerate visual stimuli like those used in many prior experiments were used, this model did require oculomotor information to recover depth. This suggests that the role binocular disparity plays in depth perception may be confined to the unnatural conditions usually favored in the laboratory.

Do Pupil-Based Binocular Video Eye Trackers Reliably Measure Vergence?

Ignace Hooge[1], Roy Hessels[1,2] and Marcus Nyström[3]
[1]Department of Experimental Psychology, Utrecht University, the Netherlands
[2]Department of Developmental Psychology, Utrecht University, the Netherlands
[3]Lund University Humanities Lab, Sweden

Distance to the binocular fixation point, vergence angle, and fixation disparity are useful measures, for example, to study visual perception, binocular control in reading, and attention in three-dimensional. Are binocular pupil-based video eye trackers accurate enough to produce meaningful binocular measures? Recent research (Wyatt et al., 2010; Wildenmann & Schaeffel, 2013; Drewes et al., 2014) revealed large idiosyncratic systematic errors due to pupil-size changes. We investigated whether the pupil-size artefact in the separate eyes may cause the eye tracker to report apparent vergence changes when the eyeballs do not rotate. To evoke large and small pupils, observers continuously fixated a dot on a screen that slowly changed from black to white in a sinusoidal manner (0.125 Hz). Gaze positions of both eyes were measured with an EyeLink 1000 plus. We obtained vergence changes up to 2° in the eye-tracker signal. Inspection of the corneal refection signals confirmed that the reported vergence change was not due to actual eye rotation. Due to the pupil-size artefact, pupil-corneal reflection or pupil-only video eye trackers are not accurate enough to determine vergence, distance to the binocular fixation point, and fixation disparity.

Talk Session 6

Visual Aesthetics

The Impact of Skin Tone on Choice of Clothing Colour: No Evidence for Fashion Style Advice

David Perrett, Reiner Sprengelmeyer, Nic Hong and Ruby Moores
University of St Andrews, UK

Fashion stylists advise clothing colour to match skin tone. Those with a "cool" skin tone (pale with pink undertones) should wear blue-purple-coloured clothes (hues 135–315°), while those with a "warm" skin tone (tanned with golden yellow undertones) should wear red-yellow-coloured clothes (hues 315–135°). We assessed whether the general public agrees with the fashion stylists' advice. Caucasian and Asian face images were first colour-transformed to create one image version with a cool skin tone (reducing melanin and increasing oxygenated blood colouration) and one version with a warm skin tone (increasing melanin and carotenoid colouration). Observers ($N = 127$) altered the hue/saturation or hue/lightness of simulated clothing and were instructed to select the clothing colour which most suited the skin tone of the face image. Observers showed a marked agreement in preferred clothing colours which were biased to red and blue hues, but there was no impact of warm–cool skin tone on hue chosen. Observers chose less saturated clothing colours for cool skin tones although stylist advice does not differentiate recommendations for clothing colour saturation based on skin tone. We conclude that there is no support for stylist advice based on colour contrast between clothes and skin tone.

Exploiting Crossmodal Correspondences: Can the Perceived Shape of an Ambient Scent Influence the Perceived Shape of a Product, a Scene, or an Actual Space?

Jan Vanrie[1] and Carmen Adams[2]
[1]Faculty of Architecture and Arts, Hasselt University, Belgium
[2]Faculty of Business Economics, Hasselt University, Belgium

Crossmodal correspondences refer to the tendency for features in one sensory modality to be matched or associated with sensory features in another sensory modality (Spence, 2012). For example, some scents are perceived as "round" (e.g., rose), while other scents are perceived as "angular" (e.g., rosemary). In a series of experiments, we

investigated the role of ambient scents with different crossmodal correspondences when visually evaluating various types of meaningful stimuli. Specifically, we looked at whether the perceived shape in terms of "roundness-angularity" of environmental scents would alter the perceived shape of other stimuli present in this environment. In a first study, 99 participants evaluated angular and rounded versions of products, while in a second study, 96 participants evaluated two-dimensional renderings of rounded and angular interior environments. Finally, during these studies and one additional study ($N = 111$), participants also evaluated the actual experimental room they were in. In all studies, participants were either in a situation with no added scent, a "round" or an "angular" ambient scent. Results suggest that environmental scents can indeed affect the perceived shape of other meaningful stimuli present, but also that this depends on both the type of stimulus and the specific task-induced mindset of observers.

Aesthetic Preferences in Visual Art: The Interplay With Mental Imagery and Face Perception

Fatima M. Felisberti[1], Rossan Actis Grosso[2], Mark Riley[3], Isa M. Paiva[1], Adebukola Salaudeen[1] and Dean Holliday[1]
[1]Kingston University London, UK
[2]Università degli Studi di Milano-Bicocca, Milan, Italy
[3]Roehampton University, London, UK

Mental imagery can be depictive or propositional and it has been linked to aesthetic preferences in the literature and visual art, but little is known about their interaction with face perception. This study used a liking rating (Likert) scale to examine whether aesthetic preferences for a set of Picasso's paintings and photographs from assorted artists were modulated by mental imagery style or prosopagnosic traits. Half of the artwork depicted landscapes or objects and half depicted people and faces. In addition, the 186 participants completed the prosopagnosic traits index and the mental imagery and art expertise questionnaires. The findings showed that participants preferred paintings and photographs of landscapes/objects, but prosopagnosic traits were not significantly correlated with liking ratings. Conversely, object-based mental imagery and art expertise were positively correlated with each other and with aesthetic preferences, but only when people were present. These findings explained up to 8% of the variability in preference for photographs and up to 4% for paintings. The results suggest the aesthetic experience of neurotypical adults is not affected by prosopagnosic traits but is rather a function of the interaction between an object--based mental imagery style and the viewer's art expertise, supporting recent theoretical propositions which will be discussed.

Contour Features Predict Valence and Threat Judgements in Scenes

Claudia Damiano, Dirk B. Walther and William A. Cunningham
University of Toronto, Ontario, Canada

Quickly scanning an environment to determine relative threat or safety is an essential part of survival. Low-level visual features, extracted rapidly from the environment, may help people detect threat. In three experiments, we probe this link between low-level visual scene features and valence/threat decisions. In Experiment 1, we asked artists to trace the contours of all images from the International Affective Picture System image set. We computationally extracted the contour curvature, length, and orientation statistics of all images and explored whether these features predict emotional valence scores. We found that images containing angular contours were rated as more negative, and images containing long contours were rated as more positive. For Experiments 2 and 3, we composed new, content-free line drawings of contours with specific combinations of length, curvature, and orientation values; 67 participants and 97 participants were presented with these images on Amazon Mechanical Turk and had to categorize them as positive or negative, and safe or threatening, respectively. In both cases, we found that low curvature, long, horizontal contours predicted participants' positive/safe responses, while short, high curvature contours predicted participants' negative/threatening responses. Our work shows that low-level scene features help people make judgements about potential threat in the environment.

Revisiting the Positive Impact of Visual Exposure to Nature: A Case of Aesthetic Preference?

Daria Burtan and Ute Leonards
University of Bristol, UK

Exposure to nature, even only as photographic images, impacts positively on physical and mental health. In line with this claim, we recently reported that walking towards images of urban as compared with nature scenes was more effortful, as indicated by a decrease in gait velocity and step length (Joyce and Leonards, ECVP 2017). Yet, what causes these gait changes: Differences in image statistics, semantic associations related to different image types, or scene

aesthetics? Here we present two studies in which participants walked towards images of natural and urban scenes matched beforehand for their aesthetics properties by an independent observer sample ($n = 300$). Gait parameters were recorded with three-dimensional-motion capture and analysed with Multilevel modelling. In the first study ($n = 22$), aesthetics but not image category was predictive of gait changes (step length). In the second study ($n = 22$), in which participants additionally rated each image for visual discomfort while they walked, visual discomfort and its interaction with aesthetics, but not image category, predicted gait changes (step length and velocity). These data raise concerns that many of the findings in the literature on the positive impact of nature could be due to stimulus selection biases rather than environment type per se.

"Being Moved" by Moving Images: fMRI of Aesthetic Experiences With Landscape Videos

Ayse Ilkay Isik and Edward A. Vessel
Max Planck Institute for Empirical Aesthetics, Frankfurt am Main, Germany

Aesthetic experience with artworks engages visual, reward, and default-mode (DMN) networks. Yet, we know very little about the dynamics of these networks during aesthetic appreciation. Here, we investigated behavioral and neural responses to temporally extended, aesthetically engaging stimuli (videos), using functional magnetic resonance imaging (fMRI) in combination with continuous behavioral ratings. Participants ($n = 26$) were scanned as they viewed 40 video clips of landscapes (30 seconds) and indicated their moment-to-moment liking as well as a final summary rating at the end of each clip. Category-selective visual regions in ventral occipitotemporal cortex (e.g., Parahippocampal Place Area [PPA], Occipital Place Area [OPA], Fusiform Face Area) were identified using a functional localizer scan, and core regions of the DMN were identified using a "rest" scan, in each individual. A parametric regression analysis of the fMRI data using overall ratings as regressors revealed sensitivity to aesthetic appreciation in several scene selective regions (PPA, Retrosplenial cortex, and OPA) as well as ventral striatum and inferior frontal sulcus. These results suggest that aesthetically pleasing landscape videos modulate a wider network of higher level visual regions than their static counterparts and may rely less on top-down information for their aesthetic appeal.

Talk Session 7

Material Perception

Gloss-Detection Image Filter Based on Center-Surround Receptive Fields

Katsunori Okajima and Masahito Nagata
Yokohama National University, Japan

Humans can detect the glossy parts on objects in images at once, which suggests the existence of a gloss-detection image filter in the visual system. Here, we proposed a computational and practicable model of the gloss-detection filter based on the front end of the human vision mechanism. Our model for the gloss-detection filter is the summation of products of half-wave rectified outputs of two center-surround receptive fields which have different sizes. By a subjective assessment, we found that such a filter can detect gloss in natural pictures with high accuracy. This fact indicates that three-dimensional-shape or illumination information is not necessary for detecting gloss and that gloss information is processed prior to spatial analysis in human vision. Next, we psychophysically showed that only gloss can be removed in natural images by subtracting the filter signals with a proper gain while keeping the diffuse components intact. These results support the idea that our filter signals directly represent the strength on gloss information in images. Finally, observers answered about their glossiness perception of created images in which the gloss-detection filter signals were modulated. The results indicated that we can control glossiness of objects arbitrarily by adding and subtracting the filter signals.

Scale Ambiguities in Material Recognition

Jacob R. Cheeseman, Filipp Schmidt and Roland W. Fleming
Justus Liebig University Giessen, Germany

As a rule, observers can reliably identify the material properties of surfaces. Here, we investigated exceptions to this rule using a set of 87 photographs of materials (e.g., water, sand, stone, metal, wood) that appear to belong to different material classes depending on their apparent distance from the viewer. In three experiments, participants viewed each image and provided a categorical judgement of the depicted material and a quantitative estimate of the distance between the camera and surface. Experiment 1 manipulated interpretations of these images by instructing two groups of participants to imagine a small or large distance between the camera and surface, while a third

control group received no such instruction. In Experiments 2 and 3, interpretations were manipulated by providing visual cues for scale (e.g., objects of familiar size), which were presented alongside the target image or digitally inserted into the image. Results indicate that these manipulations can cause identical images to appear to belong to different material classes (e.g., water vs. marble), and that susceptibility to context information (i.e., material ambiguity) correlates with higher variability in distance estimates. Under challenging conditions, therefore, the recognition of some materials is vulnerable to simple manipulations of apparent scale.

Porcelain, Pearl, or Plastic? Predicting Material Category From the Appearance of Specular Highlights

Alexandra Clare Schmid[1], Pascal Barla[2] and Katja Doerschner[1]
[1]Justus-Liebig University Giessen, Germany
[2]Inria Bordeaux, Talence, France

Previous research has shown that how glossy objects and surfaces look depends on the appearance of specular highlights (their shape, contrast, sharpness, size, and alignment). In a series of experiments, we investigate a less explored aspect of gloss: how highlight appearance affects perceived material category. We rendered complex glossy objects under natural illumination fields, manipulating five gloss parameters (specular strength, roughness, anisotropy, anisotropic rotation, and specular tint), and two diffuse shading parameters (saturation and lightness). Observers judged the material category of each object, first with no restrictions, then in a multiple-alternate-forced-choice task. Stimuli clustered into strikingly distinct perceptual categories such as plastic, glazed porcelain/ceramic, pearl, metals (e.g., gold, bronze, chrome), fabric (e.g., velvet, silk), wax/soap, and even chocolate. We implemented an image-based model of gloss appearance that (a) predicted perceived material category, (b) generalised to different objects and lighting conditions, and (c) performed better than a model based on rendering parameters. Furthermore, we developed a method to directly manipulate these image properties to alter the perceived category. Our results demonstrate that the appearance of specular highlights yields a much richer experience of glossy objects than suggested by previous studies, and that gloss perception should be considered in the context of material recognition.

Visual Perception of Elasticity in Bouncing Objects

Vivian C. Paulun, Florian S. Bayer and Roland W. Fleming
University of Giessen, Germany

We presented observers with 150 computer simulations of a cube of variable elasticity bouncing in a cubic room. Observers were able to judge the cube's elasticity from visual information alone ($R^2 = .81$). This is impressive as the cube's trajectory also depended on its initial position, rotation, and velocity, which were all randomized. We reasoned that observers likely relied on spatiotemporal features of the trajectory that reliably indicate elasticity across variations of other factors. To test this, we defined 21 possible visual features related to, for example, the bounce patterns and velocity profile. We simulated 100,000 bouncy cubes (10,000 per elasticity level) and measured the distribution of the features to derive a normative model of elasticity estimation, which predicts human judgments as good as true elasticity does. We tested all 2,097,151 possible multivariate regression models using these features to identify the best mapping between visual features and physical elasticity. We tested the causal role of the resulting best features in a separate experiment by systematically varying each feature while keeping elasticity constant or vice versa. Our results suggest that the visual system represents elastic objects in terms of characteristic visual features, that is, number of bounces, height, velocity, deceleration, and movement duration.

Talk Session 8

Development

Development and Maturation of Perceptual Sensitivity, Variability, and Stickiness

Gergő Ziman[1,2], Stepan Aleshin[3,4], Kinga Farkas[5,6], Zsolt Unoka[5], Jochen Braun[3,4] and Ilona Kovács[1,2]
[1]Institute of Psychology, Pázmány Péter Catholic University, Budapest, Hungary
[2]HAS-PPCU Adolescent Development Research Group, Budapest, Hungary
[3]Institute of Biology, Otto-von-Guericke University, Magdeburg, Germany
[4]Center for Behavioral Brain Sciences, Magdeburg, Germany
[5]Department of Psychiatry and Psychotherapy, Semmelweis University, Budapest, Hungary

[6]Department of Cognitive Science, Budapest University of Technology and Economics, Budapest, Hungary

Taking binocular rivalry dynamics as a proxy measure for general perceptual function, we studied neurotypical adolescent (ages 12 and 16 years), young adult, and senior adult groups, as well as psychiatric patient groups (autism spectrum disorder [ASD] and borderline personality disorder [BPD]). Statistics of rivalry reversals were obtained from precise (±0.1 seconds) reversal times established by a "no-report" paradigm. In general, rivalry reversals slow during development and accelerate with age, with transitional states showing an opposite trend. Reproducing the average dynamics of each group with an appropriate balance of adaptation, inhibition, and noise predicts the perceptual performance under more general conditions (e.g., randomly fluctuating inputs), which may be characterized in terms of "sensitivity," "variability," and "stickiness" (Aleshin et al., ECVP'19). This analysis reveals two developmental trends—decrease of "stickiness" and increase of "sensitivity" relative to "variability"—both reversing with age. ASD patients show immature characteristics (between 12 and 16 year olds) and BPD patients are "hypermature," that is, more "sensitive" and "sticky" than any normal group. We conclude that a quantitative and model-based analysis of binocular rivalry dynamics reveals simple and interpretable group differences, corroborating and extending prior developmental and psychopathological findings.

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Task-Irrelevant Visual Perceptual Learning Shows a Developmental Trajectory From Childhood to Adulthood

Sebastian Martin Frank[1], Susanne Bründl[2], Ulrike Ingrid Frank[2], Yuka Sasaki[1], Mark William Greenlee[2] and Takeo Watanabe[1]
[1]Brown University, Providence, RI, USA
[2]University of Regensburg, Germany

Visual perceptual learning (VPL) reflects plasticity of the adult brain. However, the developmental course of VPL is unclear. Specifically VPL for task-irrelevant features occurs in adults when the exposed visual features are at or below perceptual threshold, suggesting a critical role of inhibitory processing. Such inhibitory processes may not be fully developed in children. We tested whether task-irrelevant VPL occurs in children, and how inhibitory processing affects this form of task-irrelevant VPL. Twenty children (7–10 years old) and 20 adults (18–31 years old) were trained for 12 days on a rapid-serial visual-presentation task centrally, while task-irrelevant directionally coherent dot motion was presented within an eccentric annulus. Motion directional coherence was varied across subjects from subthreshold, threshold, and suprathreshold levels. Children and adults showed task-irrelevant VPL to visual motion directions exposed to them at subthreshold or threshold coherence levels during training. However, exposure to suprathreshold motion was learnt by children, but it was inhibited by adults. Children with more developed selective attention as measured by the Useful-Field-of-View test exhibited greater task-irrelevant VPL for suprathreshold motion directions. Therefore, our results suggest fundamental changes in the interaction between task-irrelevant VPL and inhibitory processing from childhood to adulthood.

The Asymmetry of Visual Attention Across the Life Span by the Brentano Illusion Test

Roberta Daini and Alessio Facchin
University of Milano-Bicocca, Milan, Italy

The Brentano Illusion Test (BRIT) consists of the manual bisection of simple horizontal lines and Brentano versions of the Muller Lyer Illusion. It is a neuropsychological tool for the detection of unconscious visual perception in unilateral spatial neglect and thus for disentangling the presence of a primary visual deficit (hemianopia) from its phenomenological simulation (pseudo-hemianopia) in those patients. To verify how the relationship between visual perception and visuospatial attention changes with age, we administered the BRIT to 640 healthy individuals, ranging from 6 to 89 years of age. The amplitude of the illusory effect, net of bisection, revealed three patterns: younger participants ($N = 168$; age = 6–19 years) showed a large illusory effect negatively correlated with age; adults ($N = 135$; age = 20–39 years) showed a stable, but asymmetric, small illusory effect; older adults ($N = 337$; age = 40–89 years) showed a large illusory effect positively correlated with age. We interpreted the data as a corroboration of the relatively stable visual perception across the life span and the evolution of visuospatial attention, which increases in developmental age, stabilize in adulthood, with a pick of asymmetry, and decrease in elderly. The results suggest the possible use of BRIT as a useful paradigm to study the relationship between bottom-up and top-down processing.

Development of Rapid Extraction of Scene Gist

Hugo Thomas Chow-Wing-Bom[1], Steven Scholte[2], Carina De Klerk[3], Denis Mareschal[4], Iris Groen[5] and Tessa Dekker[1]
[1]University College London, UK
[2]University of Amsterdam, the Netherlands

[3]University of Essex, UK
[4]Birkbeck College, University of London, UK
[5]New York University, NY, USA

Human's ability to rapidly categorise real-world scenes is thought to rely on extraction of scene "gist" from low-level visual information. It is unclear when and how gist processing develop; low-level spatially tuned filters in early visual pathways may develop early, but the ability to integrate visual information across space develops late, and may limit gist computation. We recorded visual event-related potentials (ERPs), while children aged 6 to 12 years and adults categorised briefly presented images (100 milliseconds) as naturalistic or man-made. Children performed poorer than adults, but accuracy was high (>80%) at all ages. Despite age differences in ERP shape, man-made and naturalistic images evoked different amplitudes from ~150 milliseconds onward in all groups. To test whether this category effect reflected similar gist-extraction mechanisms across age, we fit a computational model of gist processing based on summary statistics of simulated magno- and parvocellular contrast responses. While the model explained less variance in children compared with adults, the overall pattern was similar, and behavioral performance in both adults and children correlated with model outputs. Age differences were unlikely due to poor signal quality but might partly reflect more influence of peripheral neural sources. This suggests that mechanisms required for gist-based categorisation are present early in childhood.

Tuesday, August 27, 2019

Talk Session 9

Cortical Mapping

Microprobing the Visual Brain: High-Resolution Functional Mapping of Neuronal Subpopulations

Joana Carvalho[1], Azzurra Invernizzi[1], Khazar Ahmadi[2], Michael B. Hoffmann[2], Remco Renken[1] and Frans W. Cornelissen[1]
[1]University Medical Center Groningen, the Netherlands
[2]Otto-von-Guericke University, Magdeburg, Germany

The voxel-based estimation of population receptive field (pRF) has tremendously advanced the functional magnetic resonance imaging field by enabling the study of the properties of distributed cortical networks at the level of neuronal populations—across the entire visual cortex. However, this approach has limited ability to uncover unpredicted pRF-properties, arising, for example, fromadaptation, pathology, or reorganization. Here, we present the micro-probing framework that overcomes many critical limitations, enhances resolution, and adds the ability to uncover unexpected pRF shapes, properties, and subpopulations. It efficiently samples the entire visual space with micro-probes—tiny, fixed-size, gaussian models that make minimal prior assumptions, somewhat akin to the electrophysiologist's probe-stimulus, thereby creating high-resolution probe-maps. Subsequently, RFs are derived from these maps. We demonstrate the scope of our methodthrough simulations and by mapping the visual fields of a patient group with highly abnormal pRFs due to albinism. Microprobing uncovered and mapped—without making any prior assumptions about this—their characteric bilaterally split receptive fields. Also in controls, we show how we can map previously unknown population-RF shapes. We conclude that micro-probing provides a versatile and powerful high-resolution approach to uncover the properties of the brain, essential for linking its function to behavior and understanding its plasticity.

A Structural Exploration of Magnocellular and Parvocellular Projections in Visual Cortex With Ultra-High Field fMRI

Karen T. Navarro[1], Kimberly B. Weldon[2], Marisa J. Sanchez[3], Katherine E. M. Tregillus[1] and Cheryl A. Olman[1,2]
[1]Department of Psychology, University of Minnesota, Minneapolis, MN, USA
[2]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, USA
[3]Department of Psychiatry, University of Minnesota, Minneapolis, MN, USA

Magnocellular and parvocellular streams are important features of the primate visual system. Recent advances to high-resolution neuroimaging have facilitated the exploration of the structure of these streams at the mesoscopic level in human visual cortex. We used 7T functional magnetic resonance imaging (fMRI) to observe selective activation of these streams in seven subjects across two scanning sessions. Achromatic, low-spatial, and high-temporal frequency checkerboards targeted the magnocellular stream. Chromatic, high-spatial, and low-temporal frequency checkerboards targeted the parvocellular stream. This work resulted in three findings: First, responses driven by parvocellular-targeted stimuli resulted in a laminar profile biased toward superficial layers of V1, previously demonstrated in human fMRI. Second, we found selective activation of the parvocellular stream in foveal V1 compared with peripheral V1, corroborating data from nonhuman primates (NHP). Finally, we found thick, repeating color-selective bands of activation stemming from the V1 border into V2 and V3. These bands are

analogous to color-selective stripes found in both NHP and human extrastriate cortex, although the bands we observed with fMRI are much wider than the stripes measured by cytochrome oxidase staining. Together, our findings provide insight into the structure of magnocellular and parvocellular projections in human cortex.

Distinct Face- and House-Selective Maps in the Human Ventral Occipito-Temporal Cortex With Intracerebral Potentials and Frequency-Tagging

Simen Hagen[1], Corentin Jacques[2], Louis Maillard[1,3], Sophie Colnat-Coulbois[4], Bruno Rossion[1,2,3] and Jacques Jonas[1,2,3]
[1]CNRS, CRAN, Université de Lorraine, Nancy, France
[2]Psychological Sciences Research Institute and Institute of Neuroscience, University of Louvain, Belgium
[3]CHRU-Nancy, Service de Neurologie, Université de Lorraine, France
[4]Université de Lorraine, CHRU-Nancy, Service de Neurochirurgie, F-54000 Nancy, France

Categorization of visual entities is thought to be supported by different neural circuits in the human ventral occipito-temporal cortex (VOTC). Here, we report a global mapping of the VOTC for selective responses to faces and houses with intracerebral EEG in a large population of human subjects. Participants viewed variable objects images presented periodically at 6 Hz with either variable face- or house-images interleaved as every fifth image (separate sequences). Face- and house-selective responses were objectively quantified at the face- or house-stimulation frequency (6 Hz/5 = 1.2 Hz) and harmonics. Face- and house-selective contacts (20.1% of recorded contacts) were spatially organized along the lateral-to-medial axis, consistent with neuroimaging studies. Importantly, both contact-types, with more face- than house-contacts, were found in the anterior temporal lobe (ATL), a region contaminated by large artifacts in neuroimaging. Moreover, a substantial portion of the ATL-contacts showed no response for other objects at 6 Hz. Finally, fewer contacts responded selectively to both faces and houses (12.2% of recorded contacts) and amplitudes to the two categories were not correlated, offering no evidence that they measure the same neural population for both categories. The results indicate that both posterior and anterior VOTC contain distinct and distributed neural populations dedicated to categorization of face- and landmark-stimuli.

Neuronal Populations in Inferior Occipital Gyrus Are Organised Along Common Gradients of Spatial and Face-Part Selectivity

Ben de Haas[1,2], Martin I. Sereno[2,3] and D. Samuel Schwarzkopf[2,4]
[1]JLU Giessen, Germany; Department of Experimental Psychology, University College London, UK
[2]Department of Experimental Psychology, University College London, UK
[3]SDSU Imaging Center, San Diego State University, CA, USA
[4]School of Optometry and Vision Science, University of Auckland, New Zealand

Early visual areas are organised along gradients of retinotopic preference and dorsal areas show abstract axes of functional organisation. The ventral visual stream is subdivided into patches with categorical stimulus preferences (like faces), but much less is known about the functional organisation within these areas. Here, we used functional magnetic resonance imaging and voxel-wise tuning models to probe spatial (retinotopic) preferences in the human inferior occipital gyrus (IOG). Critically, we also tested face-part preferences in these neural populations (the preferred relative position within a face). The majority of responses were well explained by Gaussian population tuning curves for spatial location and face parts. Parameter maps revealed a common gradient of spatial and face-part selectivity, decreasing from posterior to anterior IOG. Preferred location was organised more idiosyncratically, but clustered locally and was correlated across maps of visual and face space, matching perceptual feature–location interactions. These findings reveal correlated spatial and face-part maps in IOG, which likely reflect developmental boundary conditions and constrain the neural mechanisms of face perception.

The Nature of the Animacy Organization in Human Ventral Temporal Cortex

Sushrut Thorat[1], Daria Proklova[2] and Marius Peelen[1]
[1]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands
[2]The Brain and Mind Institute, The University of Western Ontario, London, Ontario, Canada

The principles underlying the animacy organization of the ventral temporal cortex (VTC) remain hotly debated, with recent evidence pointing to an animacy continuum rather than a dichotomy. What drives this continuum? According to the visual categorization hypothesis, the continuum reflects the degree to which animals contain animate-diagnostic features. By contrast, the agency hypothesis posits

that the continuum reflects the degree to which animals are perceived as social agents. Here, we tested both hypotheses with a stimulus set in which visual categorizability and agency were dissociated based on representations in convolutional neural networks and behavioral experiments. Using functional magnetic resonance imaging, we found that visual categorizability and agency explained independent components of the animacy continuum in VTC. Modeled together, they fully explained the animacy continuum. Further analyses revealed that the clusters explained by visual categorizability were localized posterior to the clusters explained by agency. These results provide evidence for multiple animacy continua in VTC that follow different organizational principles.

The Role of Body Partonomics and Biological Class in the Representation of Animacy in the Ventral Visual Pathway

J. Brendan Ritchie, Joyce Bosmans, Shuo Sun, Kirsten Verhaegen, Astrid Zeman and Hans Op de Beeck
Brain and Cognition, KU Leuven, Belgium

Studies have shown that high-level regions of the ventral visual pathway code for animacy. Less clear is what factors structure these neural responses. Some studies used images of human and animal faces and bodies (Cichy et al., 2014; Kriegeskorte et al., 2008), which suggest that body partonomics may play a role. Other studies suggest that biological classes may be responsible (Connolly et al., 2012; Sha et al., 2015). We investigated the relative contribution of these two factors. Animate stimuli consisted of a single close-up face and full-body image of 24 animals from different biological classes (48 images total). These were contrasted with 48 images of natural objects. We collected data for behavioral tasks ($N = 102$) involving similarity judgments or categorization decisions. The responses from these tasks were used to construct dissimilarity matrices (DM) to perform representational similarity analysis, and compared with DMs constructed from neural responses from ventral pathway regions selective for objects, faces, and bodies measured with human functional magnetic resonance imaging ($N = 15$), as well as layers of a deep convolutional neural network. We found that both body partonomics and biological class are complementary predictors of the neural responses across regions of the ventral pathway.

Visual Field Biases for Words and Faces in Ventral Occipitotemporal Cortex

Lars Strother and Zhiheng Zhou
University of Nevada, Reno, NV, USA

Behavioral divided field studies and functional magnetic resonance imaging (fMRI) experiments both show opposite visual hemifield biases for words and faces. In two divided field fMRI studies of words and faces, we compare univariate and multivariate analysis results for neural differences between and within categories, at different visual field locations (center, left, and right hemifield). Between-category univariate fMRI results were consistently lateralized to the left hemisphere for words and oppositely (but to a lesser degree) for faces. Multivariate fMRI results were less restricted to category-selective areas of ventral occipitotemporal cortex (VOTC) and showed considerably less lateralization. Within-category multivariate fMRI results showed even less lateralization, despite strong evidence of neural discriminability. This finding is important because it highlights a fundamental discrepancy in the hemifield-hemisphere relationship between visual object recognition behavior and fMRI results: Divided field studies typically require within-category (exemplar level) discrimination, but fMRI results corresponding to the neural basis of within-category discriminability may not explain divided field results in a straightforward way. We interpret our findings as novel evidence that visual field advantages in divided field studies of words and faces reflect location-dependent modulation of feature-based processing by domain general neural mechanisms in bilateral VOTC, rather than cerebral laterality in VOTC per se.

Object Location Representations in the Human Ventral Stream Depend on Scene Clutter and Attention

Monika Graumann[1,2], Caterina Ciuffi[1] and Radoslaw Martin Cichy[1,2,3]
[1]Department of Education and Psychology, Freie Universitaet Berlin, Germany
[2]Berlin School of Mind and Brain, Humboldt Universitaet Berlin, Germany
[3]Bernstein Center for Computational Neuroscience, Berlin, Germany

Object category representations, that are tolerant to changes in viewing conditions such as the location in the visual field, are believed to emerge in category-selective cortex. In contrast, representations of object location are thought to already be present in low-level areas of the ventral stream. Recent primate research has questioned this view, observing representations of location to emerge in high-level visual areas when approximating realistic viewing conditions. However, it remains unknown

how such representations emerge over time, where along the human ventral visual stream, and how they depend on scene clutter and attention. To investigate this, we conducted two electroencephalography and one functional magnetic resonance imaging experiment. We found that object location representations emerged (a) later in time and (b) in higher level regions of the ventral stream when objects were presented in cluttered compared with uncluttered scenes. Moreover, we found that the emergence of location representations depended strongly on attention for cluttered scenes but was independent of attention in uncluttered scenes. Together, our results provide a new perspective on the role of ventral visual cortex in object perception and show how attention impacts the underlying neural processing.

Talk Session 10

Perception and Prediction in Autism and Schizophrenia

The Impact of Sensory Evidence and Prior Predictions on Perceptual Decisions in Patients With Paranoid Schizophrenia

Veith Weilnhammer[1], Lukas Röd[1], Anna-Lena Eckert[1] and Philipp Sterzer[1,2,3]
[1]Charité Universitätsmedizin Berlin, Germany
[2]Berlin School of Mind and Brain, Germany
[3]Bernstein Center for Computational Neuroscience, Berlin, Germany

According to Bayesian theories of brain function, perceptual inference integrates current sensory data with prior predictions derived from past experience. Distortions in the process of perceptual inference have repeatedly been implicated in the occurrence of delusions and hallucinations in schizophrenia (Scz). Here, we introduce a novel behavioral paradigm based on graded ambiguity and dissect the impact of both sensory data and prior predictions on perceptual decisions in patients diagnosed with Scz and a matched control group. We assessed the sensitivity of perceptual decisions to varying levels of sensory evidence relative to the impact of prior predictions during bistable perception and related these measures to the diagnostic group and individual symptom severity as expressed by Peter's Delusion Inventory and Cardiff Anomalous Perception Scale. We found an increased sensitivity to changes in sensory evidence in Scz as compared with controls. Within patients, the impact of sensory evidence relative to prior predictions scaled with individual symptom severity. Our results suggest a shift in perceptual inference toward an increased impact of sensory evidence in Scz, which may relate to the phenomenon of aberrant salience and contribute to the emergence of psychotic symptoms.

Visual Perceptual Inference in Children With Autism Spectrum Disorder: A Global Motion Direction Estimation Task

Lisa Lemmens[1,2], Sander Van de Cruys[1,2], Laurie-Anne Sapey-Triomphe[1,2], Ilse Noens[2,3] and Johan Wagemans[1,2]
[1]Laboratory of Experimental Psychology, Brain & Cognition, University of Leuven, Belgium
[2]Leuven Autism Research, University of Leuven, Belgium
[3]Parenting and Special Education Research Unit, University of Leuven, Belgium

Predictive coding has recently been proposed as a framework to understand autism spectrum disorder (ASD). One possible explanatory account argues that individuals with ASD assign High and Inflexible Precisions to Prediction Errors (HIPPEA), irrespective of the context. This could lead to building up overly precise priors in stable contexts, resulting in difficulties to update prior beliefs after a shift in the sensory environment. We administered a global motion direction estimation task in 24 children with ASD and 25 typically developing (TD) children (10–14 years), group-wise matched for age, gender, and IQ. Sensory uncertainty was manipulated by varying the level of noise within the sets of moving dots. Prior learning was induced by sampling the average motion direction presented at each trial from the same Gaussian distribution (i.e., stable context). After 300 trials, the mean of the motion direction distribution shifted. No differences in overall motion direction estimation performance were found between groups. Preliminary analyses reveal that both children with and without ASD were more biased toward the prior distribution when sensory information was more uncertain. After a shift in the prior mean, TD children flexibly increased the precision of prediction errors, whereas children with ASD did not, as predicted by HIPPEA.

Neural Representations of Facial Identity and Expressions in Young Adults With and Without ASD: An fMRI Study

Michelle Hendriks[1,2], Claudia Dillen[1,2], Sofie Vettori[2], Nicky Daniels[1,2], Jessica Bulthé[1], Felipe Pegado[1], Jean Steyaert[2], Hans Op de Beeck[1] and Bart Boets[2]

[1]Brain and Cognition, KU Leuven, Belgium
[2]Leuven Autism Research (LAuRes), KU Leuven, Belgium

Most people are highly skilled in recognizing faces and facial expressions. Yet, it is often suggested individuals with autism spectrum disorders (ASD) have difficulties with regard to these skills. Nonetheless, empirical evidence is mixed. For this reason, we aimed at pinpointing neural differences between individuals with and without ASD while they were looking at dynamic faces. Twenty-two individuals with ASD and 24 matched neurotypicals (NT) (all men, 17–23 years old) were scanned using 3T functional magnetic resonance imaging. They performed a one-back task on face clips in which a face transformed from a neutral to an emotional expression. The total set of stimuli comprised four identities displaying six emotions. We ran several analyses all using the same regions of interest (ROIs). Multivoxel pattern analyses revealed that differences in identity and emotion could be reliably decoded in various occipito-temporal regions. Yet, no differences were detected between the groups. Furthermore, functional connectivity analyses showed that all ROIs were highly interconnected. In the ASD group, the amygdala was more strongly associated with early occipital face processing; whereas in the NT group, amygdala was relatively more strongly connected with higher level temporal face areas, suggesting that both groups attribute a differential importance to perceptual versus higher level aspects of faces.

Frequency-Tagging EEG as a Fast and Sensitive Index of Reduced Social Bias in ASD

Sofie Vettori[1,3], Milena Dzhelyova[2,3], Stephanie Van der Donck[1,3], Corentin Jacques[2], Jean Steyaert[1,3], Bruno Rossion[2,4,5] and Bart Boets[1,3]

[1]Center for Developmental Psychiatry, Department of Neurosciences, KU Leuven, Belgium
[2]Institute of Research in Psychological Science, Institute of Neuroscience, University of Louvain, Leuven, Belgium
[3]Leuven Autism Research (LAuRes), KU Leuven, Belgium

Developmental accounts of autism spectrum disorder (ASD) hypothesize that a reduced preference for social information, such as faces, may partly underlie the characteristic social communication difficulties. Reduced viewing preferences for social stimuli have been demonstrated in ASD. However, it is unclear whether social cues are neglected because they are represented less saliently or actively avoided because they are experienced too intensively. We tested 21 school-aged boys with ASD and 21 matched neurotypical boys using frequency-tagging EEG and eye tracking. In a first experiment, streams of images of faces and streams of houses were presented alongside at different frequencies. We observe reduced social preference in ASD, both in terms of smaller frequency-tagged neural responses and reduced looking times for facial stimuli, and both measures are strongly correlated. Strikingly, time–frequency analysis shows that the group difference in saliency of social versus nonsocial processing is significant after 5 seconds of stimulus presentation and holds throughout the entire trial. These neural observations are closely replicated in a second experiment where we superimposed the two streams of stimulation, thereby controlling for possible effects of spatial attention and disengagement. We conclude that frequency-tagging electroencephalography provides a fast, objective, and reliable measure of decreased social bias in ASD.

Adaptation to Gaze Direction in Autistic Adolescents and 2-Year-Olds With High- and Low-Likelihood of Autism

Emma K Ward[1], Ricarda Braukmann[1,2], Jan K Buitelaar[1,2] and Sabine Hunnius[1]

[1]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands
[2]Radboud University Medical Centre, Nijmegen, the Netherlands

Predictive Processing accounts of autism posit that autistic individuals are less biased by expectations than those without autism when interpreting sensory information. As these expectations influence all perception, any differences should be domain general and present early in life. The current electroencephalographic studies investigate whether reduced expectations lead to smaller adaptation aftereffects detectable in event-related potential (ERP) responses and behaviour of autistic adolescents, and whether there is a comparable reduced aftereffect already detectable in ERP responses of 2-year-olds with high- and low-likelihood of autism. Children have an increased likelihood of autism if they have an older sibling with an autism diagnosis (around 20% chance), and 30% show the broader autism phenotype. Preliminary analyses indicate that autistic adolescents ($N = 7$) show reduced behavioural aftereffects on an individual level, with ERP analyses to follow, and, unexpectedly, children with high-likelihood of autism ($N = 24$) do not differ from children with low-likelihood ($N = 14$) in their ERP responses to adaptation. Preliminary findings suggest that autistic teenagers do indeed have reduced influence of previous experience on perception,

unlike young children with high-likelihood. These latter results are unexpected and raise questions about the developmental trajectory of Predictive Processing accounts of autism and Predictive Processing mechanisms in the broader autism phenotype.

Mirror System Activity Is Modulated by Eye Contact, Evidence From a Multimodal TMS/EEG Study

Jellina Prinsen and Kaat Alaerts
Neuromodulation Laboratory, Department of Rehabilitation Sciences, KU Leuven, Belgium

Both transcranial magnetic stimulation (TMS)-induced motor-evoked potentials (MEPs; an index of corticomotor excitability) and electroencephalography (EEG)-based mu rhythm (neural oscillations in the 8–13 Hz frequency band over the sensorimotor strip) have reliably shown to capture neural mirror mechanisms during action observation. However, the relationship they bear with each other remains elusive. Furthermore, although it has robustly been demonstrated with the TMS technique that observed eye contact can readily increase the "mirroring" of others' actions, it remains unknown whether the mu rhythm is also susceptible to perceived eye contact. Here, the link between TMS-induced MEPs and EEG mu suppression was further investigated in 32 participants (20 men; mean age: 24.8 years), while they observed a simple hand movements combined with either direct or averted gaze from the actor. Both measures were significantly modulated by perceived eye gaze; that is, a significant increase in MEP amplitude and a significant attenuation of the mu rhythm during direct versus averted gaze from the model. A significant correlation between both measuring systems was found at the individual level, suggesting that both EEG mu rhythm and TMS-induced MEPs are sensitive to the social relevance of the observed actions and that they may reflect similar processes within the mirror system network.

Oxytocin Therapy for Autism: Long-Term Changes in Superior Temporal Sulcus and Amygdala Activity During the Processing of Emotional States From Biological Motion

Sylvie Bernaerts[1], Bart Boets[2], Jean Steyaert[2] and Kaat Alaerts[1]
[1]Department of Rehabilitation Sciences, KU Leuven, Belgium
[2]Department of Neurosciences, KU Leuven, Belgium

The superior temporal sulcus (STS) forms a key region for social information processing and disruptions of its function have been associated with sociocommunicative impairments characteristic of autism spectrum disorders (ASD). Although intranasal administration of the neuropeptide oxytocin (OT) is increasingly considered as a potential treatment for targeting these core ASD characteristics, evidence of neural changes outlasting the time of intervention is lacking. Using task-based functional magnetic resonance imaging (fMRI), we adopted a randomized, placebo-controlled, parallel design to evaluate the neural effects of intranasal OT administration in 38 adult men with ASD (21 OT/17 placebo). fMRI scanning during emotion processing from point-light displays (PLDs) was performed at baseline, after single-dose treatment, after multiple-dose treatment, at 1-month and 1-year posttreatment. We assessed treatment-induced changes in brain activity of bilateral posterior STS (pSTS) and amygdala. Analyses revealed attenuated pSTS recruitment over sessions in both treatment groups. However, this attenuation was more pronounced in the PL than the OT group. OT treatment also specifically reduced amygdala recruitment upon presentation of PLDs conveying a positive (but not negative) emotional state until 1-year posttreatment. Our results provide first indications that OT can alter activity of social brain regions in ASD that outlast the time of intervention until 1-year posttreatment.

Developmental and Social Mechanisms in Reasoning About Mirrors: A Comparison Between Adults, Typically Developed Children and Children With Autism Spectrum Disorder

Alessandro Soranzo[1], Gabriele Pesimena[1] and Marco Bertamini[2]
[1]Sheffield Hallam University, UK
[2]Liverpool University, UK

To study people's reasoning about mirrors, Bertamini and Soranzo (2018; *Perception*) employed a top-down drawing of a room with a sketch of a person facing a wall with a mirror and objects on the opposite side of the wall (room and mirror perspective [RAMP] test). Participants selected which objects the person could see in the mirror from different viewpoints. Results showed poor sensitivity to optics (knowledge about mirror reflections) and poor sensitivity to viewpoint (knowledge that what is visible varies with the person's perspective). This last result suggests that social mechanisms may be involved in perspective taking. To explore the developmental and social aspects of this task, we conducted a new study using RAMP. Performances of adults (18+), 8 to 11 years old typically developed (TD) children, and children with a diagnosis of autism spectrum disorder (ASD) were compared. Results

show that adults are more sensitive to optics than both TD and ASD children but not more sensitive to viewpoint. Interestingly, a difference in sensitivity to viewpoint emerged between TD and ASD children. These findings support the importance of both developmental processes and social mechanisms, such as the Theory of Mind, in reasoning about mirrors.

Talk Session 11

Visual Search, Visual Selective Attention

Attentional Facilitation of Tracked Targets Limits Multiple Object Tracking Performance

Søren K. Andersen, Rafael Lemarchand and Nika Adamian
University of Aberdeen, UK

It was initially proposed that multiple object tracking (MOT) performance is afforded by four pre-attentive tracking mechanisms operating in parallel. However, more recent work has demonstrated that processing of tracked targets is enhanced in early visual cortex, underscoring the role of selective attention in MOT. The magnitude of attentional enhancement in a previous study was, however, independent of the number of tracked objects, which complicates this interpretation. Here, we measured the magnitude of attentional enhancement of tracked targets in an MOT task using steady-state visual-evoked potentials (SSVEPs). Participants tracked 2, 4 or 6 of the 12 objects. Unlike the previous study, trials were physically identical between conditions, except for the initial cue. Under these conditions of tight control of possible physical stimulus confounds, we found a consistent pattern of decreasing attentional enhancement of SSVEP amplitudes with increasing set-size of tracked objects. This finding supports the idea that limitations of attentional selection underlie the decrease of MOT performance with increasing set-size. It is also consistent with our recent proposal that concurrently selecting multiple feature values (here: object locations) within the same feature dimension reduces the magnitude of attentional selection, whereas selecting multiple features of different dimensions does not.

Attentional Enhancement of Relevant Features Precedes the Suppression of Irrelevant Features Even When Distractors Are Cued

Plamen Antonov Antonov, Ramakrishna Chakravarthi and Søren Andersen
University of Aberdeen, UK

Selective attention may mainly act by enhancing attended or suppressing unattended information. In most experiments, cues indicate to-be-attended rather than to-be-ignored stimuli, thereby potentially biasing selection towards enhancement. Here, we compared cued shifts of feature-selective attention between conditions in which attended stimuli were cued with conditions in which unattended stimuli were cued. Superimposed random-dot kinematograms (RDKs) of different colours were presented and participants had to detect brief coherent motion intervals in the attended stimuli while ignoring equivalent intervals in the unattended stimuli. Attentional selection was measured through time courses of behavioural data and steady-state visual-evoked potentials (SSVEPs) elicited by the flickering RDKs. In "attend" trials, enhancement of SSVEPs elicited by attended stimuli preceded the suppression of unattended stimuli, confirming previous findings. In "ignore" trials, enhancement still preceded suppression, but the temporal pattern of attentional shifts was shifted back by hundreds of milliseconds. We interpret this as the result of semantically translating "ignore" to "attend" cues instead of using them to directly suppress irrelevant stimuli (e.g., ignore blue is substituted by attend red). This interpretation is also supported by event-related potentials elicited by the auditory cues. In conclusion, our findings suggest that distractor suppression is not under direct voluntary control.

No Feature-Based Attention in Additional Singleton Search

Arni Gunnar Asgeirsson[1] and Árni Kristjánsson[2]
[1]University of Akureyri, Iceland
[2]University of Iceland, Iceland

It is commonplace to assume that prior knowledge of the visual properties of a target object—for example, colour or shape—will facilitate visual search for the object. Such top-down guidance plays an important role in theories of visual attention. A provocative proposal is that effects attributed to top-down guidance instead reflect attentional priming. Theeuwes and van der Burg (2011) found that observers could not use verbal or symbolic to ignore irrelevant singletons in visual search. Only when target and distractor colours were repeated on consecutive trials was target selection successful without any distractor interference. Here, we present experiments that were

variants of their additional singleton search tasks. We replicated the robust distractor interference and priming effects of Theeuwes and van der Burg but were unable to find any evidence of effective feature-based attention: Singleton distractors interfered with target selection, despite robust colour priming. This was true of task variants encouraging covert and overt visual search. The results suggest that top-down control of feature-based attention is even more limited than posited by Theeweus and van der Burg.

The Relationship Between Attentional Inertia and Inhibitory Control

Catherine Thompson[1], Maryam Jalali[1] and Peter Hills[2]
[1]University of Salford, UK
[2]Bournemouth University, UK

Effective performance in a given task requires the top-down allocation of visual attention to locations and stimuli relevant to that task. However, evidence shows that attention and visual search can be influenced by the demands of a previous, unrelated task. It is argued that this "attentional inertia" effect is due to difficulties inhibiting previously relevant attentional settings, and this was investigated in an eye-tracking experiment. In each trial, participants completed a letter search task designed to evoke a horizontal, vertical, or random spread of search and were then asked to make a judgement about a natural scene. Across the task, changes in blood flow in the prefrontal cortex were monitored using functional near infrared spectroscopy, and participants completed an attentional network task and provided a self-report measure of attentional control. Consistent with previous studies the pattern of visual search to the natural scenes was influenced by the orientation of the preceding letter search. The size of this attentional inertia effect was also associated with the measures of inhibition. The findings suggest that poor inhibitory control will increase the likelihood that performance in a task will suffer interference from previously relevant top-down settings.

Proactive and Reactive Control Over Target Selection in Visual Search

Christian N. L. Olivers, Eduart Ort, Joram van Driel and Johannes J. Fahrenfort
Vrije Universiteit Amsterdam, the Netherlands

Searching for more than one type of target often, but not always, results in switch costs, raising questions on how multiple-target search is controlled. Using a gaze-contingent eye-tracking paradigm in which we instruct participants to simultaneously look for two target objects presented among distractors, we find that the occurrence of switch costs depends on target availability. When both targets are always available in a display, thus giving the observer free choice on what to look for, little to no switch costs occur when observers change between targets. In contrast, clear switch costs emerge when only one of the two targets is there so that the target object is being imposed upon the observer. Subsequent studies combining eye tracking with electroencephalography and with funrional magnetic resonance imaging indicate that observers adopt different modes of control: Multiple-target availability allows for proactive control over target selection prior to display onsets, as was confirmed by increased involvement of a frontoparietal network and stronger preswitch beta suppression over midfrontal electrodes. In contrast, single target availability elicited postswitch frontal theta signals, indicative of reactive cognitive control processes.

The Influence of Feature Representations and Conceptual Category Membership During Search for Alphanumerical Characters

Diane Baier and Ulrich Ansorge
University of Vienna, Austria

In visual search for alphanumerical characters, search templates might be based on feature representations or conceptual category membership. To examine these possibilities, we presented alphanumerical characters as cues in two contingent-capture experiments (with overlapping or separate character sets for cues and targets). In the contingent-capture paradigm, only cues matching the top-down search template (e.g., a letter cue when searching for target letters) capture attention and lead to validity effects (shorter search times and fewer errors for validly than invalidly cued targets). Cues not matching the top-down search template (e.g., a number cue when searching for target letters) do not capture attention. To distinguish between feature-based and category-based search templates, we used both upright and inverted cues. These cues share the same features, whereas the ability to categorize inverted cues is impaired compared with upright cues. Thus, if search relies solely on category membership, inverted cues would not lead to validity effects, or at least produce considerably weaker effects than upright cues. As we found significant validity effects for both upright and inverted cues in both experiments, the results provide evidence for feature-based search templates. However, diminished validity effects for inverted cues demonstrate partial influence of category membership.

Scenes Modulate Object Processing Before Interacting With Memory Templates

Surya Gayet and Marius V. Peelen
Donders Institute, Radboud University, Nijmegen, the Netherlands

When searching for relevant objects in our environment (say, an apple), we create a memory template (a red sphere), which causes our visual system to favor template-matching visual input (apple-like objects) at the expense of template-mismatching visual input (e.g., leaves). While this principle seems straightforward in a lab-setting, it poses a problem in real-life vision in which scene-context should be taken into account: For instance, two objects that produce the same size on the retinae will differ in real-world size if one is nearby and the other is far away. Here, we capitalized on the Ponzo illusion to manipulate the perceived size of objects in natural scenes while keeping their retinal size constant. Across three experiments (and 71 subjects), we demonstrate that visual objects reflexively attract attention when their perceived size matches a memory template, compared with mismatching objects that encompass the same size on the retina. Moreover, this effect was more pronounced for subjects exhibiting, and scenes eliciting, larger differences in perceived size between nearby and distant objects. Together, our findings show that memory templates impact visual selection after object representations are modulated by scene context, thus providing a working mechanism for template-based visual search in naturalistic viewing conditions.

Visual Foraging in the "Real World"

Tómas Kristjánsson[1], Dejan Draschkow[2], Ágúst Pálsson[1], Davíð Haraldsson[1], Pétur Örn Jónsson[1] and Árni Kristjánsson[1,3]
[1]Department of Psychology, University of Iceland, Reykjavik, Iceland
[2]Brain and Cognition Laboratory, University of Oxford, UK
[3]National Research University Higher School of Economics, Moscow, Russia

Human foraging studies are most commonly conducted with two-dimensional screen-based tasks. This differs from real-world foraging, where we usually do not forage in two-dimensional environments. We present findings from a human foraging study in three-dimensional virtual-reality environment. Observers foraged for 50 targets among 50 distractors in four different conditions, where targets were distinguished from distractors on either a single feature (feature foraging) or a conjunction of features (conjunction foraging) and in static or dynamic environments. Our results replicate findings from previous foraging studies in important aspects such as stable cruise phases that are similar for feature and conjunction foraging and end points that are much larger during conjunction than feature foraging. We show that these end points cannot be explained away as motor component artifacts. Notable differences from two-dimensional tasks are also seen, such as higher number of runs during conjunction foraging than previously reported and no mid-peaks during conjunction foraging. Furthermore, movement does not appear to affect search organization as previously found in two-dimensional tasks, but the results suggest that feature foraging is overall more organized than conjunction foraging. Overall, the results show the importance of bringing visual attention tasks, closer to natural three-dimensional environments.

Talk Session 12

Perceptual Decision-Making

Intrinsically Photosensitive Retinal Ganglion Cell Contributions to Decision-Making

Prakash Adhikari[1,2], Subodh Gnyawali[1,3], Andrew J. Zele[1,2] and Beatrix Feigl[1,3,4]
[1]Visual Science and Medical Retina Laboratories, Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Australia
[2]School of Optometry and Vision Science, Queensland University of Technology, Brisbane, Australia
[3]School of Biomedical Sciences, Queensland University of Technology (QUT)
[4]Queensland Eye Institute, Brisbane, Australia

Melanopsin-containing intrinsically photosensitive Retinal Ganglion Cells (ipRGCs) predominantly regulate the pupil light response via their projections to the Olivary Pretectal Nucleus. In rodents, ipRGCs directly project to arousal- and decision-promoting brain centres which activate the Locus Coeruleus (LC). The LC mediates pupil dilation with decision-making tasks to visual stimuli via norepinephrine. However, whether ipRGCs directly contribute to decision-making in humans is unknown. Here, we investigate ipRGC contributions to decision-making by measuring visual-decision-evoked pupil dilation under photopic isoluminant ipRGC-directed stimulation. A silent-substitution technique was applied to independently control the ipRGC, LMS-cone and rod photoreceptor excitations using a five-primary photostimulator. The decision-making task involved reporting the offset reaction time (RT) under continuous pupil recording for (a) rod/cone silent, ipRGC-directed pulses; (c) rod/ipRGC silent,

LMS-cone-directed pulses; and (c) combined LMS+ipRGC pulses; cone-directed stimuli were control conditions. We demonstrate that the peak pupil dilation amplitude from the baseline following the offset RT was 5.5% ± 0.6% (mean ± standard error of the mean) for ipRGC pulses, 3.2% ± 0.7% for LMS-cone pulses, and 6.3% ± 0.5% for LMS+ipRGC pulses, with the peak dilation at 477.9 ± 43.6 milliseconds, 283.3 ± 21.4 milliseconds, and 366.7 ± 7.6 milliseconds, respectively after the offset RT. Our finding of major ipRGC contributions to visual-decision-evoked pupil dilation points toward potential role of ipRGCs in decision-making in humans.

Neural Substrates of Magnitude Sensitivity in Perceptual Decision-Making With Equal Alternatives

Angelo Pirrone[1,2], Hui Huang[1], Lin Chen[1] and Sheng Li[1]
[1]School of Psychological and Cognitive Sciences, Peking University, Beijing, China
[2]Faculty of Psychology, University of Bergen, Norway

Subjects are slower if asked to choose the brighter between two alternatives having equally low brightness, compared with when equal alternatives have a higher brightness. This result, named "magnitude sensitivity," challenges optimal accounts of decision-making that only take into account difference in evidence between alternatives, which in the case of equal alternatives is zero, regardless of the magnitude. Here, we present results from the first functional magnetic resonance imaging (fMRI) investigation of a brightness discrimination task with equal alternatives of varying magnitude. Computational analysis shows that this result is driven by nondecisional, sensory-motor components; fMRI data show that an increase in brightness for equal alternatives is associated with activations in (a) visual cortex, (b) superior frontal cortex, which includes supplementary motor area and presupplementary motor area, and it is involved in movement and cognitive control, and (c) rostral regions of prefrontal cortex which are known to play a role in late stages of decision-making. This pattern of results is in accordance with the assumption that activations in visual cortex due to high-magnitude stimuli may be associated with a decrease in inhibition of movement, which in turn allows the execution of faster decisions. Evolutionary plausible argumentations for this mechanism will be discussed.

Automatic Coding of Uncertainty in the Perception of Visual Relative-Frequency: An MEG Study

Xiangjuan Ren[1,2], Huan Luo[3,4] and Hang Zhang[1,3,4]
[1]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China
[2]Academy for Advanced Interdisciplinary Studies, Peking University, Being, China
[3]School of Psychological and Cognitive Sciences, Peking University, Beijing, China
[4]PK U-IDG/McGovern Institute for Brain Research, Peking University, Beijing, China

People systematically distort probability and relative-frequency in a variety of decision-making and judgment tasks, typically overestimating small probabilities and underestimating large probabilities. Many theories hypothesize that probability distortion arises from a compensation for the uncertainty inherent in the perception of probability information. Here, we used magnetoencephalography (MEG) to investigate the neural coding of uncertainty in a visual relative-frequency estimation task. For a specific relative-frequency p, the perceptual uncertainty is proportional to $p(1-p)$. Subjects ($N=22$) were asked to continuously track the relative-frequency of one color of dots in each display of a sequence of displays (7 at least and 41 at most) of yellow and cyan dots. On each trial, we varied the value of either p or $p(1-p)$ periodically at 3.3 Hz while controlling the other variable to be aperiodic. MEG signal was recorded simultaneously. We found converging evidence for automatic encoding of uncertainty. Although $p(1-p)$ was task-irrelevant, periodic changes of $p(1-p)$ as well as p entrained neural rhythms. Temporal response function analysis of the neural signal from aperiodic sequences showed that the neural coding of $p(1-p)$ peaked around 400 milliseconds after stimulus onset, more than 100 milliseconds later than the coding of p.

Cognitive Modelling Reveals Distinct Electrophysiological Markers of Decision Confidence and Error Monitoring

Manuel Rausch, Michael Zehetleitner, Marco Steinhauser and Martin E. Maier
Catholic University of Eichstätt-Ingolstadt, Germany

Are decision confidence and error awareness generated by the same or distinct neurocognitive mechanisms? In a masked-orientation task with varying stimulus-onset-asynchrony, we observed that participants' decision confidence increased with stimulus-onset-asynchrony in correct and to a lesser degree in incorrect trials. That behavioural pattern was just opposite to the prediction of established mathematical models of confidence. An

electrophysiological correlate of confidence was detected during the stimulus-locked P3 time window. In contrast, stimulus-onset-asynchrony in incorrect trials had just opposite effects on decision confidence and on electroencephalography activity during the time windows of error-related negativity and Pe, two established electrophysiological markers of error processing. Many standard mathematical models of decision confidence were inconsistent with confidence judgements, including the signal detection model, the signal detection model with unsystematic noise superimposed on ratings, the postdecisional accumulation model, the two-channel model, the response-congruent evidence model, the two-dimensional Bayesian model, and the constant noise and decay model. Only one mathematical model of decision confidence, the weighted evidence and visibility model, was able to account for both the distributions of confidence and event-related potential amplitudes in the P3 range. It is concluded that electrophysiological markers of decision confidence and error awareness are at least in parts distinct.

Corrupted Feedback to Perceptual Decisions Impairs Metacognitive Sensitivity

Matthias Guggenmos[1], Rekha Varrier[1,2] and Philipp Sterzer[1,2]
[1]Charité Universitätsmedizin Berlin, Germany
[2]Bernstein Center for Computational Neuroscience Berlin, Germany

Previous studies have demonstrated that corrupted feedback impairs the objective quality of perceptual decisions, but little is known about its effects on metacognition. How does corrupted feedback affect our confidence in perceptual decisions? How does it affect the accuracy of such metacognitive judgments, that is metacognitive sensitivity? To answer these questions, we provided 32 human participants with either correct or corrupted feedback on perceptual choices in a challenging-orientation discrimination task. In intermittent test sessions, we found that both objective performance and subjective confidence decreased over time following corrupted (vs. noncorrupted) feedback. Closer inspection revealed a decrease of confidence even when correct and incorrect choices were analyzed separately, showing a general negative confidence bias beyond what was expected from the performance drop. Critically, we found that the accuracy of confidence judgments likewise deteriorated, that is, they tracked objective performance to a lesser degree. None of these effects were related to the participants' awareness of the feedback manipulation. Together, these results show that corrupted feedback compromises both first-order (perceptual) and second-order (metacognitive) judgments. Moreover, they provide important constraints for theoretical models of perceptual metacognition.

Does Slow-Motion Replay Introduce Bias in Refereeing Decisions?

George Mather[1] and Simon Breivik[2]
[1]University of Lincoln, UK
[2]Professional Game Match Officials Limited, Wembley, UK

Recent research indicates that when we view actions in slow motion, the perceived degree of intent behind those actions can increase. Slow-motion replays are widely used in reviews of refereeing decisions by Video Assistant Referees (VAR). Are the reviews potentially subject to such a bias? To answer this question, 80 elite English professional football officials viewed video clips of 60 offences recorded in professional European leagues: 20 fouls, 20 yellow-card offences, and 20 red-card offences (according to the on-field referee). Both real-time (1×) and slow-motion (0.25×) playback speeds were used. Participants had no knowledge of the incidents, playback speeds, or disciplinary sanctions relating to each clip. Three judgements were made about each incident: heaviness of contact, degree of intent, and disciplinary sanction. Results showed that the effect of playback speed depended on the offence. Yellow-card offences were judged as heavier, more intentional, and more serious offences in real-time playback than in slow-motion playback. The opposite applied to red-card incidents, though to a smaller degree. These results show that slow-motion playback does not introduce a consistent bias in decision-making for all incidents. Instead, its use and effect depend on the type of incident reviewed.

Talk Session 13

Aging

Selective Age-Related Changes in Orientation Perception

Karin S. Pilz
University of Groningen, the Netherlands

Previous research has suggested that age-related changes are due to general decline of cognitive, perceptual, and sensory functions. However, more recent studies show that age-related perceptual changes cannot be explained by one common underlying factor. Here, we measured age-related changes in the oblique effect. The oblique effect describes the phenomenon that we are generally worse at processing oblique contours compared with

cardinal ones (horizontal and vertical). It is thought that the effect is based on the relevance of cardinal contours and their frequency in our visual environment. In a series of experiments, we measured the ability of healthy older and younger participants to discriminate and identify cardinal and oblique contours. Our results confirmed the oblique effect in that discrimination thresholds and identification errors were overall larger for oblique compared with cardinal contours. More importantly, however, older adults only performed worse than younger adults for oblique contours. Performance for cardinal contours was overall the same for both age groups. Our results demonstrate that age-related perceptual changes are selective and suggest that visual experience shapes our brain even into adulthood.

Is the Effect of Age on Multisensory Integration Mediated by Age-Related Sensory Loss? Findings From the Irish Longitudinal Study of Ageing

Rebecca J. Hirst[1,2], Annalisa Setti[3], Rose Anne Kenny[2,4] and Fiona N. Newell[1]
[1]Institute of Neuroscience, Trinity College Dublin, Ireland
[2]The Irish Longitudinal Study on Ageing, Trinity College Dublin, Ireland
[3]School of Applied Psychology, University College Cork, Ireland
[4]Mercer Institute for Successful Ageing, St. James's Hospital, Dublin, Ireland

Age-related sensory loss is thought to bring about compensatory increases in multisensory integration. To test this, we used cross-sectional data from the Irish Longitudinal Study of Ageing (TILDA). Over 2,900 older adults completed the Sound Induced Flash Illusion (SIFI) alongside measures of visual function (visual acuity, contrast sensitivity, and self-reported vision) and auditory function (self-reported hearing). To probe visual and auditory temporal discrimination (VTD and ATD), accuracy for identifying two stimuli under unimodal conditions was assessed. Structural equation modelling showed that SIFI susceptibility increased with age. Visual acuity, self-reported hearing, and VTD mediated this effect; better acuity predicted weaker SIFI; and better hearing predicted stronger SIFI. Curiously, VTD improved with age, and this was associated with greater SIFI susceptibility. A second model showed that age did not directly influence compensatory multisensory gain (i.e., increased accuracy under multisensory vs. unimodal conditions). However, indirect effects were observed via visual acuity, contrast sensitivity, and ATD. Better acuity and ATD predicted fewer gains, and better contrast sensitivity predicted larger gains. Finally, multisensory gains predicted SIFI susceptibility, and this was mediated by the relative gains for vision and audition. We interpret these findings as illustrating the impact of age-related sensory loss on multisensory integration in ageing.

Ageing and Visual Attentional Control in Naturalistic, Dynamic Road Crossing Situations

Victoria Ida Nicholls[1] and Sebastien Miellet[2]
[1]Bournemouth University, Poole, UK
[2]University of Wollongong, Australia

Executive functions (EF), including attentional control, decline in older age. Here, we investigated whether this decline affects the visual sampling strategies and behavioural performance in road crossing. In previous work, we showed that riskier crossing decisions in children younger than 10 years old were associated with a lesser control of overt attention. As attentional control deteriorates in older age, we expected similar visual sampling and crossing decisions to young children. We monitored visual exploration and crossing decisions, in adults aged 18 to 35 and 60+ while they watched videos of road traffic and indicated safe crossings. Automatic image detection techniques were used to extract time to impact. In conjunction with data-driven statistical mapping of eye movements, these techniques allowed us to study the fine-grained dynamics of attentional control and decision-making. We found that, although older adults look more at distractors than younger adults and were slower to perform EF tasks, their crossing decisions were remarkably similar to those of younger adults. Our findings suggest the involvement of compensatory mechanisms that might be effective in simple situations but lead to mistakes in more complex ones. This provides avenues for future research into the potential compensatory mechanisms used by older adults.

Biomarkers of Spatial Attention in Young and Older Adults

Monika Harvey[1], Gesine Märker[1], Gemma Learmonth[2] and Gregor Thut[2]
[1]School of Psychology, University of Glasgow, UK
[2]Institute of Neuroscience and Psychology, University of Glasgow, UK

Young adults tend to overestimate object properties located in the left side of space ("pseudoneglect"), a spatial bias deemed to be caused by a right-hemisphere dominance for visuospatial attention. Healthy older adults have been shown to lose this leftward bias, yet little is known as to whether these bias shifts reflect hemispheric changes. Here, we firstly aimed to identify a spatial task teasing out age-related spatial bias changes. We then investigated

potential hemispheric alterations with electroencephalography (EEG). We found that for a single given task, both young and older participants showed consistent spatial biases across different testing days. However, different tasks generated different biases, with only the landmark task (in which participants are instructed to indicate which side of a pretransected line is shorter/longer) showing significant age-related bias shifts. In the EEG experiment, when comparing the groups, full-scalp cluster mass permutation tests identified a larger right parieto-occipital response for long compared with short landmark stimuli in young adults, an effect not present in the older group. Future studies will need to determine whether these hemispheric changes can be mapped for other spatial tasks and methodologies and whether they represent normal aging processes or a marker of neurodegeneration.

Modulating Visual Attention in the Aging Brain: A Combined Network-Based MRI-TMS Approach

Caitlin Mullin[1], Katherine M. Newman[1], Lily M. Solomon-Harris[1], Naail Khan[1], Gary Turner[1], Mark Halko[2] and W. Dale Stevens[1]
[1]Department of Psychology, Centre for Vision Research, York University, Toronto, Ontario, Canada
[2]Berenson-Allen Center for Noninvasive Brain Stimulation, Harvard Medical School, Boston, MA, USA

Behavioural studies have shown that age-related impairments in visual attention tasks across the healthy adult life span are due to a declining ability to inhibit task-irrelevant information. Functional magnetic resonance imaging (fMRI) studies indicate that older adults fail to modulate the activity and functional connectivity (FC) of the default mode network (DMN), a group of brain regions critically involved in internally focussed cognition (e.g., memory, semantic knowledge), during externally focussed visual perception tasks. However, whether age-related changes in DMN activity and FC are a cause or consequence of task-irrelevant distraction is unknown. The current aim is to modulate FC of the DMN using transcranial magnetic stimulation (TMS) in order to establish causal brain–behaviour relationships underlying age-related decline in visual attention. We collected behavioural and resting-state fMRI data before and after TMS to a core node of the DMN (inferior parietal lobule) in young and older adults. Results revealed that TMS successfully modulated FC within the DMN and between the DMN and other brain networks. This modulation impacted the ability of older adults to report task-relevant internal details during a visual attention task. These findings provide critical insight into causal brain–behaviour interactions underlying age-related declines in visual attention.

Working Memory Practice Enhances Object Individuation and Memorization in the Elderly

Chiara Tagliabue[1], Sara Assecondi[2] and Veronica Mazza[1]
[1]Center for Mind/Brain Sciences, University of Trento, Italy
[2]School of Psychology and Centre for Human Brain Health, University of Birmingham, UK

A decrease in working memory (WM) is a major cognitive change in aging. To face this decline, a growing number of WM trainings have been recently proposed. However, most of them are long-term behavioral trainings aimed at generalizing gains to other cognitive tasks/domains. Thus, it remains unclear which are the neural mechanisms that, in the first instance, can be genuinely modified by practice. To this end, we analyzed the electrophysiological (electroencephalography [EEG]) effects of a short WM practice in young and older participants performing a lateralized delayed match-to-sample task over 4 days. At the behavioral level, practice-related improvements were only visible in older participants who showed increased sensitivity and WM capacity. While an EEG correlate of item maintenance in WM (contralateral delay activity) was modulated by target numerosity both before and after practice in young participants, it started indexing memory load in the elderly only after practice. Moreover, the EEG signature of item individuation (N2pc) was modulated by target numerosity only after practice in both groups. These results indicate that practicing WM enhances item individuation, which in turn boosts item memorization. This ultimately allows older participants to reduce the gap in the WM limit compared with young individuals.

Talk Session 14

Perspective, Distance, Space

The Müller-Lyer Illusion Is Explained by Shape Constancy, Not Size Constancy

Bence Nanay
University of Antwerp, Belgium

The Müller-Lyer illusion is one of the best-known and most frequently examined optical illusions. After pointing out that it is unlikely that any one account would give a full explanation for all the features of this illusion, I argue for two claims. First, I aim to point out that an essential component of the Müller-Lyer illusion has something to do with picture perception (just as Gregory initially claimed).

Second, I give an account of this essential component of the Müller-Lyer illusion that is not susceptible to the counterexamples and objections which Gregory's inappropriate size constancy scaling theory was susceptible to. The gist of my account is that the Müller-Lyer illusion is explained not by inappropriate size constancy scaling but by inappropriate shape constancy scaling within pictorial space.

The Moon Size Illusion Does Not Improve Perceptual Judgments

Gregory Francis[1], Benjamin Cummins[1], Jiyoon Kim[1], Lukasz Grzeczkowski[2] and Evelina Thunell[1,3,4]

[1]Department of Psychological Sciences, Purdue University, West Lafayette, IN, USA
[2]General and Experimental Psychology, Ludwig-Maximilian University of Munich, Germany
[3]Centre de Recherche Cerveau et Cognition, Centre National de la Recherche Scientifique, Université de Toulouse, France
[4]Department of Clinical Neuroscience, Karolinska Institute

Recent studies suggest that the accuracy of perceptual judgments can be influenced by the perceived illusory size of a stimulus, with judgments being more accurate for increased illusory size. This phenomenon seems consistent with recent neuroscientific findings that representations in early visual areas reflect the perceived (illusory) size of stimuli rather than the physical size. We further explored this idea with the moon illusion in which the moon appears larger when it is close to the horizon and smaller when it is higher in the sky. Participants ($n = 230$) adjusted the orientation of an image of the moon on a smartphone to match the perceived orientation of the moon in the sky. Contrary to previous studies that investigated accuracy and size illusions, we found slightly lower perceptual judgment accuracy when the moon appeared large (close to the horizon) compared with when it appeared small (high in the sky).

Walking on Illusions—How Perceived Pattern Depth Affects Gait

Greig McMaster Dickson[1], Qasim Zaidi[2] and Ute Leonards[1]

[1]University of Bristol, UK
[2]State University of New York College of Optometry, NY, USA

Little is known about whether and, if so, how high-contrast visual illusions, fashionable as floor patterns in modern design, affect walking behaviour. Here we asked participants ($n = 100$) to walk on a floor with a high-contrast wavy pattern, perceived as alternating three-dimensional "furrows and ridges." To estimate the perceived depth of these illusory furrows, participants first horizontally aligned two equally sized spheres, one placed on top of a "ridge," the other within a "furrow," 2 m away from them. Alignment accuracy was compared with sphere alignment on a plain white control floor. Then, people walked repeatedly across pattern and control floors, while their gait was recorded on video camera. Sphere alignment on the pattern systematically deviated from that of the control as expected for the perceived illusion. Crucially, the vast majority of participants walked within a narrow furrow, placing one foot in front of the other, or, albeit far less frequently, on top of a ridge. Accordingly, step width was far narrower than the step width seen on the pattern-free control floor. Very few participants' gait remained unaffected by the illusory depth. Results are discussed with regard to their possible impact on walking stability and fall risk.

Depth Cues for Perception of Distance: A Virtual Walk in a Pictorial Park

Tim S. Meese and Stuart A. Wallis
Aston University, Birmingham, UK

Contemporary work on depth perception has been dominated by desktop displays where the stereo qualities of binocular disparity (BD) and motion parallax (MP) are readily experienced; pictorial cues, less so. We broaden the investigation by bringing a "real world" immersive scene into the controlled environment of the laboratory using a virtual reality CAVE. Participants walked to a standing point in a virtual park containing various pictorial cues. Virtual footballs were presented either on the floor or at eye height at virtual distances in the range: 1.75 to 20 m. Participants matched the size of the virtual football to a real one at their feet using a flystick. Participants stood still or swung from side to side to achieve MP. BD and MP had no effect when the pictorial cues were rich even though perceived distance was underestimated. Both a power-law exponent (perceived vs. virtual distances) and R2 decreased as pictorial cues were removed. BD and MP benefitted both measures when pictorial cues were poor and empowered the pictorial cue gradients when the ball was at eye height, BD more than MP. Our working hypothesis is that the quality known as stereo derives from numerous sources and is an expression of the system's certainty in its estimates of depth.

Updating of Visual Expectations From Naturalistic Scene Viewpoint

Giacomo Aldegheri, Surya Gayet and Marius Peelen
Radboud University, Nijmegen, the Netherlands

Visual perception is increasingly regarded as an active process, shaped by the observer's expectations based on prior experience. Thus far, such predictive processes have primarily been investigated using simple spatial or temporal associations between isolated objects on uniform backgrounds. In everyday life, however, we deal with more complex regularities, such as the change in an object's appearance as we move around it. Using a novel behavioral paradigm, we investigated whether human observers use scene context to predict the appearance of an object after the scene has rotated. On each trial, observers viewed a central object (e.g., a bed) within a naturalistic scene (a room). Next, the object was occluded, and the room rotated in a series of discrete steps. Eventually, the object reappeared in an orientation that was either congruent or incongruent with the rotated viewpoint of the scene. Importantly, because the rotation angle of the last scene was unpredictable, the object's orientation could only be inferred from the scene itself. Results showed that participants were better able to perform a simple (orthogonal) visual discrimination task on the object when it matched the inferred orientation. This result indicates that context-based predictions facilitate object processing in a naturalistic scenario.

Picture Perception Explored by Comparing Multiple Photographs of Perspective Scenes

Casper Johannes Erkelens
Utrecht University, the Netherlands

A picture is a powerful and convenient medium for inducing the illusion that one perceives a three-dimensional scene. The relative invariance of picture perception across viewing positions has aroused the interest of visual scientists for decades. This study explores variables that may underlie the invariance. To that end, sizes and distances of objects were analysed in sets of photographs of perspective scenes taken from different camera positions. Focal lengths of the lens were chosen such that one of the objects was depicted equally large in the two equally sized photographs. Manipulation of viewing distance and picture size showed that perceived distance is fully determined by angular size. Based on angular size, perceived distances of a near and a far object in a photograph were computed as function of viewing distance and compared with distances of the real objects. For real objects, differences between distances are constant as a function of viewing distance, however, ratios between distances change. The opposite is true for depicted objects: Ratios of distances are constant whereas differences between distances change. Constant ratios signal standstill in the real world. Constant ratios are proposed as the reason for invariance of picture perception over a range of viewing distances.

Talk Session 15

Clinical Neuropsychology

Face Discrimination Abilities in Patients With Temporal Lobe Epilepsy

Angelique Volfart[1,3], Jacques Jonas[1,2], Louis Maillard[1,2], Bruno Rossion[1] and Helene Brissart[1,2,3]
[1]CNRS, CRAN UMR 7039, Université de Lorraine, Nancy, France
[2]Department of Neurology, Regional University Hospital of Nancy, France
[3]Institute of Research in Psychological Science, Institute of Neuroscience, Université Catholique de Louvain, Belgium

Given the questionable relevance of animal studies for understanding the neural basis of human face recognition, intracranial recordings in temporal epileptic patients become increasingly valuable. However, temporal lobe epilepsy (TLE) patients' ability to individuate faces remains poorly documented. Here, we tested 42 patients with left ($n = 17$) or right ($n = 25$) TLE and 42 healthy matched controls. Seven computerized neuropsychological tests were administered: the Benton Face Recognition Test, the Cambridge Face Memory Test, delayed matching of upright and inverted faces and objects, famous face recognition and naming, and old/new face and object tasks. Overall, we found that (a) left TLE patients did not differ from their controls at individuating unfamiliar faces; (b) at the group level, right TLE patients had lower accuracy at matching upright faces than their controls. However, this was explained by only a subset (24%) of patients being impaired in several face and object tasks. This impaired subgroup was clearly identifiable by several clinical features (i.e., longer epilepsy duration, lower IQ, older age) that should be taken into consideration when evaluating the neural basis of human face recognition with intracerebral recordings.

Shape-Centered Representation of Connected Regions of the Visual Field Implied by the Study of a Person With an Extraordinary Perceptual Disorder

Gilles Vannuscorp[1,2], Albert Galaburda[3] and Alfonso Caramazza[2]
[1]Psychological Sciences Research Institute, Université catholique de Louvain, Belgium
[2]Department of Psychology, Harvard University, Cambridge, MA, USA
[3]Department of Neurology, Harvard Medical School and Beth Israel Deaconess Medical Center, Boston, MA, USA

A fundamental question in vision science concerns the way (s) retinotopic images are transformed into higher levels of representation. We report evidence related to this issue from the study of a young woman (Davida) whose perception of the shape, color, size, tilt, movement, and location of two-dimensional objects (letters and arrows) is intact, but who reports seeing these stimuli randomly fluctuating between their true orientation and their reflection across axes centered on and aligned to the shape's most elongated part and its perpendicular. Davida's results in more than 80 experiments probing her perception of different types of stimuli through verbal judgments, visual illusions, copy, and directed movements corroborated this report and implied that an intermediate stage in vision consists in representing connected regions of the visual field relative to a perceptual frame centered and aligned on the shape itself. In addition, the selectivity of Davida's errors, her intact perception of the orientation of objects composed of nonconnected elements, and of the orientation of three-dimensional, blurred and low-contrast stimuli, provides new insights into the componentiality of the mechanisms underlying the perception of orientation of a shape and into the contribution of the magnocellular and parvocellular pathways to these processes.

Behavioural Profiles of Higher Level Vision After Posterior Cerebral Artery Stroke

Grace E. Rice[1], Sheila J. Kerry[2], Ro Julia Robotham[3], Alex P. Leff[2], Matthew A. Lambon Ralph[1] and Randi Starrfelt[3]
[1]University of Cambridge, UK
[2]University College London, UK
[3]University of Copenhagen, Denmark

The presence and degree of category-selective responses in the human brain remain a central research question in visual neuroscience. Evidence for category-selectivity in higher level vision stems from neuroimaging studies of healthy participants and converging evidence in patients after brain injury. However, the neuropsychological literature often focusses on either in-depth analysis of single case-studies or behavioural testing of one category, for example, faces or words. Here, we adopt a novel approach to studying higher level vision after brain injury by exploring the largest sample of posterior cerebral artery stroke patients currently available ($n = 64$). Patients were tested using an in-depth behavioural battery encompassing both low-level visual tests and higher level visual tests of word, object, and face processing. A data-driven approach (principal component analysis) was used to establish a pattern of co-occurrence within higher level vision. The data revealed two principal components underlying patients' performance. The first component included tests with a nonverbal (picture) input, including face and object processing. The second component included tests with a verbal (written word) input/output. Using a data-driven approach to study higher level vision after brain injury suggests that patient's behavioural performance does not reflect strict category-selective responses.

Sensorimotor Learning Effects of Prism Adaptation for Spatial Neglect Across and Within Sessions

Maria Nordfang[1], Inge Wilms[2] and Lars Evald[3]
[1]Department of Neurology, Rigshospitalet—Glostrup, Denmark
[2]Department of Psychology, University of Copenhagen, Denmark
[3]Hammel Neurorehabilitation Centre and University Research Clinic, Denmark

Prism Adaptation Therapy (PAT) is widely used in rehabilitation of spatial neglect (SN). Standard PAT comprises 20 sessions of numerous pointing movements while wearing prismatic goggles. Neuropsychological tests are typically administered before and after completion of all sessions. The optimal number of sessions and the effects within each session is therefore largely unknown. Using a touch screen version of PAT, we recorded within/across data on the progress of the sensorimotor adaptation on 14 patients with left SN during hospitalization. Each session began and ended with a series of closed-loop pointing. Both baseline precision and sensorimotor aftereffect shifted continuously to the left across sessions (p's $< .001$). The latter with a slower acceleration than the former. The shifts did not level out after 20 sessions. Extrapolation predicted that the session baseline would reach the aftereffects after more than 40 sessions—indicating room for further effects of PAT with continued training. Within PAT sessions, we see a significant effect of the target position (right being most accurate, $p < .001$) and a consistent rightward bias across training sessions. Detailed session data on open- and closed-loop pointing may provide new insights into PAT effectiveness.

Talk Session 16

Temporal Aspects of Processing

Temporal Gradients Produce Vivid Afterimages

Marnix Naber, Tijn Knaap and Stefan van der Stigchel
Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands

Viewing a static stimulus for several seconds produces an illusory afterimage opposite to the stimulus' appearance (negative aftereffect). However, the effect of short-term adaptation to changing stimuli on perceptual afterimages is unknown. We conducted three experiments to assess the vividness of illusory aftereffects evoked by stimuli that gradually changed along a feature dimension. In all experiments, a trial contained two phases: a static and a subsequent dynamic stimulus episode, each with a duration that was varied between 0.5 and 3.5 seconds. In Experiment 1, a target gradually changed from black to gray. In Experiment 2, a random noise pattern changed in contrast from 0%, 25%, 45%, or 75% to 80%. In Experiment 3, a target's color saturation changed from 100% to 0% with variable trajectories through color space. Observers reported the strength of the afterimages after the stimulus turned physically identical to its background. Results indicated that observers perceive vivid afterimages in all modalities. The vividness of afterimages depended mostly on recent stimulus dynamics rather than on less recent static stimulus properties. The overall pattern of results across experiments indicates that stimuli with temporal gradients trigger a fast adaptation process that propels perception toward a negative afterimage.

Disentangling the Temporal Effects of Attention and Decision-Making

Denise Moerel[1], Alexandra Woolgar[1,2] and Anina N. Rich[1,3]
[1]Department of Cognitive Science, Perception in Action Research Centre, Macquarie University, Sydney, Australia
[2]MRC, University of Cambridge, UK
[3]Centre for Elite Performance, Expertise and Training, Macquarie University, Sydney, Australia

Attention and decision-making processes are fundamental for human cognition. Although they are separable cognitive constructs, it is often hard to separate their neural bases because decisions usually pertain to attended stimuli. The aim of this study was to disentangle attentional and decision-making processes in the brain. We separated the processes in time and capitalised on the high temporal resolution of magnetoencephalography (MEG) to examine the effect of each process on neural coding. Participants attended to one of the two oriented gratings overlaid at fixation. After a delay, they saw a comparison stimulus and decided whether the attended grating was rotated clockwise or anticlockwise relative to the comparison. A final response screen determined which button to press for each decision. We used multivariate classification of MEG data to examine the coding of the gratings and decisions through time. Initially, both the attended and ignored gratings were coded, but coding of the ignored grating attenuated after approximately 250 milliseconds, whereas coding of the attended orientation was maintained. The decision could only be decoded in the second phase, after the onset of the comparison line. These results show an effect of attention on the representation of visual stimuli, which was separate from the decision-making process.

Temporal Dynamics of Response Activation in the Stroop and Reverse-Stroop Paradigm

Maximilian P. Wolkersdorfer, Sven Panis and Thomas Schmidt
Technische Universität Kaiserslautern, Germany

In the classic Stroop paradigm, participants are asked to identify the color in which a color-word is written. Interference effects can be observed when the task-irrelevant color-word is mapped to a different response than the task-relevant color (inconsistent trials). Facilitation occurs when color-word and color are mapped to the same response (consistent trials). In contrast, in the Reverse-Stroop paradigm, participants are instructed to identify the color-word while ignoring the color. In this case, typically only interference effects can be observed. Here, we present an experimental design which allows investigating both effects and their respective time courses. Furthermore, it is possible to manipulate the stimulus-onset asynchrony (SOA) between the task-irrelevant stimulus (word or color prime) and the target stimulus (color or word target). In a series of experiments (small-*N* design, eight participants, 80 trials per cell and subject), Event History Analysis shows that (a) Stroop and Reverse-Stroop effects are present, (b) both tasks show similarly shaped reaction time distributions, (c) effects increase with SOAs, (d) color information is processed faster than word information, (e) Stroop effects are time-locked to the onset of the task-irrelevant word

stimulus, whereas (f) Reverse-Stroop effects are time-locked to the onset of the task-relevant word stimulus.

Top-Down and Bottom-Up Influences in Face-Voice Multimodal Integration

Clement Abbatecola, Peggy Gerardin, Henry Kennedy and Kenneth Knoblauch
Inserm, Stem Cell and Brain Research Institute U1208, Université Claude Bernard Lyon 1, Univ Lyon, Bron, France

The distinction between top-down (e.g., endogenous) and bottom-up (e.g., stimulus-driven) influences is fundamental to understanding of cognition. How similar are these processes, and how do they interact? We address this question using a modification of the Maximum Likelihood Conjoint Measurement psychophysical paradigm applied to a face–voice, multimodal, gender decision task. Twelve observers performed 1,500 paired gender comparisons of face–voice stimuli in which face and voice gender were varied independently and randomly by morphing. Top-down influences were manipulated by changing the observer's task (face, voice, or bimodal judgment) and bottom-up influences via added visual, auditory, or bimodal noise. Both top-down and bottom-up effects could be modeled as similar changes in weighting parameters on the visual and auditory contributions. Interactions emerged when attentional and noise effects were combined. Adding noise to the attended modality increased the contribution of the irrelevant modality in compensation, but no compensation was observed when adding noise to the nonattended modality. These results are considered in the context of computational simulations and reports on patients suffering from unimodal face and voice perception deficits (prosopagnosics, phonagnosics, and cochlear-implanted patients). Finally, we propose a common neural mechanism inspired by the communication through coherence framework.

Wednesday, August 28, 2019

Talk Session 17

Color, Luminance, and Brightness

"Judging Colors by the Company They Keep": Ibn al-Haytham, Newton, Chevreul, Young, and Maxwell on Experiments on Color

Gül A. Russell
Texas A&M University Health Science Center College of Medicine, Bryan, TX, USA

The "spinning top" has played a fundamental role as a "color wheel" in experimental investigations of color perception, following Newton's brilliant decomposition of light into its spectral colours through a prism. Starting with Newton's own series, attempts to recompose "white" from primary/spectral colors continued in "spinning" experiments in the 19th century, particularly with Young, Chevreul, Helmholtz, and finally Maxwell. Historically, it was introduced in Ptolemy (90–168) and systematically exploited with variations in the Optics (Kitāb al-Manāẓir, 1027) of Ibn al-Haytham (L. Alhazen, d. 1040) as a spinning device, on the surface of which individual colors could be painted in sectors. This was part of Ibn al-Haytham's search for invariance. His extensive investigations of the properties and propagation of light in dark chamber experiments included color, which for him always accompanied light, and obeyed the same rules. His observational experiments with the revolving "color wheel" which include blending, the effect of the speed of motion, time, and the persistence of images will be described and their significance in relation to subsequent experiments will be discussed.

Improving the Accuracy of Memory Color Matching

Shining Ma[1], Peter Hanselaer[1], Kees Teunissen[2] and Kevin Smet[1]
[1]KU Leuven, Belgium
[2]Signify, Eindhoven, the Netherlands

The Memory Color Matching method extends the achromatic matching method, widely used in color constancy and chromatic adaptation research. It involves observers adjusting the color appearance of a familiar object stimulus under each adaptive condition until it matches their internal memory color. This study reports on the precision and accuracy of the method as a function of the number of observers and repetitions of matches made for each condition. Data were collected for three familiar objects (gray cube, green apple, and yellow lemon) and two 600 cd/m^2 adapting fields (a white background lit by a neutral and by a yellowish, high chroma illumination). To investigate the influence of the starting points, 10 matches were made starting from 10 initial chromaticities equally distributed along the hue circle centred at the chromaticity of each object. Results show that the matched chromaticities can be substantially biased by the starting point chromaticity. More symmetric starting point distributions lead to more accurate average matches, especially under the neutral illumination condition. As expected, more starting points

leads to higher accuracy. However, considering both matching accuracy and time efficiency, six observers and four starting points were estimated as sufficient to obtain accurate and stable results.

Colour Variations Within Light Fields: Interreflections and Colour Effects

Cehao Yu[1], Elmar Eisemann[2] and Sylvia Pont[1]
[1]Perceptual Intelligence Laboratory, TUDelft, the Netherlands
[2]Computer Graphics and Visualization Group, TUDelft, the Netherlands

The human visual system incorporates knowledge about local chromatic and lightness effects of interreflections (Bloj et al., Nature, 1999). Here, we study basic principles behind chromatic effects of interreflections using computational modelling and photometric measurements. The colour of interreflections varies as a function of the number of bounces they went through. Using a computational model, we found that those colour variations can show brightness, saturation, and even hue shifts. Using a chromatic Mach Card, a concave folded card with both sides made of the same colour, we demonstrated those three types of colour effects empirically. Finally, we tested the effects of such coloured interreflections on light fields in three-dimensional spaces. Via cubic spectral illuminance measurements in both computer simulations and full mock up room settings under different furnishing scenarios, we measure the chromatic variations of first-order properties of light fields. The types of chromatic variations were found to depend systematically on furnishing colour, lighting, and geometry, as predicted, and also vary systematically within the light field and thus throughout the space. We will next compare the physical light fields with visual light fields (including chromatic properties) and test perceived material colours for (combinations of) the three types of effects.

Is Color Assimilation Only Due to a Luminance–Chromatic Interaction?

Xavier Otazu and Xim Cerda-Company
Department of Computer Science, Computer Vision Center, Universitat Autonoma de Barcelona, Spain

Color induction is the influence of surrounding objects (the inducers) on the color of the target region. When the target's color shifts away from the one of the first inducer, color contrast is occurring; and when the target's color shifts toward the one of the first inducer (opposite effect), color assimilation (CA) occurs. In a previous study, we observed that CA depends on the luminance differences. We concluded that this luminance effect is stronger along the *s*-axis of the MacLeod–Boynton color space, supporting the mutual-inhibition hypothesis (activated luminance neurons inhibit color neurons and, thus, CA is stronger). To test this hypothesis for a chromatic–chromatic interaction instead of a chromatic–luminance one, we defined four chromatic conditions along the diagonals of MacLeod–Boynton color space (activating both konio- and parvocellular pathways) and five luminance conditions (two darker and two brighter than the first inducer, plus equiluminant). Similar to the previous study, we observed that CA is stronger along the *s*-axis. Moreover, we observed that CA only depends on the luminance contrast (i.e., we observe no CA at equiluminance). This could suggest that mutual-inhibition hypothesis is only valid considering a luminance–chromatic interaction and that no mutual-inhibition exist between konio- and parvocellular pathways.

Saturating Luminance-Sensitive Mechanisms Reveals the Sensitivity of hV4 and V3A to Colour

Rebecca Lowndes[1,2], Lauren Welbourne[1,2], Molly Williams[1], Andre Gouws[1,2], Alex Wade[1,2,3] and Antony Morland[1,2,3]
[1]Department of Psychology, University of York, UK
[2]York Neuroimaging Centre, University of York, UK
[3]York Biomedical Research Institute, University of York, UK

Ventral visual areas are thought to play an important role in colour perception, while the dorsal pathway appears to be more aligned with achromatic motion processing. Here, we explored how a typical ventral area (hV4) and a typical dorsal stream area (V3A) respond to chromatic and achromatic contrast modulations when achromatic responses are attenuated. We used population receptive field techniques to identify areas hV4 and V3A in six subjects. We then presented chromatic and achromatic probe patterns (L+M+S contrast at 15%, L-M contrast at 2.7%, or S-cone contrast at 10.5%) superimposed on a constantly present, flickering achromatic background to saturate responses from luminance-sensitive mechanisms. The background comprised an array (100×100) of dynamically modulated 0.2° checks (50% L+M+S contrast). The probe gratings were additional modulations of this background that added chromatic or achromatic contrast in a square wave pattern (1.25 c/deg or 2.5 c/deg) within the central 10°. hV4 was more responsive to colour than V3A, and hV4, but not V3A, showed a reduced response for higher spatial frequency, particularly for the S-cone stimuli. We show that "pure" colour responses in hV4, but not V3A, are robust and depend on spatial frequency in a way that maps onto human behaviour.

Heterochromatic Brightness

Karl Gegenfurtner[1], Jing Chen[2], Matteo Toscani[1], Matteo Valsecchi[1], Alice Chadwick[1], Andrea van Doorn van Doorn[1,3,4] and Jan Koenderink[1,3,4]
[1]Giessen University, Germany
[2]Shanghai University of Sport, China
[3]KU Leuven, Belgium
[4]Utrecht University, the Netherlands

The standard luminance function, $V(\lambda)$ is mainly defined by heterochromatic flicker photometry (CIE, 1924). It is, however, often in disagreement with heterochromatic brightness judgments. While luminance is firmly grounded physiologically in the retino-geniculo-cortical M-pathway, no such correlate is known for heterochromatic brightness. Here, we wanted to explore whether steady-state visually evoked potentials (SSVEP) at low temporal frequencies could serve as such a neural correlate in humans. We recorded SSVEPs to chromatic stimuli with a wide range of (r,g,b) values, flickering at 3 Hz or at 15 Hz against a black background. At a flicker frequency of 15 Hz, which is often used in flicker photometry, the SSVEP amplitudes could be well predicted by stimulus luminance ($r^2 = .81$). However, when the frequency was 3 Hz, SSVEP amplitudes were barely related to luminance ($r^2 = .13$). They were much better accounted for by stimulus max [r,g,b] values ($r^2 = .65$). This max rule (a) weights the red, green, and blue channels equally, (b) combines them nonlinearly with a maximum rule, and (c) agrees quite well with recent psychophysical findings on color-weight photometry by Koenderink et al. (*Vision Research*, 2018). Our results provide a consistent, reliable, and easy to measure neural correlate of heterochromatic brightness.

Gamut Expansion in Low-Range Mondrians Increases With Articulation Level

Alan L. Gilchrist
Rutgers University, New Brunswick, NJ, USA

Many lightness theories incorporate Wallach's classic results suggesting that the relative lightness of two shades of gray is equal to their relative luminance. Observers viewed two faces of a cube suspended in midair within a vision tunnel. Both faces were covered with a Mondrian pattern, one composed of only dark gray patches, the other only light gray patches. Although both faces were equally illuminated, they appeared, not surprisingly, differently illuminated. But surprisingly, Munsell matching revealed a perceived range of grays far greater than the actual range. Displays with 2, 5, 25, and 156 patches were tested, each with a separate group of 15. Gamut expansion increased significantly with articulation level but saturated above 25. Our findings nicely complement the dramatic gamut compression reported by Radonjić et al. (2011) with high dynamic range Mondrians. For example, in our 25-patch condition, targets that stood in a 5:1 luminance ratio appeared as Munsell values 9.0 and 3.1, whereas in the high range Mondrian, those same Munsell values were associated with a 200:1 ratio. These results support the idea of a normalization of the range within frameworks (Gilchrist, 2006), underscoring the pressing challenge of how relative luminance values are translated into relative lightness values.

Color Improves Edge Classification

Camille Breuil[1,2], Ben J. Jennings[3], Simon Barthelmé[1], Nathalie Guyader[1] and Frederick A. A. Kingdom[2]
[1]Université Grenoble Alpes, France
[2]McGill Vision Research, Montreal, Quebec, Canada
[3]Centre for Cognitive Neuroscience, London, UK

Our visual environment contains both luminance and color (chromatic) information. Understanding the role that each plays in our visual perception of natural scenes is a continuing topic of investigation. In this study, we explore the role that color cues play in a specific task: edge classification. Despite the complexity of the visual world, humans rarely confuse variations in illumination, for example, shadows, from variations in material properties, for example, paint or stain. This ability to distinguish illumination from material edges is crucial for determining the spatial layout of objects and surfaces in natural scenes. Color is believed to be a useful cue to this categorization, given that most color changes tend to be material in origin, whereas luminance changes tend to be either material or illumination in origin. We conducted a psychophysical experiment that required subjects to classify edges as "shadow" or "other," for images containing or not color information. We found edge classification performance to be superior for the color compared with grayscale images. We also defined machine observers sensitive to simple image properties and found that they too classified the edges better with color information. Our results show that color acts as a cue for edge classification in images of natural scenes.

Talk Session 18

Facial Expressions and Emotions

Foveal Bubbles: "Diagnostic" Facial Features for Emotion Recognition as Revealed by Foveal Versus Extrafoveal Processing

Anthony P. Atkinson
Durham University, UK

At normal interpersonal distances, all features of a face cannot fall within one's fovea simultaneously. Does the ability to identify emotions expressed on such faces vary according to the feature fixated? To answer this question, previous studies have presented faces for a brief time, insufficient for a saccade, at a position that guaranteed that a specific feature (e.g., an eye) falls at the fovea. Here, we take a more data-driven approach. On each trial, participants fixated a point randomly selected from anywhere on the face, rather than one of a few predefined facial features. Emotion classification accuracy was highest when foveating the central brow for anger, the centre of the face for surprise, the mouth for disgust, and either on and just below the right eye or just below the left eye for fear. These results can be explained partly but not entirely in terms of the additional high-resolution information extracted at fixation. We go on to test the extent to which these emotion-specific foveal processing advantages are predicted by a "foveated ideal observer" that integrates information optimally across the face but is constrained by the varying spatial resolution of visual processing across the retina (Peterson & Eckstein, 2012).

Face Detection Features Are Modulated by the Observer's Level of Arousal

Daniel Gill[1], Sarah Austen[1] and Sarah E. Campbell[2]
[1]University of Winchester, UK
[2]University of Surrey, Guildford, UK

The human visual system is specialized in its ability to detect faces and interpret the social signals they transmit. Here, we show in two experimental stages that these two skills are not only strongly conjugated, but they are also modulated by the level of arousal of the observer. In the first experiment, we successfully induced high and low levels of arousal by playing up-beat and mindful music correspondently to two independent groups of naive participants. To stimulate the top-down visual pathway required for face detection, we instructed the participants to detect faces in colorful random visual noise patterns in which there were no faces. We then used a novel method, based on statistical shape analysis and reverse correlation, to reconstruct the individual face-like mental representations utilized by the observers to detect the faces. In a second experiment, we instructed a new group of observers to rate the perceived emotional expressions of the face-like mental representations, derived in the first experiment, along the dimensions of happiness and surprise. The results show a significantly higher level of perceived happiness in the mental representations derived from the low arousal induction condition in comparison to those derived from the high arousal induction condition.

Idiosyncratic Face Exploration Strategy Is Influenced by Face's Emotion Type and Observer's Empathic Profile

Antoine Coutrot[1], Astrid Kibleur[2], Morgan Le Chénéchal[2], Barbara Lefranc[3], Céline Ramdani[3], Marion Trousselard[3,4] and Jonas Chatel-Goldman[2]
[1]CNRS—Laboratoire des Sciences du Numérique de Nantes (LS2N), University of Nantes, France
[2]Open Mind Innovation, Paris, France
[3]French Armed Forces Biomedical Research Institute Neurosciences and cognitive sciences Department Neurophysiology of stress Unit, France
[4]French Military Health Service Academy, France

Previous studies have shown that people have different face exploration strategies, and that different facial emotions elicit different gaze patterns. However, little is known about the factors driving these differences. Here, we hypothesized that the type of emotional facial expression has a stronger effect on the gaze patterns of more empathic individuals. We recorded the eye movements of 165 observers looking at neutral, sad, disgusted, and surprised faces and asked them to complete empathy questionnaires. First, we predefined regions-of-interest (ROI) and counted their fixation rates. We showed that the type of emotion had an effect on ROIs fixation rate and that more empathic participants looked more at the eye region. Then, we modeled participants' scanpaths with Hidden Markov Models (HMMs), which encapsulate the dynamic and individualistic dimensions of gaze behavior, and do not rely on predefined ROIs. We found that the Kullback–Leibler divergence (KLD) between HMMs representing scanpaths elicited by disgust (disgust-HMM) and neutral-HMM was bigger than for any other emotion, and that this KLD was linked to the empathy score. This suggest that the effect of empathy on gaze patterns depends on the emotion type.

Modelling Dynamic Facial Expressions of Emotion Using Data-Driven Methods

Rachael Elizabeth Jack
University of Glasgow, UK

Understanding how facial expression communicate social information is challenging due to the sheer complexity and number of facial movements the human face can make. Consequently, knowledge of facial expressions has remained limited on several important dimensions such as cultural variability. To address this challenge, we use a novel social psychophysics approach that combines social and cultural psychology, vision science, mathematical psychology, and three-dimensional dynamic computer graphics to map the dynamic information space of human face movements against social perception in different cultures. Using this data-driven approach, we provide a precise characterization of the culturally common and culture-specific face movements that convey broad dimensional (e.g., positive, high arousal) and specific (e.g., delighted) emotion information and show that four, not six, core expressive patterns are common across cultures. We also show that facial expressions transmit signals in an evolving hierarchy of broad-to-specific information over time. Together, our work challenges longstanding dominant views of universality and forms the basis of a new theoretical framework that has the potential to unite different views (i.e., nature vs. nurture; dimensional vs. categorical). Our most recent work also informs the design of socially and culturally intelligent robots by providing a generative syntactical model for social face signaling.

Rapid Fear Discrimination Is Mainly Determined by High Spatial Frequency Information: Evidence From Fast Periodic Visual Stimulation EEG

Stephanie Van der Donck[1,2], Tiffany Tang[1], Milena Dzhelyova[3], Bruno Rossion[3,4,5], Johan Wagemans[6] and Bart Boets[1,2]
[1]Center for Developmental Psychiatry, KU Leuven, Belgium
[2]Leuven Autism Research Consortium (LAuRes), KU Leuven, Belgium
[3]Institute of Research in Psychological Sciences, Institute of Neuroscience, UCLouvain, Belgium
[4]CNRS, CRAN, Université de Lorrai, Nancy, France
[5]Université de Lorraine, Service de Neurologie, CHRU-Nancy, France
[6]Brain and Cognition, KU Leuven, Belgium

It has been suggested that facial fear processing is mainly driven by low spatial frequency (LSF) visual information. Yet, empirical evidence on which spatial frequencies (SFs) are crucial for the detection of fearful faces is mixed. To determine the relative dominance of LSFs versus high spatial frequencies (HSFs) to detect fearful faces among neutral faces, we combined fast periodic visual stimulation with scalp electroencephalography within a Sweep Visual-Evoked Potential (sVEP) oddball paradigm. Neutral faces of one individual were presented at 6 Hz, periodically interleaved with fearful faces of the same individual at 1.2 Hz. During the sVEP, we systematically varied the SF content across a broad range. Starting from a stimulus containing only LSFs or HSFs, SF information was progressively added toward a stimulus containing the full spectrum. Exclusive LSF faces do not allow rapid fear detection in healthy neurotypical adults ($n = 20$), but adding higher SFs to LSF faces leads to an almost linear increase in oddball response, progressively originating from more lateral occipito-temporal brain areas. Interestingly, exclusive HSF faces do elicit a fear detection response, which is not impacted by adding lower SFs. This suggests that rapid fear discrimination mainly relies on HSFs.

Spatiotemporal Patterns of Social and Emotional Relevance in Scene Perception: Evidence From ERPs and fMRI

Annekathrin Schacht[1,2], Simon Weber[1,3] and Pascal Vrticka[4]
[1]University of Goettingen, Germany
[2]Leibniz ScienceCampus Primate Cognition, Goettingen, Germany
[3]Humboldt-Universität zu Berlin, Germany
[4]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

As the human species is inherently social, stimuli carrying social and emotional content are of particular relevance and typically gain beneficial processing. Recent research established social and emotional information as distinct stimulus dimensions, which are appraised separately but integrated at very early processing stages. However, the precise spatio-temporal pattern of social content and emotional valence processing is still unclear. In two experiments, we presented complex visual scenes differing in their social (social and nonsocial) and emotional (positive, negative, and neutral) content, while we recorded electroencephalography (EEG; Experiment 1; $N = 24$) and functional magnetic imaging (fMRI)-EEG data in separate sessions from the same study participants (Experiment 2; $N = 24$). The main finding of Experiment 1 was an early interaction between social and emotional relevance. We observed enhanced amplitudes of early event-related potential (ERP) components to emotionally positive and neutral pictures of social compared with nonsocial content, presumably reflecting rapid allocation of attention and counteracting an overall negativity bias. Importantly,

we could replicate this interaction effect in Experiment 2, with main sources located in the right middle occipital gyrus. Together, our data indicate that relevance detection may occur as early as around 100 milliseconds after stimulus onset, reflecting combined relevance detection of both emotional valence and social content.

Fast Subcortical Processing of Emotional Faces: Evidence From Physiology and Anatomy in Macaque Monkeys

Mikio Inagaki[1,2], Ken-ichi Inoue[3], Masahiko Takada[3] and Ichiro Fujita[1,2]

[1]Graduate School of Frontier Biosciences, Osaka University, Japan
[2]Center for Information and Neural Networks (CiNet), Osaka University and National Institute of Information and Communications Technology (NICT), Japan
[3]Primate Research Institute, Inuyama, Japan

The amygdala is implicated in detecting potential danger from visual signals such as facial expression of other individuals. A subcortical pathway through the superior colliculus (SC) and the pulvinar is hypothesized to transmit information about facial expression rapidly to the amygdala, shortcutting the ventral cortical stream. However, this hypothesis lacks evidence for short-latency single-neuron responses selective for emotional faces in the primate amygdala. Also, evidence for multisynaptic connections from the SC through the pulvinar to the amygdala is scarce. Here, we performed neurophysiological and neuroanatomical experiments in macaque monkeys to seek for the missing evidence. We recorded single-unit activity of amygdala neurons in response to visual presentations of threat, affiliative, and neutral faces. A linear classifier analysis revealed that ensemble neuronal responses within ~50 milliseconds after the stimulus onset discriminated threat faces from the others. To explore a possible pathway responsible for this response, we injected a rabies-virus tracer (trans-synaptic retrograde tracer) into the lateral amygdala. After a survival period of 2 days, we found labeled neurons in the pulvinar and the SC, presumably resulting from mono- and disynaptic transports from the amygdala, respectively. The results provide strong evidence for the subcortical pathway underlying fast emotional processing in the primate.

Cross-Species Differences in the Perception of Dynamic Facial Expressions

Michael Stettler[1,2], Nick Taubert[1,2], Louisa Sting[1,2], Ramona Siebert[2], Silvia Spadacenta[2], Peter Dicke[2], Hans-Peter Thier[2] and Martin A. Giese[1,2]

[1]Section for Computational Sensomotorics, Hertie Institute for Clinical Brain Research, Tübingen, Germany
[2]Department of Cognitive Neurology, CIN & HIH, University of Tübingen, Germany

Primates' facial expressions represent an important channel to communicate emotions. Human and monkey expressions of the same emotion can be quite different. How efficiently can we learn to recognize facial expressions of another primate species and can we understand human facial movements, even if it is linked to faces of another species? To clarify these questions, exploiting state-of-the-art technology in computer animation, we have developed a highly realistic model of a dynamically moving macaque monkey and human head, which is animated by both monkey and human motion capture data. Using a hierarchical generative Bayesian models (combining GP-LVMs and GPDMs), we are able to interpolate continuously between the facial movements representing emotional expressions in humans and monkeys. We validated the accuracy of the generated movements exploiting a "Turing test" that contrasts generated and original captured motion. We investigate the categorization of two different emotions (anger and fear) with respect to human- and monkey-specific movements. Our "Turing test" shows that the generated motion is highly accurate and indistinguishable from the original motion-captured motion. Preliminary results on species differences indicate a better perceptual discrimination of monkey expressions, arguing against more accurate perceptual representations of expressions of the own species.

Talk Session 19

Ambiguity, Rivalry, Switching

Motor and Vestibular Self-Motion Signals Drive Perceptual Alternations of Opposed Motions in Binocular Rivalry

David Alais[1], Chris Paffen[2], Keys Robert[1], MacDougall Hamish[1] and Verstraten Frans[1]
[1]University of Sydney, Australia
[2]Utrecht University, the Netherlands

We investigated whether motor and vestibular self-motion signals modulate rivalry between left versu right drifting gratings. Rivalry dynamics in vision-only were compared with two observer-rotation conditions—passive and active. Passive: Observers viewed motion rivalry on a motion platform undergoing sinusoidal yaw oscillations ($\pm 24^{\circ}$, sine period = 4 seconds). Active: Observers wore a virtual reality headset and made trunk rotations reproducing the same sinusoidal yaw. Alternations over 64-second trials were modelled with a sinewave. Perceived direction in motion rivalry correlated with direction of yaw rotation. Passive data: Rivalry dynamics entrained to self-motion oscillation rate (group mean period 3.88 seconds), mean amplitude was 0.37. Active data: All observers showed strong in-phase oscillations with mean period 3.98 seconds and stronger amplitude (0.53) than passive rotation. Rivalling up/down motions showed no effect of yaw rotation (active or passive), ruling out response bias linked to oscillation rate, or direction reversals. Head and eye movements: Head was stable throughout trials and eye movement timing showed no correlation with rotation profile. We conclude both motor and vestibular self-motion signals input to vision and can help resolve perceptual ambiguity. In both cases, perceived visual direction follows rotation direction, with active self-motion (vestibular+motor) particularly salient.

Perceptual Sensitivity, Variability, and Stickiness Predicted From Binocular Rivalry Dynamics

Stepan Aleshin[1,2], Gergő Ziman[3,4], Ilona Kovács[3,4] and Jochen Braun[1,2]
[1]Institute of Biology, Otto-von-Guericke University, Magdeburg, Germany
[2]Center for Behavioral Brain Sciences, Magdeburg, Germany
[3]Institute of Psychology, Pázmány Péter Catholic University, Budapest, Hungary
[4]HAS-PPCU Adolescent Development Research, Budapest, Hungary

Multistable reversals reflect a dynamical balance of inhibition (between alternative representations), adaptation (of dominant representations), and intrinsic noise (in each representation). Dynamic modeling of these factors reveals distinct regimes in which either adaptation is sufficient or noise is necessary for reversals. Typically, reversal statistics is reproduced near, but not at, a bifurcation surface separating these regimes. Here, we identify precise dynamical regimes that reproduce the average binocular rivalry statistics of developmental, mature, and patient groups (12, 16, 25, 60 years old, autism spectrum and borderline personality disorder; Ziman et al., ECVP '19). The results reveal group differences in strength of adaptation, time of adaptation, and noise amplitude. To predict impact on general perceptual performance, we performed in silico experiments to characterize the probability of model reversals in response to randomly fluctuating inputs. Distinguishing two components of "reversing force" (input and adaptation), we define perceptual "sensitivity" (probability gain per unit force), perceptual "variability" (variance of reversal state), and perceptual "stickiness" (relative contribution of input and adaptation). Our analysis opens up new territories in computational psychiatry by showing the profound power of theoretical models on predicting complex behavior and departures from the norm.
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How Does Attention Modulate the Switch Frequency of Binocular Rivalry?

Stella C. Qian[1] and Jan W. Brascamp[1,2]
[1]Department of Psychology, Michigan State University, East Lansing, MI, USA
[2]Neuroscience Program, Michigan State University, East Lansing, MI, USA

Binocular rivalry (BR) is observed when the two eyes receive conflicting information, leading to perceptual switches between the eyes' images. Previous studies have examined the effect of reduced attention to a BR stimulus. Computational models predict that attention reduction should increase switch frequency, yet empirical work shows the opposite. To resolve this inconsistency, we aimed to verify the empirical finding using a design that, contrary to existing work, does not pose observers with the challenge of reporting switches and performing an attention task simultaneously. Instead, while observers performed an auditory attention task, we used reflexive eye movements to track perceptual switches of task-irrelevant, moving rivalry stimuli. Our results show that BR switch frequency decreases as the attention task becomes more challenging, thus confirming the existing empirical result.

Further analysis shows that this decrease in switch frequency under reduced attention to the BR stimulus is attributable to an increased proportion of nonexclusive (piecemeal) perception. We propose that attention influences BR by facilitating grouping of the percept across space, and that a reduction of this grouping under conditions of reduced attention is responsible for the observed reduction of switch frequency as well as the observed increase in the proportion of piecemeal perception.

Whole-Brain Functional Correlations Underlying Spontaneous Reversals of Kinetic Depth

Ehsan Kakaei[1,2,3], Stepan Aleshin[2,3], Adam Ponzi[2,3] and Jochen Braun[2,3]
[1]ESF Graduate School ABINEP, Otto-von-Guericke University, Magdeburg, Germany
[2]Institute of Biology, Otto-von-Guericke University, Magdeburg, Germany
[3]Center for Behavioral Brain Sciences, Magdeburg, Germany

The dynamical causes of reversals in multistable perception remain contentions. We correlated functional magnetic resonance imaging signal time courses while observers viewed ambiguous kinetic depth displays with spontaneous reversals, similar displays with forced reversals, or control displays with forced reversals. Gray matter voxels in MNI152 standard space were grouped in 758 functional clusters (MD758 parcellation) to obtain 758 $\times$ 758 matrices of temporal covariance (Siemens 3T Prisma, TR 1 second, 4,800 seconds per condition). The significance of differences (between conditions) of individual cluster pair correlations was assessed with a permutation test. In addition, the significance of anatomically related differences and a standard false discovery correction was considered. Depending on the level of significance applied (in successive tests), we find between 200 ($p < .001$), 3 $\times$ 103 ($p < .01$) and 2 $\times$ 104 ($p < .05$) cluster pairs for which functional correlations differ between spontaneous and forced reversals (from 105 correlated pairs). Differential correlations are concentrated in cluster pairs involving occipital and inferior temporal regions, parietal, and postcentral regions as well as in mid- and superior frontal regions, including supplementary motor regions. We conclude that high-resolution functional connectivity provides rich empirical constraints for modeling the effective causal interactions that underlie multistable reversals.
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Common Neural Generators of the ERP Ambiguity Effects With Different Types of Ambiguous Figures

Lukas Hecker[1,2,3], Ellen Joos[1,2,3,4], Bernd Feige[2,3], Ludger Tebartz van Elst[2,3] and Juergen Kornmeier[1,2,3]
[1]Institute for Frontier Areas of Psychology and Mental Health, Freiburg, Germany
[2]Department of Psychiatry and Psychotherapy, Medical Center, University of Freiburg, Germany
[3]Faculty of Medicine University of Freiburg, Freiburg, Germany
[4]INSERM U1114, Cognitive Neuropsychology and Pathophysiology of Schizophrenia, University of Strasbourg, France

Recent studies reported unusually large "ERP Ambiguity Effects" with small amplitudes of two event-related potentials (ERPs) when participants observed an ambiguous figure and huge amplitudes with disambiguated stimulus variants. This effect occurred for ambiguity in different lower level stimulus categories (geometry, motion, and gestalt) and even at higher levels during the perception of emotional face content. In this study, we investigated whether this common ERP pattern is based on common neural sources in the brain. We applied Kornmeier et al.'s ambiguity paradigm to ambiguous Necker cubes and disambiguated cube variants and to face stimuli with ambiguous and distinct facial expression of emotions expressions (happy vs. sad). Independent component analysis and electroencephalogram source imaging (e.g., eLORETA) were applied in order to localize the neural generators underlying the ERP Ambiguity Effects and compare them between stimulus types. We found very similar neural generators and time courses of their activity across ambiguity in geometry and in emotion. Our findings indicate that the ERP Ambiguity Effects reflect processing of stimulus ambiguity at a very generalized, abstract level. We discuss our results in the context of meta-perception and executive attentional networks.

Perceptual Inference Is Facilitated by Transient Propagation of Information About Newly Established State to Nearby Locations

Alexander Pastukhov[1,2] and Claus-Christian Carbon[1,2]
[1]University of Bamberg, Germany
[2]EPÆG Bamberg, Germany

Perception faces a fundamental challenge to construct a single representation of the world based on noisy and intrinsically ambiguous inputs. We used simultaneous as well as asynchronous presentation of pairs of bistable kinetic-depth effect displays to demonstrate that this process is facilitated by transient propagation of information

to adjacent regions once it is resolved at one of the locations. When several multistable displays are viewed simultaneously, they all tend to be in the same perceptual state and switch together. Analysis of perceptual state durations and transition probabilities showed that this perceptual synchronization relies on transient rather than sustained influence. When a single object switches to a new state, this state spreads a brief activation that boosts same perceptual state in the object's vicinity. An experiment with an asynchronous presentation that produced opposite predictions for sustained versus transient bias also supported transient bias mechanisms. The switch-time transient nature of state bias propagation is consistent with neural correlates of perceptual switches in frontoparietal network. Cascading switch-time propagation also points toward similar mechanisms as for piecemeal perception in binocular rivalry. We surmise that similar transient spatial propagation of information might underpin other cases of ambiguous visual perception, such as perceptual grouping or filling-in.

How Metaperception Helps to Process Ambiguity in Geometry and Emotion

Ellen Joos[1,2,3,4], Anne Giersch[1], Lukas Hecker[2,3,4], Julia Schipp[2,3,4], Ludger Tebartz van Elst[2,3] and Juergen Kornmeier[2,3,4]

[1]INSERM U1114, Cognitive Neuropsychology and Pathophysiology of Schizophrenia, University of Strasbourg, France
[2]Department of Psychiatry and Psychotherapy, Medical Center, University of Freiburg, Germany
[3]Faculty of Medicine, University of Freiburg, Germany
[4]Institute for Frontier Areas of Psychology and Mental Health Freiburg, Germany

The information available through our senses is noisy, incomplete, and ambiguous. Our perceptual systems have to resolve this ambiguity to construct stable and reliable percepts. Recent electroencephalographic (EEG) studies found large amplitude differences in two event-related potential (ERP) components 200 and 400 milliseconds after stimulus onset when comparing ambiguous with disambiguated visual information ("ERP Ambiguity Effects"). These effects so far generalized across different stimulus categories at lower (geometry and motion) and intermediate (Gestalt perception) levels of complexity and are interpreted as correlates of metaperceptual processing of stimulus ambiguity. This study examined whether these ERP Ambiguity Effects also occur at higher levels of complexity, namely, with ambiguity in emotion. We thus compared effects of ambiguity in geometric cube stimuli (low-level ambiguity) and emotional faces (high-level ambiguity). ERP Ambiguity Effects were replicated for the geometric stimuli, and very similar ERP Ambiguity Effects were found for emotional face expressions. Conclusively, the ERP Ambiguity Effects generalize across fundamentally different stimulus categories and complexity levels of ambiguity. We postulate a high-level metaperceptual instance that evaluates the reliability of perceptual constructs. The ERP Ambiguity Effects may reflect these evaluation results. Our results are possibly important in relation to perceptual symptoms in psychiatric disorders.

What Happens in the Brain of Meditators When Perception Changes But Not the Stimulus?

Jürgen Kornmeier[1,2,3], Evelyn Friedel[2,3], Lukas Hecker[1,2,3], Stefan Schmidt[3,4] and Marc Wittmann[1]

[1]Institute for Frontier Areas of Psychology and Mental Health, Freiburg, Germany
[2]Department of Psychiatry and Psychotherapy, Medical Center, University of Freiburg, Germany
[3]Department of Psychosomatic Medicine, Medical Center, University of Freiburg
[4]Department of Psychosomatic Medicine, Medical Center, University of Freiburg, Germany

During observation of an ambiguous figure, our perception becomes unstable and alternates between mutually exclusive interpretations, while the stimulus itself remains unchanged. The rate of these perceptual alternations has been discussed as reflecting basic endogenous brain dynamics. Recent evidence indicates that extensive meditation practice evokes long-lasting changes in the dynamics and quality of brain processing. As one consequence, the perceptual processing of ambiguous figures and the rate of perceptual reversals seem to be altered in experienced meditators. In this study, we presented the ambiguous Necker cube in a well-established electroencephalography paradigm to measure the neural processes underlying endogenous perceptual reversals with high temporal precision. We compared reversal-related event-related potentials (ERPs) between experienced meditators and nonmeditating controls. For both groups, we found similar chains of reversal-related ERPs, starting early in visual areas. Meditators showed smaller (nicht besser: slower?) reversal rates compared with nonmeditators and an additional early (160 milliseconds after stimulus onset) frontal ERP signature which was absent in nonmeditators. We replicated previous findings of reversal-related ERP signatures. Our meditation-specific behavioral and ERP results indicate that extensive meditation practice changes even low-level visual processing steps and alters the overall endogenous processing dynamics of the brain.

Talk Session 20

Perceptual Awareness

Use of Sensory Information But Not Top-Down Influence of Expectation Is Gated by Conscious Awareness

Christoph Teufel
Cardiff University, UK

Expectation shapes early visual processing but the principles underlying this top-down influence are not well understood. Here, I explored whether expectation acts only on perceptual representations in conscious awareness or, alternatively, influences visual processing independently of consciousness. I used a statistical learning paradigm in which observers implicitly learn to expect a nonuniform distribution of orientations and provide two different judgments: a categorical judgment about stimulus presence and a judgment about specific stimulus orientations. Observers show systematic biases in orientation estimates, even when no stimulus was presented. Critically, this influence of expectation is found when observers report having seen a stimulus (hits and false alarms) but not when stimuli were not seen (misses and correct rejections). This finding could suggest that the modulation of specific stimulus properties by expectation is gated by conscious awareness of a stimulus. Alternatively, expectation might impact on sensory processing independently of conscious awareness, but the use of modulated sensory information is gated. Three follow-up experiments provide strong evidence for this latter view. Together, the experiments suggest that conscious awareness of a stimulus' presence gates the extent to which information about expectation-shaped sensory properties is used, but that the influence of expectation itself is independent of consciousness.

Target–Mask Interactions in Continuous Flash Suppression

Jan Drewes[1] and Weina Zhu[2]
[1]Physics of Cognition Group, Chemnitz University of Technology, Germany
[2]School of Information Science, Yunnan University, Kunming, China

Continuous Flash Suppression (CFS) has become widely used in the study of visual processing in the absence of conscious awareness. Varieties of masks have been used in CFS studies; however, little is known about mask/target interactions, even though these may severely bias results. We investigated the effect of orientational alignment between targets and masks in a breaking-CFS paradigm. Masks were pink noise patterns filtered with a narrow-orientation band pass. Target stimuli were Gabor patterns varying in their orientational alignment with the masks. When both targets and masks were realized as luminance patterns, targets that were well aligned with the mask orientation remained suppressed significantly longer (~80% above average) than unaligned targets. This effect was stronger when the alignment occurred in cardinal orientations. When adding color to both masks and stimulus, the general pattern remained only when mask and target were of identical color. With different colors, the alignment effect was greatly diminished. Our results show that similarities in basic features between target and mask in a CFS paradigm can greatly affect suppression duration. However, the visual system appears capable of avoiding this by utilizing independent/orthogonal information. Careful design of CFS masks is required to not bias results due to mask–target interactions.

The Content of Visual Working Memory Regulates the Priority for Access Visual Awareness as an Integral Object

Yun Ding, Andre Sahakian, Chris Paffen, Marnix Naber and Stefan Vander Stigchel
Utrecht University, the Netherlands

Previous studies suggest that (a) pre-activating a visual representation in visual working memory (VWM) prioritizes access to visual awareness for this item and that (b) VWM can contain representations of bound features. It is currently unclear whether VWM affects access to visual awareness at a feature level, a bound conjunction level, or both. To investigate this question, we conducted experiments by combining a delayed match task with a breaking Continuous Flash Suppression (b-CFS) task. In each trial, subjects memorized an object consisting of a disk with two halves with different colors for the later recall test and, between them, detected the target location during CFS. We varied the congruence in colors between the memory representation and to-be-detected target. Our results show that memory congruent objects (consisting of a conjunction of features) break CFS faster than memory incongruent objects. We also observe this congruence effect when we presented the memorized object in a horizontally mirrored configuration of colors. However, we do not observe a faster effect when the target shares only a single feature of a memorized object (semicongruent). Our results suggest that VWM prioritizes access to visual awareness for objects with bound features for which the spatial configuration is not relevant.

Auditory–Visual Integration During Nonconscious Perception

April Ching, Jeesun Kim and Chris Davis
The MARCS Institute, Western Sydney University, Australia

Our study proposes a test of a key assumption of the most prominent model of consciousness—the global workspace (GWS) model (e.g., Baars, 2005). This assumption is that multimodal integration requires consciousness; however, few studies have explicitly tested if integration can occur between nonconscious information from different modalities. The proposed study examined whether a classic indicator of multimodal integration—the McGurk effect—can be elicited with subliminal auditory–visual (AV) speech stimuli. We used a masked speech priming paradigm in conjunction with continuous flash suppression to present video stimuli subliminally. Applying these techniques together, we carried out two experiments in which participants categorised auditory syllable targets which were preceded by subliminal AV speech primes. Subliminal AV primes were either illusion-inducing (McGurk) or illusion-neutral (Incongruent) combinations of speech stimuli. The combined results of both experiments demonstrate a type of nonconscious multimodal interaction that is distinct from integration—it allows unimodal information that is compatible for integration (i.e., McGurk combinations) to persist and influence later processes but does not actually combine and alter that information. As the GWT model does not account for nonintegrative multimodal interactions, this places some pressure on such models of consciousness.

Face Expertise and the Unconscious Perception of Faces

Michael Papasavva[1], Ines Mares[1], Louise Ewing[2], Anne Richards[1] and Marie L. Smith[1]
[1]Birkbeck College, University of London, UK
[2]University of East Anglia, Norwich, UK

Humans are an extraordinarily social species that form large interpersonal social networks. The ability to extract identity-relevant information from faces is considered to be a normal ability in typically developing individuals, though a wide varying range of abilities is commonly observed. Across two experiments, we utilise a particularly powerful variant of binocular rivalry, called Continuous Flash Suppression (b-CFS) to investigate the mechanisms that might be driving individual differences in face identity recognition (as measured by the Cambridge Face Memory Test). In Experiment 1 ($n = 48$), we explored whether consciously suppressed faces (attractive and unattractive) and houses break into conscious awareness at different speeds in high versus low ability face processors. Relative to weaker face processors, stronger face processors demonstrate a selective breakthrough advantage for faces compared with houses. Results also indicate that only better face processors are sensitive to facial attractiveness. In Experiment 2 ($n = 42$), we added an image orientation condition and tested a new cohort of typically developing participants. In addition to replicating our earlier findings, we demonstrate that only superior face processors are sensitive to the b-CFS face inversion effect.

Perceptual Organization and Visual Consciousness

Ruth Kimchi
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 to render the stimulus inaccessible to visual awareness takes place.

Talk Session 21

Patterns, Textures, Contours, and Shapes

Two-Photon Imaging of Neural Responses to Complex Stimulus Patterns in Macaque V1

Shu-chen Guan, Nian-sheng Ju, Shi-ming Tang and Cong Yu
Department of Psychology, Center for Life Sciences, McGovern Institute for Brain Research and Life Sciences, Peking University, Beijing, China

We compared neural responses with gratings and complex two-dimensional Hermite patterns in V1 superficial layers of two awake macaques with long-term two-photon calcium imaging (GCaMP5). The parafoveal (2–4o) grating stimuli were high-contrast 2 cycles/s drifting Gabors at various orientations and spatial frequencies, and Hermite patterns included vignette, checkboard, and circular/dartboard-like types. We found V1 neurons that responded to gratings only, Hermite patterns only, or both types, with similar response strengths. More Hermite neurons and less grating neurons existed at 150 μm than at 300 μm (Hermite neurons: 23% vs. 11%; grating neurons: 33% vs. 66%). Hermite neurons preferred lower spatial frequencies than grating neurons (1.01 vs. 2.70 c/deg), overlapped with neurons untuned to orientation, and exhibited trends of clustering; 51% of Hermite neurons responded to circular/dartboard-like patterns, with the rate increased from 300 μm to 150 μm (41% vs. 60%), which was confirmed by a principal component analysis. These results suggest that neurons responding to complex stimulus patterns may emerge in V1 and form a specialized subpopulation for feature integration. The high rate of neurons responding to circular/dartboard patterns may carry biological significance for monkey's survival, such as early detection of round-shaped face- or fruit-like stimuli.

From Borders to Bumps: Circular Flows Are Invariant Across Materials

Steven Zucker[1] and Benjamin Kunsberg[2]
[1]Yale University, New Haven, CT, USA
[2]Brown University, Providence, RI, USA

Bumps and dents arise intuitively when describing shape, but their formal definition is elusive. This is problematic both psychophysically (where is the border of a Gaussian bump?) and computationally (what image properties relate to surface properties for different materials?). By contrast, the outer border of a shape is defined crisply as the locus of noninterior positions that are grazed by the line of sight. Note this is a surface property—slant is maximal—not an image property. We propose a definition of bumps that is a relaxation of that for outer borders. Closed contours along which slant is extremal relaxes the maximal requirement and criticality connects them to shape descriptors. The image counterpart for bumps derives from the tangency relationship between the orientation of flows as they approach boundaries but relaxes the need for a boundary. Instead the flows reveal cycles of orientation, to which we are exquisitely sensitive, and these surround the bump. We demonstrate how the flows reveal a hierarchy of multistable convex/concave ambiguities in shape, how they relate to visual cortex, and how they arise from specular as well as shaded and textured materials.

Point-to-Point Contour Correspondence Based on Shape Features and Semantic Parts

Filipp Schmidt, Jasmin Kleis, Yaniv Morgenstern and Roland W. Fleming
Justus Liebig University Giessen, Germany

Establishing correspondence between objects is fundamental for object constancy, similarity perception, and identifying transformations. Previous studies measured point-to-point correspondence between objects before and after rigid and nonrigid shape transformations. However, we can also identify "similar parts" on extremely different objects such as lizards and whales or airplanes and stingrays. We measured point-to-point correspondence between 11 such object pairs. In each trial, a dot was placed on the contour of on one object, and participants had to place a dot on "the corresponding location" of the other object. Responses show correspondence is established based on similarities between shape features (such as curvature) but also between semantic parts (such as head, wings, or legs). We then measured correspondence between ambiguous objects with different labels (e.g., between "duck" and "rabbit" interpretations of the classic ambiguous figure). We developed a zero-parameter model based on curvature measures and labeled semantic part data (obtained from a different group of participants) that can explain a substantial portion of response variance of all our data. This demonstrates how we establish correspondence between very different objects by evaluating similarity between shape features as well as between semantic parts, combining perceptual organization and cognitive processes.

A Psychophysically Validated Computational Model of Perceived Shape Similarity

Yaniv Morgenstern, Filipp Schmidt, Frieder Hartmann, Henning Tiedemann, Eugen Prokott, Guido Maiello and Roland Fleming
Justus-Liebig University, Giessen, Germany

Shape is the most important defining feature of objects. Yet, despite decades of research on perceived shape, there still exists no image-computable model that accurately predicts how similar different shapes appear to human observers. Here, we present a model ("ShapeComp") based on over 100 image-computable shape features (e. g., area, compactness, shape context, Fourier descriptors), which predicts human shape similarity judgments for complex, naturalistic two-dimensional (2D) silhouettes. Using a database of $>$25,000 animal silhouettes, we applied MDS to the model, to identify 11 orthogonal dimensions that

capture >90% of the variance between shapes. We then created novel shapes by training a Generalized Adversarial Network on the animal silhouettes. Drawing samples from the latent space learned by the network allows us to synthesize novel 2D shapes that are related to one another in systematic ways. Using carefully selected stimulus sets equated for pixel similarity, we show that (a) the ShapeComp predicts human shape similarity judgments and (b) it organizes stimuli in meaningful, perceptually uniform shape space. Together, these findings show that ShapeComp is a powerful tool for investigating the representation of shape and object categories in the human visual system.

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Novel Object Categories Generated From Single Exemplars

Henning Tiedemann, Yaniv Morgenstern, Filipp Schmidt and Roland W. Fleming
University of Giessen, Germany

When categorizing unfamiliar objects, observers must decide which features are diagnostic of the category. That humans agree on which objects belong together is impressive, given the task's highly underconstrained nature. To study how such categories are formed, 17 participants viewed silhouettes of eight exemplar objects from different classes, which were created to have distinctive features. For each exemplar, they were asked to draw 12 new variants belonging to the same class, yielding 1,632 drawings. In a control condition, they copied each exemplar 12 times ("copies"). The variants were significantly more variable than the copies, yet for each exemplar, participants were consistent in which features they preserved and which ones they altered. Another group of participants then assigned the variants to the exemplars in a categorization task. They classified the variations with high accuracy, suggesting that similar category boundaries were used in drawing and categorization. The shapes were transformed into a "shape-space" based on a set of image-computable metrics (e.g., curvature, area). The distributions of the variants in the "shape-space" reveal that participants modified different features of each exemplar. These findings support that humans infer sophisticated generative models of object appearance from single exemplars.

Cue Reliability Is Reflected at a Late Stage in Visual Processing

Giovanni Mancuso, Amélie Le Breton de Vannoise and Gijs Plomp
University of Fribourg, Switzerland

Humans integrate sensory evidence from relevant cues for adaptive behaviour. In perceptual decisions about shapes, contour and texture information are integrated according to their reliability. Here, we investigated at what latencies and over which brain regions cue reliability is reflected using a using model-based analysis of visual-evoked potentials (VEPs). We parametrically varied the reliability of contour or surface cues, while participants performed a shape discrimination task on Gaborised ellipsoids. Using signal detection theory, we modelled the expected behavioural performance as a linear function of cue reliability, allowing us to identify latencies and electrodes where electroencephalographic activity reflected the quantities predicted by our model (*d'* slopes). We found that VEPs were linearly related to the individual parametric predictors at around 400-millisecond poststimulus at electrodes over parietal cortex. The effect was similar for variations in reliability of contour and surface cues. Notably, effects of cue reliability were absent at earlier latencies where visual shape information is typically reported and in data time-locked to the behavioural response. These results suggest that reliability of visual cues is reflected at a late stage of processing in line with the idea of accumulated sensory evidence in parietal cortex.

Talk Session 22

Individual Differences

Interindividual Differences in Psychophysical Measures of "Cortical Inhibition": A Behavioural and Proton Magnetic Resonance Spectroscopy Study

Allison McKendrick[1], Kabilan Pitchaimuthu[1,2], Yu Man Chan[1], Bao Nguyen[1], Olivia Carter[1] and Gary Egan[3]
[1]The University of Melbourne, Australia
[2]Universität Hamburg, Germany
[3]Monash Biomedical Imaging, Monash University, Melbourne, Australia

Numerous studies purport that psychophysically measured surround suppression is an analogue for the strength of inhibitory neural mechanisms in visual cortex. There is also

a purported link between neural inhibition and bistable perception as measured in binocular rivalry paradigms. Here, we correlate commonly measured behavioural estimates of cortical inhibition (centre-surround suppression of contrast, spatial suppression of motion discrimination, and binocular rivalry) with magnetic resonance spectroscopy (MRS) estimates of γ-aminobutyric acid (GABA) in the visual cortex. Data were collected from 57 participants, with behavioural measures and MRS conducted within 3 hours. Increased GABA was associated with longer binocular rivalry median percept duration ($r = .33$, $p = .01$), and with suppression strength for motion discrimination ($r = -.31$, $p = .02$). The strength of centre-surround suppression of contrast did not correlate with GABA ($p = .50$). Within the behavioural tasks alone, suppression strength for the motion and contrast tasks was not correlated ($p = .45$); however, both were individually correlated with binocular rivalry median percept duration (motion: $r = -.37$, $p < .01$; contrast: $r = .37$, $p < .01$). Our findings suggest that multiple neural mechanisms govern interindividual differences in performance on these psychophysical tasks, and that centre-surround suppression of contrast and motion discrimination measures of suppression reflect predominantly different neural processes.

Individual Differences in Perceptual Organization: Rediscovering, Reanalyzing, and Reinterpreting Thurstone's (1940–1950) Factor Analyses of Visual Data

David Henry Peterzell[1,2]
[1]JFK University, Pleasant Hill, CA, USA
[2]UC Berkeley, CA, USA

Thurstone's (1940, 1943, 1944, 1950) factor-analytic discoveries regarding primary visual abilities, gestalt effects, and perceptual dynamics seem forgotten yet important. Studies culminated in the discovery of seven processes or "primary abilities," and other factors (e.g., illusions). Two involved perceptual speed and visual memory. Three were "space" factors involving (a) the ability to recognize an object when viewed from different angles (e.g., mental rotation of a whole object), (b) the ability to imagine the movement or parts of a configuration (e.g., movement within a whole configuration), and (c) the ability to think about spatial relations in which an observer's body orientation is an essential component of the problem. Two were gestalt closure factors including abilities to (a) achieve perceptual closure in which a degraded stimulus field becomes organized into a single percept and (b) keep in mind a visual configuration despite distracting and confusing detail in the visual field. This study used correlational and modern factor analytic methods to reanalyze Thurstone (1944), which measured 194 individuals' performance on 60 visual tests. Factors were recomputed, with some differences from the original solution, but with robust evidence for each primary ability. This reanalysis rediscovers and reidentifies specific processes seemingly essential to perceptual organization.

Evidence for Three Motion Sensing Mechanisms Tuned to Fine-, Middle-, and Coarse-Features: An Individual Differences Approach

Raúl Luna[1], **Carlos Ibáñez**[1] and **Ignacio Serrano-Pedraza**[1,2]
[1]Faculty of Psychology, Complutense University of Madrid, Spain
[2]Institute of Neuroscience, Newcastle University, UK

Motion discrimination becomes impaired when a static coarse scale is added to a moving fine-scale pattern and also in some conditions where these patterns move coherently. We therefore hypothesize that different motion sensing mechanisms, at least segregating coarsely and finely tuned motion sensors, must exist. To test this, two experiments were performed using an individual differences approach. Particularly, we measured duration thresholds for moving spatial frequencies of 0.25, 0.5, 0.75, 1, 1.5, 2, 3, and 6 c/deg, first (Experiment 1) drifting with a speed of 2 deg/s with Michelson contrasts of 0.1 or 0.9 ($n = 28$) and second (Experiment 2) with a contrast of 0.9, drifting with a temporal frequency of 2 Hz or 8 Hz ($n = 30$). Interestingly, results from both experiments show an opposite tendency in which duration thresholds stabilize for frequencies lower than 1 to 1.5 c/deg and then decrease (Experiment 1) or increase up to 1 to 1.5 c/deg and then stabilize (Experiment 2), suggesting two spatial-frequency mechanisms. However, a factor analysis yields three factors: one for frequencies lower than 0.5 c/deg, another for intermediate frequencies up to 1 to 1.5 c/deg, and another for higher ones. Therefore, for the first time under this approach, we show evidence favorable for the existence of at least three underlying motion sensing mechanisms tuned to different scales.

Using Machine Learning Techniques on Screen-Based Eye-Tracking Data to Classify Individual Traits

Callum Woods[1], **Zhiyuan Lou**[2], **Dawn Watling**[1] and **Szonya Durant**[1]
[1]Department of Psychology, Royal Holloway University of London, UK
[2]Department of Computer Science, Royal Holloway University of London, UK

Literature has shown that behaviour on online social networking sites (OSNS) provides insight into our traits and values. Eye movements can reflect endogenous attention and provide a vital source of information about social and emotional cues that influence our behaviour. In the same way that personality can be predicted from "likes" upon OSNS, can personality be predicted from our oculomotor behaviour whilst browsing these sites? We tracked eye movements of 35 participants as they engaged with socially relevant information presented within two different social media inspired webpages. We describe fixations and saccadic behaviour across the page to form a set of global features and use a region of interest approach to characterise responses to content and location. Within a binary classification paradigm, we evaluate the performance of three different learning algorithms upon these three different feature sets. We identified that the feature set and presented stimuli influence classification performance. Some models predicted the personality traits of Extroversion (80% Accuracy), Conscientiousness (77%), and Openness (67%) significantly above chance. We found that more general statistical descriptions of fixations and saccadic behaviour, coupled with an RIDGE classification algorithm, were the most successful in producing models that reliably predict an individual's personality.

Rapid Objective Assessment of Contrast Sensitivity and Visual Acuity With Sweep Visual-Evoked Potentials and an Extended Electrode Array

Coralie Hemptinne[1], Joan Liu-Shuang[2], Demet Yuksel[1,3] and Bruno Rossion[2,4]
[1]Department of Ophthalmology, Cliniques Universitaires Saint-Luc, Woluwé-Saint-Lambert, Belgium
[2]Psychological Sciences Research Institute, Institute of Neuroscience, University of Louvain, Belgium
[3]Faculty of Medicine, University of Louvain, Belgium
[4]Neurology Unit, Centre Hospitalier Regional Universitaire (CHRU) de Nancy, France

Sweep visual-evoked potentials (sVEPs) provide an implicit, objective, and sensitive evaluation of low-level visual functions. For practical and traditional reasons, sVEPs in ophthalmologic examinations have usually been recorded over a limited number of electrodes. We examined whether a higher density of recording electrodes improves the estimation of individual low-level visual thresholds with sVEPS, and to which extent such testing could be streamlined for clinical application. To this end, we tested contrast sensitivity and visual acuity in 26 healthy adult volunteers with a 68-electrode electroencephalogram system. While the most sensitive electrophysiologic response was found at the traditional electrode Oz in a small majority of individuals, it was found at neighboring electrodes for the remaining participants. More generally, visual function was evaluated more sensitively based on electroencephalography recorded at the most sensitive electrode. Our data suggest that recording over seven posterior electrodes while limiting the testing session to less than 15 minutes ensures a sensitive and consistent estimation of acuity and contrast sensitivity threshold estimates in every individual. This study shows that sampling from a larger number of electrodes is relevant to optimize visual function assessment and could be achieved efficiently in the time-constrained clinical setting.

Assessing the Reliability of Neural Face Identity Discrimination With FPVS

Lisa Stacchi[1], Joan Liu-Shuang[2], Meike Ramon[1] and Roberto Caldara[1]
[1]University of Fribourg, Switzerland
[2]Université Catholique de Louvain, Belgium

Over the past years, fast periodic visual stimulation (FPVS) has been used extensively as an objective measure of neural face discrimination. Here, we use FPVS to investigate how neural face identity discrimination varies in amplitude and topography across observers and as a function of the foveally presented facial information (i.e., viewing position [VP]). Specifically, we determined the intersession reliability of VP-dependent neural face discrimination responses both across and within observers (6-month intersession interval). All observers exhibited idiosyncratic VP-dependent neural response patterns, with reliable individual differences in terms of response amplitude for the majority of VPs. Importantly, the topographical reliability varied across VPs and observers, and the majority of which exhibited reliable responses only for specific VPs. Crucially, this topographical reliability was positively correlated with the response magnitude over occipito-temporal regions: Observers with stronger responses also displayed more reliable response topographies. Our data extend previous findings of idiosyncrasies in visuo-perceptual processing. These findings invite to careful consideration of individual differences according to their reliability, as those that are expressed more consistently could be functionally more meaningful. Moreover, our observations suggest that the magnitude of neural face identity discrimination responses is an indicator of response reliability.

Talk Session 23

Neural Dynamics

Decoding Rules and Attended Features Over Multiple Task Phases

Lydia Barnes[1,2], Erin Goddard[3] and Alexandra Woolgar[1,2]
[1]University of Cambridge, UK
[2]Macquarie University, Sydney, Australia
[3]McGill University, Montreal, Quebec, Canada

Foundational studies of nonhuman primate prefrontal cortex show that single-neuron responses rapidly reconfigure as task demands change. These findings motivated the adaptive coding hypothesis, which proposes that flexible cognition is supported by neural populations that encode features of the environment that are relevant to the current task. Human functional magnetic resonance imaging shows that frontoparietal activity patterns contain more information about an object's length or orientation when that feature is task-relevant. In magnetoencephalography (MEG), we see the same process unfold over time: the task-relevant feature of a target object is preferentially encoded over irrelevant features within a few hundred milliseconds of stimulus onset. Here, we used MEG to test for rapid reconfiguration of information processing when a new feature becomes relevant within a single task. Participants observed two visual objects in sequence and reported the shape of the first and the colour of the second or vice versa. We expected to see preferential coding of relevant features, with a possible lag as attention shifted. Contrary to our predictions, we found a strong preference to encode all the object information regardless of the task, until briefly before the response. We present possible reasons for this strategy and directions for future work.

Image Coherence Modulates Strength of Feedback to Early Visual Cortex

Kirsten Petras[1,2], Sarang S. Dalal[3] and Valerie Goffaux[1,2]
[1]UC Louvain, Belgium
[2]Maastricht University, the Netherlands
[3]Aarhus University, Denmark

Human object recognition is characterized by a low spatial frequency (LSF) bias at the earliest latencies of visual processing. We have previously shown that coarse (LSF) image information guides the integration of high spatial frequency (HSF) detail, presumably through feedback to early visual cortex (EVC). However, both the origin and the information content of such feedback remain unclear. Inferior temporal cortex with its category selective patches would be a plausible source of feedback as it is thought to contribute crucially to the highly efficient processing of visual objects and shows spatial frequency sensitivity dynamics consistent with coarse-to-fine integration. Here, we leverage the high temporal resolution and adequate spatial specificity of source reconstructed magnetoencephalography recordings to investigate the origin and information content of feedback to EVC. Participants watched LSF, HSF, and broadband images of faces, houses, and their scrambled versions. Preliminary results of region of interest analyses of power spectra as well as directional connectivity measures indicate inferior temporal cortex parcels as a source of feedback to EVC. This feedback was stronger for intact, compared with scrambled image trials. Future analysis will attempt to link higher level feedback to the dynamics of spatial frequency dominance in EVC.

Alpha Bursts in Inferior Parietal Cortex Underlie Spatiotemporal Object Individuation

Andreas Wutz and Nathan Weisz
University of Salzburg, Austria

Current theories suggest that alpha oscillations (9–13 Hz) reflect pulsed-inhibitory neural computations that structure visual perception into discrete time frames supporting spatiotemporal object individuation. We investigated the impact of alpha oscillations in a multiple-object tracking task (MOT) while simultaneously recording whole-head magnetoencephalography. On each trial, the participants were required to track two, four, or eight objects over a period of 2 to 3 seconds. In different blocks, they switched between an individuation task (i.e., partial report) and average object-position processing (i.e., centroid task). During MOT, we found a strong alpha power increase from pretrial baseline in bilateral inferior parietal cortex for both tasks. By contrast, we found stronger oscillatory bursting in the alpha band for individuation versus averaging. Oscillatory bursting captures single-trial dynamics better compared with across-trial averaged power, because it measures time- and band-limited, high-signal periods above each trial's respective pretrial mean. Critically, the alpha bursting effect was only significant below the typically reported capacity limit (i.e., for two/four objects) and not when object-capacity was exceeded (i.e., eight objects). This pattern was supported by behavioral performance. These results suggest that oscillatory alpha bursts underlie spatiotemporal object individuation and its capacity limits.

A Hierarchical Network of Topographic Visual Timing-Tuned Responses in Human Association Cortex

Ben M. Harvey[1], Serge O. Dumoulin[1,2,3], Alessio Fracasso[2,4] and Jacob M. Paul[1]
[1]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[2]Spinoza Center for Neuroimaging, Amsterdam, the Netherlands
[3]Experimental and Applied Psychology, VU University Amsterdam, the Netherlands
[4]Institute of Neuroscience and Psychology, University of Glasgow, UK

Precisely, quantify the timing of subsecond events is vital to understanding and interacting with our dynamic environment. However, despite the central role of timing in perception and action planning, it remains unclear how the brain encodes and represents sensory event timing. We acquired ultra-high field (7T) functional magnetic resonance imaging (fMRI) data while showing subjects visual events (a circle appearing and disappearing) that gradually varied the time between circle appearance and disappearance (duration) and the time between consecutive circle appearances (period, i.e., 1/frequency). We summarized the fMRI responses to these events using population receptive field neural models tuned to duration and period. We found nine widely separated bilateral timing maps, each showing topographically organized, tuned responses to duration and period. Duration and period representations were closely linked. Left-hemisphere maps were larger, with clearer responses. We found hierarchical transformations of timing representations from posterior to anterior maps: integrating responses to multiple events, narrowing response tuning, and focusing increasingly on the middle of the presented timing range. Our results suggest the neural representation of event timing is similar to that of both sensory spaces and other quantities, such as numerosity and object size. Their locations suggest roles in visual motion processing, multisensory integration, and sensory-motor transformations, respectively.

Talk Session 24

Visual Memory

Dissociating Perceptual Serial Dependence From Working Memory

Mauro Manassi[1], Kathy Zhang[2] and David Whitney[1]
[1]University of California, Berkeley, CA, USA
[2]Kavli Institute for Neuroscience, Yale University, New Haven, CT, USA

Recent research showed that our percept is strongly biased toward the past. However, the mechanism(s) underlying serial dependence remains unclear: Serial dependence was proposed to occur at the level of perception, decision, or as a by-product of working memory. Here, we investigated the relationship between serial dependence and working memory. In a first series of experiments, we measured serial dependence strength under different memory load conditions. On each trial, observers were asked to adjust a random face to match the identity of the face they previously saw (low memory load). In another experiment, observers were additionally asked to remember the face in the previous trial (high memory load). Serial dependence strength diminished in trials with high memory load conditions compared with low memory load conditions. Hence, contrary to the working memory account, high working memory conditions modulate serial dependence in an anticorrelated manner. In a second series of experiments, we compared serial dependence strength with measures of working memory capacity (operation span task and change detection task). No significant correlation was found across observers. Taken together, our results show that serial dependence operates independently from working memory.

The Role of Working Memory in the Perception of Motion Coherence

Josef G. Schönhammer[1,2], Luke Palmer[1] and Nilli Lavie[1,2]
[1]Mind Vision Labs, London, UK
[2]Institute of Cognitive Neuroscience, University College London, UK

Previous research suggests that working memory (WM) load, associated with lateral prefrontal cortex (LPFC) activation, is crucial for the control of selective attention to target signals and inhibition of distracting signals. Here, we examined whether the effects of WM load extend to perception of coherent motion among random motion distractors. Observers were instructed to detect brief

presentations of coherent motion among extended streams of random-dot motion, while WM load was manipulated with a secondary active digit maintenance task. LPFC activation was measured throughout using functional near-infrared spectroscopy (fNIRS). Higher WM load was associated with increased activity in LPFC and resulted in lower motion discrimination thresholds, suggesting that limited WM availability leads to reduced discrimination between coherent motion target signals and random motion noise. Moreover, a temporal cue indicating the onset of motion coherence eliminated the effect of WM load, reinforcing the specific role WM plays in control of motion perception when this requires extended monitoring for motion target signals among noise. Taken together, the findings confirm a significant role of WM and the associated LPFC activation in the control of coherent motion perception among noise and furthermore establish an fNIRS measure of WM load during motion perception.

Feature Relations Among Colours Modulate Visual Short-Term Memory

Aimee Martin and Stefanie I. Becker
The University of Queensland, Brisbane, Australia

Visual short-term memory (VSTM) allows us to store and recall information. Current theories postulate that stimuli are encoded individually. However, studies on the relational account of attention have shown that stimuli are often encoded in a relational, context-dependent manner (e.g., redder). Given the tight link between VSTM and attention, this study investigated whether the relational account of attention can be applied to VSTM. A change detection task was used with a range of dissimilar and similar colours (blue to green, etc.). Experiment 1 showed that accuracy/sensitivity was highest when there was a relational change (e.g., the bluest item changed, while another item become the bluest) compared with when the relative colour stayed the same (e.g., bluest item underwent the same colour change but remained the bluest) and compared with a change among dissimilar colours. Experiment 2 measured the contralateral delay activity (CDA) in electroencephalography to similar colours in the memory display and found that the CDA was smaller when the colours were arrayed to match a specific order (e.g., bluest to greenest) than when they were randomly distributed. Moreover, accuracy/sensitivity for relational changes were highest among ordered colours. With this, the study provides the first direct demonstration that relationships are encoded into VSTM.

Highly Memorable Images Compete for Attention With Serial Search

Qi Li and Kazuhiko Yokosawa
The University of Tokyo, Japan

This study investigated whether the processes of encoding and maintaining highly memorable images consume more attentional resources than less memorable images. Our participants performed a main task of serial search and a subtask of memorizing an image simultaneously. The results revealed that highly memorable images interfered with serial search to a greater extent than less memorable images, indicating that encoding and maintaining highly memorable images may consume more attentional resources compared with less memorable images. Furthermore, the results of the memory test showed better performance for highly memorable images than for less memorable images, indicating that images that attract more attention are more likely to be encoded into memory. In our second experiment, a set of shuffled images was created by randomly shuffling blocks of each image used in Experiment 1. The shuffled images had feature statistics and objects but dramatically reduced spatial context. The results showed that neither serial search performance nor memory recognition performance differed significantly between images created from highly memorable and less memorable images, ruling out the possibility that greater interference from highly memorable images observed in Experiment 1 was due to the fact that those images contain basic features or objects that can capture attention.

Talk Session 25

Perception-Action

Investigating How Prior Knowledge Influences Perception and Action in Developmental Coordination Disorder

Gavin Buckingham[1], Kate Allen[1], Samuel J. Vine[1], David J. Harris[1], Greg Wood[2], Krasimira Tsaneva-Atanasova[3] and Mark R. Wilson[1]
[1]Sport and Health Sciences, University of Exeter, UK
[2]Research Centre for Musculoskeletal Science and Sports Medicine, Manchester Metropolitan University, UK
[3]Mathematics, University of Exeter, UK

Developmental coordination disorder (DCD) is characterised by a broad spectrum of difficulties in performing motor tasks, in the absence of any physical or sensory

impairment. It has recently been proposed that a selective deficit in sensorimotor prediction and feedforward planning might underpin these motoric impairments. The purpose of this study was to use a naturalistic object lifting paradigm to investigate whether deficits in sensorimotor prediction might underpin the broad spectrum of difficulties individuals with DCD face when interacting with objects in their environment. We examined perceptions of heaviness and fingertip force application in children aged 8 to 12 years with DCD ($n = 48$) and without DCD ($n = 53$). In the context of the size-weight illusion, we examined these measures in the context of the size-weight illusion paradigm, where participants lifted objects which varied in their apparent, but not actual, weight. Overall, participants showed the expected perceptual and sensorimotor behaviours—small objects felt heavier, and were initially lifted with lower rates of force, than large objects. We found no evidence for a difference in the magnitude of perceptual or sensorimotor effects between children with and without DCD, suggesting that it is unlikely that DCD represents a selective deficit in sensorimotor prediction and feed-forward planning.

Eye Movement Signatures of Go/No-Go Decisions With Different Task Constraints

Jolande Fooken and Miriam Spering
University of British Columbia, Vancouver, British Columbia, Canada

In baseball, hitters and umpires alike have to decide if a pitch will pass or miss the strike box. As motor preparation and execution of batting takes time, the hitter only has 200 milliseconds to decide whether or not to swing, whereas the umpire can wait to see the full pitch. Situations that require similar perceptual decisions but have different temporal demands may result in different predictive strategies. Here, we investigate the role of movement constraints on decision accuracy by manipulating response modality (button press vs. interceptive hand movement) and eye movements (free viewing vs. fixation) during rapid go/no-go decisions. Observers ($n = 40$) had to judge whether a briefly presented moving target would pass (interception required) or miss (no action) a strike box. Go/no-go decisions had to occur 50 to 100 milliseconds earlier when interceptive hand movements had to be planned and carried out. Congruently, decision accuracy was higher in trials with button press than with manual interceptions. Moreover, eye movements (compared with fixation) enhanced accurate decision-making regardless of response modality. These results indicate that perceptual decision formation occurs dynamically, relying on the continuous updating of sensory information until an action is required.

The Motion-Induced Position Shift in a Target Tracking Task

Loes C. J. Van Dam
University of Essex, UK

The motion-induced position shift (MIPS) arises from conflicting information about an object's position from its contours and an objects motion from its moving texture. The result is that the object is perceived to be displaced in the direction of texture movement. Here, we used this idea to investigate how position and motion estimates may differently influence perception of an object's movement compared with our own limb movements. To this end, participants tracked a moving target with a cursor that they controlled by moving a stylus over a graphics tablet. In half the trials, the MIPS stimulus was the target and the cursor a simple dot, and vice versa for the other half of the trials. The motion direction of the texture within the MIPS stimulus varied in a random walk fashion. The results show a positive correlation between the tracking error and the MIPS manipulation for the MIPS-target and a negative correlation for the MIPS-cursor, indicating that the illusion works in both cases. However, the correlation was stronger for the MIPS-target compared with the MIPS-cursor suggesting that visual texture motion is used less for estimating the movements of our own limbs compared with those of an external object.

Hitting a Target: Fast Responses to Visual Perturbations Are Scaled to the Remaining Time to Impact

Eli Brenner and Jeroen B. J. Smeets
Vrije Universiteit Amsterdam, the Netherlands

People adjust their movements to changes in the positions of the targets of such movements with a latency of about 100 milliseconds. To examine to what extent such adjustments consider the prevailing circumstances at each moment, we asked participants to intercept targets that moved at about 60 cm/s to the right across a large 120 Hz display. Rather than moving 10 mm to the right every 8.3 milliseconds, the targets moved in randomly interleaved steps of either 6.7 or 13.3 mm. We compared average movements of the hand on trials that had large or small steps at selected times before the moment of impact. Doing so revealed that at any moment a single different step is enough to elicit a response after about 100 milliseconds. Such responses were more vigorous for times that were closer to the moment of impact. The extent to which they were more vigorous was largely consistent with adjustments being distributed across the remaining time to keep the movement as smooth as possible (minimize jerk). When the remaining time became very short,

the response stopped increasing and participants failed to fully compensate for the different step sizes. Thus, human movements are continuously guided toward their goal on the basis of visual information.

Thursday, August 29, 2019

Talk Session 26

Deep Neural Networks

Abstract Painting Composition: A Deep Learning Model of the Orientation Perception and Judgment

Pierre Lelièvre and Peter Neri
ENS, PSL University, Paris, France

Artistic composition (the structural organization of pictorial elements) is often characterized by some basic rules and heuristics, but art history does not offer quantitative tools, for example, segmenting individual elements and measuring their interactions. To discover whether a metric description of this kind is even possible, we exploit a deep-learning algorithm that attempts to capture the perceptual mechanism underlying composition in humans. We rely on a robust behavioral marker with known relevance to higher level vision: orientation judgments, that is, telling whether a painting is hung "right-side up." Humans can perform this task even for abstract paintings. To account for this finding, existing models rely on arbitrarily selected recognizable content and specific image statistics, often in accordance with explicit rules from art theory. Our approach does not commit to any such assumptions/schemes, yet it outperforms previous models as well as human observers tested in a web-based experiment. It appears that our model captures more compositional regularities than the average human observer. Interestingly, the more abstract the painting, the more our model relies on deeper layers. We attempt to interpret this result via filter visualization techniques that expose the strategy adopted by the model.

Modelling Visual Complexity of Real-World Scenes

Fintan S. Nagle and Nilli Lavie
UCL Institute of Cognitive Neuroscience, London, UK

Visual perceptual load is a well-established determinant of attentional engagement in a task. So far, perceptual load has been typically manipulated by either increasing the number of task-relevant items or the perceptual processing demand (e.g., conjunction vs. feature tasks). The tasks used often involved rather simple visual displays (e.g., letter or single objects). How can perceptual load be operationalised for richer real-world images? A promising proxy is the visual complexity of an image. However, there is a lack of models that predict complexity of diverse real-world images. Here, we modelled visual complexity using a deep convolutional neural network trained to learn human ratings of visual complexity. We presented 53 observers with 4,000 images from the PASCAL VOC data set, obtaining 35,000 two-alternative forced choice paired comparisons across observers. The TrueSkill algorithm was used to obtain image visual complexity scores. Using weights pretrained on an object, recognition task predicted complexity ratings with $r = .83$. In contrast, feature-based models as used in the literature, regressing on image statistics such as entropy, edge density, and JPEG compression ratio, only achieved $r = .62$. Thus, our model offers a promising method to operationalise the perceptual load of real-world scenes through visual complexity.

Do Deep Convolutional Neural Networks Perform Scene Segmentation in a Similar Way Humans Do?

Noor Seijdel[1,2], Nikos Tsakmakidis[3], Edward H. F. de Haan[1,2], Sander M. Bohte[3] and H. Steven Scholte[1,2]
[1]Department of Psychology, University of Amsterdam, the Netherlands
[2]Amsterdam Brain & Cognition Center, University of Amsterdam, the Netherlands
[3]Machine Learning Group, Centrum Wiskunde & Informatica, Amsterdam, the Netherlands

Feedforward deep convolutional neural networks (DCNNs) are matching and even surpassing human performance on object recognition in natural scenes. This performance suggests that activation of a loose collection of image features could support the recognition of natural object categories, without dedicated systems to solve specific visual subtasks. Recent findings in humans, however, suggest that while feedforward activity may suffice for sparse scenes with isolated objects, additional visual operations ("routines") that aid the recognition process (e.g., segmentation or grouping) are needed for more complex scenes. Linking performance of DCNNs with increasing depth to human visual processing, we here explored if, how, and when objects are treated differently than the backgrounds they appear on. To this end, we controlled the information in both objects and backgrounds as well as the relationship between them by adding noise, manipulating background congruence, and systematically occluding parts of the image. Results indicate less distinction between object- and background features for more shallow networks. For those networks, results indicated a

benefit of training on segmented objects (as compared with unsegmented objects). Overall, deeper networks trained on natural (unsegmented) scenes seem to perform implicit "segmentation" of the objects from their background, possibly by improved selection of relevant features.

Deep Neural Networks and Meaning Maps Are Insensitive to Meaning When Predicting Human Fixations During Natural Scene Viewing

Marek A. Pedziwiatr[1], Thomas S. A. Wallis[2,3], Matthias Kümmerer[2] and Christoph Teufel[1]
[1]School of Psychology, Cardiff University, UK
[2]Werner Reichardt Centre for Integrative Neuroscience, University of Tübingen, Germany
[3]Wilhelm-Schickard Institute for Computer Science (Informatik), University of Tübingen, Germany

The hypothesis that human eye movements are guided by the meaningfulness of image regions is receiving growing attention. Key support for this idea comes from Meaning Maps (MMs) in which images are segmented into isolated patches and then crowdsourced judgements about the meaningfulness of these image parts are aggregated. The resulting MMs are thought to capture the distribution of meaning across an image. To test this idea, we compared the performance of MMs in predicting fixations with saliency models that are based on image features rather than meaning and assessed the extent to which MMs are sensitive to changes in meaning. DeepGaze II—a deep neural network trained to predict fixations based on high-level features—outperformed MMs, providing initial evidence to suggest that MMs might not measure meaning. To test this hypothesis experimentally, we assessed whether MMs predict changes in fixations elicited by manipulations of meaning. We used stimuli in which objects were consistent with the scene (e.g., mug in a kitchen) or inconsistent (e.g., toilet roll in a kitchen). Replicating previous findings, observers responded to changes in meaning by fixating more on inconsistent objects. However, both MMs and DeepGaze II were insensitive to these changes in meaning.

Representation of Nonlocal Shape Information in Deep Neural Networks

Shaiyan Keshvari, Ingo Fründ and James H. Elder
Centre for Vision Research, York University, Toronto, Ontario, Canada

It is uncertain how explicitly deep convolutional neural networks (DCNNs) represent shape. While neurons in primate visual areas such as V4 and IT are known to be selective for global shape, some studies suggest that DCNNs rely primarily on local texture cues. Here, we employ a set of novel shape stimuli to explicitly test for the representation of nonlocal shape information in DCNNs. We employ a set of animal silhouettes as well as matched controls generated by two distinct generative models of shape. The first model generates silhouettes that are matched for local curvature statistics, but are otherwise maximally random, containing no global regularities. The second model generates sparse shape components that contain many of the global symmetries seen in animal shapes but are otherwise not identifiable. To assess the selectivity of DCNNs for nonlocal shape information, we train a linear classifier to distinguish animal shapes from control shapes based on the activations in each layer. For both AlexNet and VGG16, discriminability improved monotonically from early to late convolutional layers, reaching 90% to 100% accuracy. These results show that DCNNs do represent nonlocal shape information, that this information becomes more explicit in later layers, and goes beyond simple global geometric regularities.

Learning About Shape, Material, and Illumination by Predicting Videos

Katherine R. Storrs and Roland W. Fleming
Justus-Liebig University Giessen, Germany

Unsupervised deep learning provides a framework for understanding how brains learn rich scene representations without ground-truth world information. We rendered 10,000 videos of irregularly shaped objects moving with random rotational axis, speed, illumination, and reflectance. We trained a recurrent four-layer "PredNet" to predict the next frame in each video. After training, object shape, material, position, and lighting angle could be predicted for new videos by taking linear combinations of unit activations. Representations are hierarchical, with scene properties better estimated from deep than shallow layers (e.g., reflectance can be predicted with $R^2 = .78$ from Layer 4, but only 0.43 from Layer 1). Different properties emerge with different temporal dynamics: Reflectance can be decoded at Frame 1, whereas decoding of object shape and position improve over frames, showing that information is integrated over time to disambiguate scene properties. Visualising single "neurons" revealed selectivity for distal features: A "shadow unit" in Layer 3 responds exclusively to image locations containing the object's shadow, while a "salient feature" unit appears to track high curvature points on the object. Comparing network predictions to human judgments of scene properties reveals they rely on similar image information. Our findings suggest unsupervised objectives lead to representations that are useful for many estimation tasks.

Color Constancy in Deep Neural Networks

Alban Flachot[1], Heiko Schuett[2], Roland W. Fleming[1], Felix A. Wichmann[3,4,5,6] and Karl R. Gegenfurtner[1]
[1]Department of Experimental Psychology, Giessen University, Germany
[2]Center for Neural Science, New York University, NY, USA
[3]Max Planck Institute for Intelligent Systems, Stuttgart, Germany
[4]Neural Information Processing Group, University of Tübingen, Germany
[5]Centre for Integrative Neuroscience, Tübingen, Germany
[6]Bernstein Center for Computational Neuroscience Tübingen

Color constancy is our ability to perceive constant colors across varying illuminations. Here, we trained a deep neural network to be color constant and compared it with humans. We trained a six-layer feedforward network to classify the reflectances of objects. Stimuli consisted of the cone excitations in three-dimensional (3D)-rendered images of 2,115 different 3D shapes, the reflectances of 330 different Munsell chips, and 278 different natural illuminations. One model, Deep65, was trained under a fixed daylight D65 illumination, while DeepCC was trained under varying illuminations. Testing was done with four new illuminants with equally spaced CIELab chormaticities, two along the daylight locus, and two orthogonal to it. We found an average color constancy of 0.69 for DeepCC, and constancy was higher along the daylight locus (0.86 vs. 0.52). When gradually taking cues away from the scene, constancy decreased. For an isolated object on a neutral background, it was close to zero, which was also the level of constancy for Deep65. Within the DeepCC model, constancy gradually increased throughout the network layers. Overall, the DeepCC network shares many similarities to human color constancy. It also provides a platform for detailed comparisons to behavioral experiments.

Similarity Judgments of Hand-Based Actions—From Human Perception to a Computational Model

Paul Hemeren[1], Vipul Nair[1], Elena Nicora[2], Alessia Vignolo[3], Nicoletta Noceti[2], Francesca Odone[2], Francesco Rea[3], Giulio Sandini[3] and Alessandra Sciutti[4]
[1]University of Skövde, Sweden
[2]DIBRIS, University of Genoa, Italy
[3]RBCS Department, Instituto Italiano Di Technologica, Genoa, Italy
[4]Contact Unit, Italian Institute of Technology, Genoa, Italy

How do humans perceive actions in relation to other similar actions? How can we develop artificial systems that can mirror this ability? This research uses human similarity judgments of point-light actions to evaluate the output from different visual computing algorithms for motion understanding, based on movement, spatial features, motion velocity, and curvature. The aim of the research is twofold: (a) to devise algorithms for motion segmentation into action primitives, which can then be used to build hierarchical representations for estimating action similarity and (b) to develop a better understanding of human action categorization in relation to judging action similarity. The long-term goal of the work is to allow an artificial system to recognize similar classes of actions, also across different viewpoints. To this purpose, computational methods for visual action classification are used and then compared with human classification via similarity judgments. Confusion matrices for similarity judgments from these comparisons are assessed for all possible pairs of actions. The preliminary results show some overlap between the outcomes of the two analyses. We discuss the extent of the consistency of the different algorithms with human action categorization as a way to model action perception.

Talk Session 27

Face Processing

Contrast Sensitivity Tuning Function for Rapid Categorization of Natural Face Images

Yu-Fang Yang[1], Joan Liu-Shuang[1], Bruno Rossion[1,2,3,4] and Valerie Goffaux[1,2,5]
[1]Institute of Research in Psychology (IPSY), University of Louvain, Belgium
[2]Institute of Neuroscience, University of Louvain, Belgium
[3]CNRS, CRAN, Université de Lorraine, Nancy, France
[4]CHRU, Université de Lorraine, Nancy, France
[5]Department of Cognitive Neuroscience, Maastricht University, Maastricht, 6229, the Netherlands

How contrast sensitivity, a fundamental low-level visual function, influences human face categorization is not well understood. We investigated the role of contrast on neural face-selective responses using an electroencephalography "sweep" frequency-tagging paradigm. Subjects viewed 1-minute sequences of naturalistic object images presented at a fast 12 Hz rate, with faces interleaved every eighth stimuli (1.5 Hz). Throughout a sequence, stimulus contrast either increased (low-to-high [L to H]) or decreased (high-to-low [H to L]) logarithmically in 14 steps between 0.8% and 100%. Responses at 12 Hz, reflecting general visual processing, emerged over medial-occipital cortex at 3.5% contrast to reach ceiling at 32.8% contrast and did not differ between conditions. However,

responses at 1.5 Hz (and harmonics), indexing generic face categorization located over right occipito-temporal regions, emerged at slightly lower contrast in L to H (7.4%) than their disappearance threshold in H to L (10.8%) sequences. Response saturation occurred at the same 15.6% contrast in both conditions. To summarize, the human brain requires nearly twice as much contrast for rapidly categorizing faces among objects than to merely detect visual stimuli. Yet the small offset between onset and saturation of the neural face-selective response suggests fast and efficient information accumulation for face categorization.

Integration of Spatial Frequency Information in Familiar Face Recognition in a Dynamic Visual Stream

Xiaoqian Yan[1,2], Valérie Goffaux[1] and Bruno Rossion[1,2,3]
[1]Institute of Research in Psychological Science, Institute of Neuroscience, Université de Louvain, Belgium
[2]CNRS, CRAN, Université de Lorraine, Nancy, France
[3]Service de Neurologie, CHRU-Nancy, France

Here we investigated how visual information at different spatial frequencies (SFs) is integrated when recognizing familiar faces in a dynamic stream. Human participants observed 63-second sequences of unfamiliar face images presented at a fast rate of 6 Hz, with different images of different familiar faces embedded every sixth image (1 Hz). Each sequence comprised nine SF steps (from 3 to 40 cycles/image with low-pass Gaussian filter) in two orders: (a) from coarse to fine images and or (b) the reverse. We found different response patterns during two presentation orders. In the coarse-to-fine sequences, the neural responses emerged over the occipito-temporal cortex at around 11 cycles/image (cpi). Response increased and reached to plateau at around 15 cpi. In the fine-to-coarse order, we observed peak responses for faces filtered from 30 to 40 cpi. However, the recognition responses reduced strongly at 11 cpi, to an insignificance level. Our results provide neural threshold consistent with previous observations that a middle SF range (8–16 cpi) is important for face recognition. The lower recognition threshold found in the coarse to fine sequence, compared with the reverse order, supports visual perception theories that the visual system integrates visual input in a coarse-to-fine manner.

Does Holistic Processing Explain Ultra-Rapid Saccades Toward Face Stimuli?

Louise Kauffmann[1,2], Sarah Khazaz[2], Carole Peyrin[2] and Nathalie Guyader[1]
[1]CNRS, Univ. Grenoble Alpes, France
[2]CNRS, LPNC, Univ. Savoie Mont Blanc, Univ. Grenoble Alpes, France

Previous studies have shown that face stimuli influence the programming of eye movements by eliciting extremely fast saccades toward them. This effect would be mediated by rapid processing of their low spatial frequencies. This study further examined whether these effects also reflected a holistic processing of faces. We used a saccadic choice task in which participants ($N = 24$) were presented simultaneously with two images and had to perform a saccade toward the target stimulus (face or vehicle). Stimuli were either upright or upside-down, the latter condition being used to disrupt holistic processing of stimuli. While stimuli inversion generally impaired performances (overall higher error rate and longer latencies of saccades toward the target when stimuli were upside-down than upright), saccades toward face targets were still faster and had lower error rates than saccades toward vehicle targets, irrespective of the inversion condition. Interestingly, Y-ending positions of saccades toward faces (but not vehicles) were flipped upside-down (relative to the center of images) according to the inversion condition suggesting that the same face features were targeted in both conditions. These results suggest that the bias for faces is not entirely explained by their holistic processing and rather relies on the detection of specific features.

Wild Lab—Characterizing Face-Selective ERPs Under More Natural Conditions

Anna Lisa Gert[1], Benedikt V. Ehinger[2], Silja Timm[1], Peter König[1,3] and Tim C. Kietzmann[4]
[1]Osnabrück University, Germany
[2]Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen, the Netherlands
[3]Department of Neurophysiology and Pathophysiology, University Medical Center Hamburg-Eppendorf, Germany
[4]MRC Cognition and Brain Sciences Unit, University of Cambridge, UK

Over more than two decades, neural mechanisms of face processing have been studied in the laboratory using highly constrained experimental conditions. Typical paradigms include passive fixation tasks, randomized image sequences, and adjusted low-level stimulus features. These controls help overcoming technical challenges in subsequent

analyses but at the same time yield paradigms that strongly contrast natural vision. Here, we overcome these limitations by combining a set of novel analysis techniques. We record visually responsive event-related potentials (ERPs) in an unrestricted viewing paradigm, while participants freely explore natural scenes. We use nonlinear deconvolution in a mass-univariate analysis framework to separate neural responses to previous and current fixations as well as other confounding variables. Focusing on fixation-locked ERPs in a 2 × 2 design (previous/current fixation, face/background), we find a main effect of current fixation, reproducing the classic N170. Furthermore, our analyses reveal that fixation responses are strongly modulated by fixation history, in particular by the presence of a previously fixated face. To conclude, we here use a combination of novel analysis techniques to embed the classical N170 paradigm in an ecological more valid experimental setup. Replicating and extending classic laboratory-based findings, this project paves the way for future experimental investigating using more natural, less constrained paradigms.

The Lateral Inferior Occipital Gyrus as a Major Cortical Source of the Face-Evoked N170: Evidence From Simultaneous Scalp and Intracerebral Human Recordings

Corentin Jacques[1], Jacques Jonas[2,3], Louis Maillard[2,3], Sophie Colnat-Coulbois[2,3,4], Laurent Koessler[2,3] and Bruno Rossion[2,3]
[1]Psychological Science Research Institute, UCLouvain, Belgium
[2]CNRS, CRAN UMR 7039, Université de Lorraine, Nancy, France
[3]CHRU-Nancy, Service de Neurologie, Université de Lorraine, France
[4]CHRU-Nancy, Service de Neurochirurgie, Q4 Université, France

The onset of a face image leads to a prominent face-selective response in human scalp electroencephalographic (EEG) recordings at occipital-temporal (OT) scalp sites: the N170. According to a widely held view, the main cortical source generating the N170 lies in the fusiform gyrus (FG), whereas the posteriorly located inferior occipital gyrus (IOG) would rather generate earlier face-selective responses. Here, we report neural responses to faces recorded in an epileptic patient using intracerebral electrodes implanted in the right IOG and above the right lateral FG (LFG). Simultaneous scalp-EEG recording identified the N170 over the right OT scalp region. The latency and amplitude of this scalp N170 were correlated at the single-trial level with the N170 recorded in the lateral IOG, close to the scalp lateral occipital surface. In addition, a positive component maximal around the latency of the N170 was prominent above the LFG, suggesting the field orientation generated in the LFG is incompatible with a strong contribution of this region to the N170 measured over lateral OT scalp. Altogether, these observations provide evidence that the IOG is a major cortical generator of the face-selective scalp N170, questioning a strict postero-anterior spatio-temporal organization of the human cortical face network.

P-Curving the Right Fusiform and Occipital Face Areas: Meta-Analyses Support the Expertise Hypothesis

Edwin James Burns and Cindy Bukach
University of Richmond, VA, USA

This year is the 20th anniversay of the first functional magnetic resonance imaging (MRI) paper that demonstrated nonface expertise effects in the fusiform and occipital face areas (FFA and OFA). Despite many direct and conceptual replications of these effects since, the evidence supporting the expertise hypothesis has been repeatedly criticised as relying upon small sample sizes, small effects, and *p* values close to .05. Moreover, it has been claimed that these studies are difficult to replicate. A modern reader familiar with the replication crisis may therefore question if the expertise effect is just another finding that is based upon problematic data. Recently developed meta-analysis techniques enable researchers to assess the evidential value for any given effect independently of failed replications that are present in the literature. We therefore put the expertise MRI studies to the test by running a series of meta-analyses on the papers that remained eligible after our exclusion criteria. Contrary to the aforementioned criticisms, our results confirmed that that the right FFA and OFA expertise effects are based upon evidential value. We therefore propose a number of suggestions that will improve the replicability of expertise studies and narrow the ideological divide between the modular and expertise hypotheses.

Neural Representation of Social Categories of Familiar Faces in Human Brain

Neda Afzalian[1] and Reza Rajimehr[2]
[1]Institute for Research in Fundamental Sciences, Tehran, Iran
[2]University of Cambridge, UK

Humans are highly social species. For proper interactions in the society, they need to recognize the social status of other people. In this study, we tested whether different subcategories of famous faces (actors, singers, politicians, and football players) could elicit different patterns of activity in visual and semantic regions of human brain. In an

event-related functional magnetic resonance imaging experiment, 40 face stimuli (eight faces from each celebrity group and eight unfamiliar faces) were presented to the subjects. The subjects' task was to report whether the face was matched with a successively presented letter indicating the category of the face. Consistent with previous findings, the univariate comparison between familiar versus unfamiliar faces revealed "familiarity-selective" regions in posterior cingulate cortex (PCC) and isthmus cingulate cortex (ICC). We then performed multivariate pattern analysis in PCC, ICC, face-selective areas, and early visual cortex. PCC showed the highest decoding performance in classification of familiar face categories. A searchlight analysis confirmed that PCC contained the most separable representations of these categories. Thus, the categorical information related to social classes of familiar faces could be decoded from the pattern of activity in a specific region of brain, which is typically involved in coding semantic (rather than visual) aspects of faces.

Prior Entry of Self-Faces: Dissociating Effect of Familiarity and Self-Reference

Aditi Jublie and Devpriya Kumar
Indian Institute of Technology Kanpur, India

Previous research has shown that self-related stimuli such as self-name receives attentional processing advantage. Similar questions have been asked regarding the processing of self-face, but the results are not conclusive. Although many studies show advantage in processing of self-face, there is lack of consensus regarding the stage at which self-faces modulate attentional processing. We investigated whether or not self-faces capture attention, and if the attentional advantage for self-face can be explained using confounds such as familiarity. We asked participants to perform temporal order judgment for two faces presented at different onset asynchronies on left and right side of a fixation cross. We manipulated the pair of faces presented (self-friend, self-stranger, and friend-stranger) and calculated point of subjective simultaneity. Results indicate that participants perceived their own face earlier compared with friend (15.9 milliseconds) and stranger (8.3 milliseconds). Study suggests that self-referentiality of a face results in an advantage in terms of attentional capture and that this advantage can be dissociated from effects of familiarity.

Talk Session 28

Retina, Visual Field, Eccentricity

The Regularity of Cat Beta Cell Dendritic Arrays Across the Retina

John Troy and Xue Zhan
Northwestern University, Evanston, IL, USA

Arrays of cat alpha and cat beta cell somata and, to a lesser extent, of cat alpha and cat beta cell dendritic field arrays laid the foundation of our understanding of regularity in retinal ganglion cell spacing. This work resulted from studies of cell mosaics taken from peripheral retina where the somata of these cells form a single layer. In central retina where cell bodies stack, it has been considerably more difficult to quantify spacing regularity. Here, we report on results we have obtained by looking at small arrays of OFF and of ON beta cell dendritic fields located at a range of retinal eccentricities. The arrays of dendritic fields are as regular and generally more regular than those of their corresponding somata at all eccentricities with the most significant improvement evident for central arrays. These data indicate that regularity based on soma location is likely to underestimate that which applies for dendritic and, by inference, receptive fields. Quantitative models of retinal sampling if based on the regularity of soma arrays should therefore be adjusted to assume a somewhat more regular pattern.

Naso-Temporal Division of Retinal Ganglion Cells Is Adapted to Natural Binocular Disparities

Agostino Gibaldi and Martin S. Banks
School of Optometry and Vision Science, University of California at Berkeley, CA, USA

In primates with binocular vision, ganglion cells from nasal retina project to contralateral brain, and those from temporal retina to ipsilateral. If the division were nonoverlapping along the vertical meridians, stimuli above and below the foveas would send signals to opposite hemispheres, making disparity estimation difficult. In macaques, the division is actually overlapping near the vertical meridians and overlap expands with eccentricity. It is biased toward crossed disparities in the lower visual field (not known in the upper). Would a similar overlap in humans ensure that common disparities project to the same hemisphere? Using an eye tracker and stereocamera, we measured everyday disparities in humans. The most likely disparities

near the vertical meridian are uncrossed in the upper field and crossed in the lower. Bias and variance increase with eccentricity. If we assume human and macaque overlaps are the same size and are symmetric in the two eyes, ∼80% of observed disparities would send signals to the same hemisphere. If we assume the same size, but asymmetry as in macaque's lower field, the number increases to ∼90%. Thus, nasal-temporal overlap of retinal-cortical projections ensures that common disparities are routed to the same hemisphere, thereby aiding disparity estimation.

The Temporal Margin of the Visual Field

John Mollon[1], Peter Vetö[1], Philip Alexander[2] and Peter B. M. Thomas[3]
[1]University of Cambridge, UK
[2]Addenbrooke's Hospital, Cambridge, UK
[3]Moorfields Eye Hospital, London, UK

The extreme periphery of the retina is little studied and yet is functionally important—in the maintenance of balance and in the detection of threats from behind us. The temporal margin of the visual field lies as much as 90° from the line of sight, but estimates in the literature vary, and the extent of individual differences is unknown. We set out to design a protocol that gives a reliable and precise estimate for untrained subjects. As only moving stimuli of low spatial frequency are visible in the far periphery, we used a vertically oriented Gabor stimulus of 0.55 c/deg. The envelope of the Gabor was fixed in position on a given trial, but its grating component moved, with random direction and starting phase; and observers were asked to make a forced-choice judgement of the direction of motion. Observers' fixation and pupil diameter were concurrently monitored. For a group of 18 healthy young adults, the test–retest reliability after a minimum interval of 5 days was high: $r = .85$, $p = .0001$. The mean threshold eccentricity was close to 90°, but there was a range of 10° among observers.
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fMRI Investigation of the Central–Peripheral Difference Along the Human Cortical Visual Pathway for Depth Perception of Correlated and Anticorrelated Random-Dot Stereograms

Li Zhaoping[1], Pablo Grassi[2], Michael Erb[2], Klaus Scheffler[1] and Andreas Bartels[2]
[1]Max Planck Institute for Biological Cybernetics, University of Tuebingen, Germany
[2]University of Tübingen, Germany

In a random-dot stereogram (RDS), the percept of object surfaces in a three-dimensional scene is generated by images presented to the left and right eyes that comprise interocularly corresponding random black and white dots. The spatial disparities between the corresponding dots determine the depths of object surfaces. If the dots are anticorrelated, such that a black dot in one monocular image corresponds to a white dot in the other, disparity tuned neurons in the primary visual cortex (V1) respond as if their preferred disparities become nonpreferred and vice versa, thereby reversing the disparity signs reported to higher visual areas. In central vision fields, humans have great difficulty perceiving the reversed, or any, depth in an anticorrelated RDS. Zhaoping and Ackermann (2018) showed that in peripheral vision, the reversed depth can be perceived, confirming a prediction (Zhaoping, 2017) that feedback from higher visual areas to V1, for analysis-by-synthesis to aid recognition, is weaker or absent peripherally for vetoing the feedforward "fake-news" in anticorrelated RDSs which violate internal knowledges about the visual world. In this study, we use functional magnetic resoncnce imaging (fMRI) to measure brain responses to such stereograms across the visual hierarchy to examine the neural correlates of the central–peripheral dichotomy in visual inference.

The Anisotropic Space of Integration in Ensemble Coding

David Pascucci[1], Nadia Ruethemann[1,2] and Gijs Plomp[1]
[1]University of Fribourg, Switzerland
[2]University of Zurich, Switzerland

Human observers can accurately estimate statistical summaries from an ensemble of multiple stimuli, including the average size, hue, and direction of motion. The efficiency and speed with which statistical summaries are extracted suggest an automatic mechanism of ensemble coding that operates beyond the capacity limits of attention and memory. However, the extent to which ensemble coding reflects a truly parallel and holistic mode of processing or a

nonuniform and biased integration of multiple items is still under debate. In this work, we used a new technique, based on a Spatial Weighted Average Model (SWAM), to recover the spatial profile of weights with which individual stimuli contribute to the estimated average during mean size adjustment tasks. In a series of experiments, we derived two-dimensional SWAM maps for ensembles presented at different retinal locations, with different degrees of dispersion and under different attentional demands. Our findings revealed strong spatial anisotropies and left-side biases in ensemble coding that were organized in retinotopic reference frames and persisted under attentional manipulations. These results demonstrate an anisotropic spatial contribution to ensemble coding that could be mediated by the differential activation of the two hemispheres during spatial processing and scene encoding.

No Help for Lost Lines: Redundancy Masking Is Strong Under Focused and Diffuse Attention

Fazilet Zeynep Yildirim[1], Daniel R. Coates[1,2] and Bilge Sayim[1,3]
[1]Institute of Psychology, University of Bern, Switzerland
[2]College of Optometry, University of Houston, TX, USA
[3]SCALab—Sciences Cognitives et Sciences Affectives, CNRS, UMR 9193, University of Lille, France

Redundancy masking is the phenomenon that the number of (as few as three) repeating items in peripheral vision is underestimated. Here, we investigated the role of attention in redundancy masking. Stimuli consisted of three to seven radially arranged lines, presented in one of the eight locations at 10° eccentricity around fixation (in cardinal and intercardinal directions). There were three attentional cue conditions: valid (an arrow precue indicated the target location), ambivalent (two positions with equal target probability were precued), and uncued (no cue was presented). The task was to indicate the number of lines. The perceived number of lines was reduced compared with the presented number of lines in all three cue conditions. Redundancy masking did not differ between the three conditions, but there was a trend for weaker redundancy masking in the valid compared with the other two conditions, indicating a subtle reduction of masking when the target location was known. Overall, our results show that redundancy masking is strong under focused and diffuse attention, suggesting that attentional deployment does not play a decisive role for the underestimation of the number of repeating items in peripheral vision.

What Dyslexics See: Excessive Information Loss Characterizes Peripheral Appearance in Dyslexia

Natalia Melnik[1], Daniel R. Coates[1,2] and Bilge Sayim[1,3]
[1]Institute of Psychology, University of Bern, Switzerland
[2]College of Optometry, University of Houston, TX, USA
[3]SCALab—Sciences Cognitives et Sciences Affectives, CNRS, UMR 9193, University of Lille, France

It has been shown that the peripheral vision of dyslexic readers differs from that of nondyslexics. In particular, crowding, the deterioration of target identification by clutter, has been shown to be stronger in dyslexia. However, to date, it is unclear to what extent target appearance systematically differs between the two groups. Here, we captured the peripheral appearance of letters and letter-like shapes in dyslexic and nondyslexic adults. Singleton and crowded targets were presented at 10° eccentricity. The task was to reproduce the target's peripheral appearance by connecting points on a foveally viewed grid. We analyzed differences between the targets and the responses by quantifying deviations of the depicted from the presented elements. Overall, accuracy was higher with singletons compared with crowded targets, and with letters compared with letter-like targets. Importantly, dyslexics made more line omission errors compared with nondyslexics with letter-like targets. There was no difference between dyslexics and nondyslexics with letter targets. Our results indicate that peripheral appearance in dyslexic readers is characterized by an excessive loss of elements. We suggest that the systematic capture of appearance in dyslexics sheds light on visual factors related to poor reading in dyslexia.

Waiting for Carrasco: Assessing Processing Speeds Across Eccentricities

Rama Chakravarthi
University of Aberdeen, UK

The visual periphery fares worse than the fovea and parafovea according to most measures. However, a set of studies (Carrasco et al., 2003, 2006) made the startling claim that (orientation) processing in the periphery (9°) was faster than in the parafovea (4°) by ∼90 milliseconds, a substantial difference. This difference persisted despite changes in task difficulty or attention. We investigated the prevalence and generality of this finding in five experiments that probed the visual system at different levels of processing. We evaluated processing speeds across eccentricities using (a) temporal order judgment (TOJ), (b) orientation discrimination, (c) visual search, (d) flash-lag, and (e) feature-binding tasks. We found no evidence of faster peripheral processing in the TOJ, flash-lag, and feature-binding tasks. Drift diffusion modelling (DDM) of responses in the visual search task

corroborated these findings by showing that the rate of evidence accumulation did not differ across eccentricities. However, DDM of responses in the orientation discrimination task provided partial support for faster peripheral processing. These results suggest that the peripheral superiority might be present under very limited circumstances. The periphery appears to process various kinds of stimuli at a rate comparable to that of the parafovea.

Talk Session 29

Eye Movements

Accommodation Corrections Following Microsaccades During Fixation

Josselin Gautier, Harold Bedell and Clifton Schor
University of Berkeley, CA, USA

In this study, we simultaneously recorded fixational eye movements and accommodation. Ten subjects fixated a polychromatic Maltese cross for 10 seconds at three viewing distances (0, 2, and 5D). Accommodation was recorded from the RE with a PowerRef II (25 Hz) synchronized to an Eyelink 1000 Plus (500 Hz) that recorded LE vertical and horizontal position. After microsaccade onset, median accommodation corrections (across subjects and trials) lasting approximately 100 milliseconds occurred at 120 milliseconds when the accommodative error was negative, and at 260 milliseconds when accommodative error was positive. The velocity of error corrections (lasting $<$100 milliseconds) was higher following microsaccades in all directions for 7 of the 10 subjects compared with when there were no saccades. The corollary is that when microsaccades occurred there was significantly faster accommodation changes in the corrective than error-producing direction. Microsaccades appear to participate in the fine adjustment of blur-driven accommodation during fixation. Omnipause neurons associated with saccades may trigger higher velocity accommodation.

Microsaccade Inhibition as an Indicator of Visual Resolution

Stefan F. Nüesch and Sven P. Heinrich
University of Freiburg, Germany

Perception of a visual stimulus is typically followed by an inhibition of microsaccades. This study was designed to evaluate the feasibility of using microsaccade inhibition as tool for objective testing of visual acuity, that is, whether microsaccade inhibition can be used as a correlate of stimulus perception that indicates whether the visual system is able to resolve (and thus perceive) a given stimulus. We presented sinusoidal gratings of five different spatial frequencies to 18 normally sighted participants and measured fixational eye movements. In one condition, all gratings were easily visible. In a second condition, reduced acuity was simulated by placing a blurring filter in front of the stimulus monitor. This made the finer gratings invisible. For validation purposes, participants pressed a key whenever they had perceived a stimulus. Statistical significance of microsaccade inhibition was established by applying a resampling test to fixed time intervals. In 15 of the 18 participants, significant microsaccade inhibition closely mirrored stimulus perception with simulated reduction of acuity. A more flexible analysis approach will allow for avoiding confounding factors and further improve performance. In summary, microsaccade inhibition is a promising marker of stimulus perception for use in objective testing of visual acuity.

Visual Closed-Loop Dynamics via Ocular Drift

Liron Zipora Gruber and Ehud Ahissar
Weizmann Institute of Science, Rehovot, Israel

The human visual system perceives its environment via eye movements, which are typically classified as saccades and drifts. Saccades are quick transitions of the gaze from one region of interest (ROI) to another and drifts are slower scanning motions in each ROI. Here, we examine two contrasting schemes of perception via these ocular movements: an open-loop computational and a closed-loop dynamical scheme. The two schemes entail contrasting predictions, specifically regarding the kinematics of ocular drifts and their dependency on concurrent visual inputs. We have thus designed an experiment in which measuring ocular kinematics while modulating the available visual information (controlled by image size and by a gaze-contingent display) can discriminate between the two schemes. Our results reveal that vision is a closed-loop dynamic process. This is demonstrated by (a) a dependency of the drift trajectory on the concurrent visual input, (b) condition-specific convergence of the drift speed within $<$100 milliseconds (c) periodic drift kinematics around 10 Hz, and (d) maintenance of selected motor-sensory "controlled variables." As these dynamics cannot be accounted for by an open-loop visual scheme, our results suggest that vision is inherently a closed-loop process, which dynamically and continuously links the brain to its environment.

Trans-Saccadic Updating of Spatial Attention: Classification Images and Generative Model Comparisons

William J. Harrison[1], Imogen Stead[1], Thomas S. A. Wallis[2,3], Peter J. Bex[4] and Jason B. Mattingley[1,5]
[1]Queensland Brain Institute, The University of Queensland, Brisbane, Australia
[2]Werner Reichardt Center for Integrative Neuroscience, Eberhard Karls Universität Tübingen, Germany
[3]Bernstein Center for Computational Neuroscience, Tübingen, Germany
[4]Department of Psychology, Northeastern University, Boston, MA, USA
[5]School of Psychology, The University Of Queensland

There are well-documented but poorly understood changes in the allocation of spatial attention across saccadic eye movements. We distinguished models of dynamic trans-saccadic attentional allocation using a large-field classification image task and analysis. An observer's task was to make a saccade and report the polarity of a target bar. The display consisted of a 13 × 13 grid (cell width = 2.3°) of potential saccade target locations and separate perceptual target locations. Prior to the start of each trial, the saccade target and perceptual target locations were cued. The target duration was 17 milliseconds, with a random onset time during each one second trial, requiring observers to attend to the cued location throughout each trial and saccade. Within each cell, we displayed 9 × 9 "superpixels" of dynamic Gaussian noise (60 Hz; contrast S.D. = 12.5%) and fit temporally varying template-matching models of trans-saccadic updating to our data set (84,000 trials). A presaccadic remapping model and a competing spatial-convergence model both predict large spatial shifts in the attentional template location prior to saccadic onset, which were not observed. The best-fitting model for each observer was one in which the attentional template shifts only after the saccade, consistent with a rapid postsaccadic redeployment of attention.

Trans-Saccadic Perceptual Learning of Orientation Discrimination Is Location Unspecific

Lukasz Grzeczkowski and Heiner Deubel
Ludwig-Maximilian University of Munich, Germany

Visual perceptual learning (VPL) is the ability to improve perception through practice. Usually, VPL is specific for stimulus properties such as orientation and location. For example, training in discriminating Gabors' orientation does not improve Gabor orientation discrimination at untrained locations. VPL is mostly studied during fixation. However, in everyday life, a given stimulus is actively explored through eye movements, resulting in successive projections of that stimulus at different retinal locations. Here, we studied VPL of orientation change discrimination across saccades. In our experiment, during training, observers saccaded to the peripheral grating and discriminated the orientation change occurring during the saccade. Before and after training, observers were tested with the same task but with an orthogonal orientation at the trained location, and the trained orientation at an untrained location. Interestingly, we found trans-saccadic VPL for orientation change discrimination. VPL did not transfer to the untrained orientation. Surprisingly, however, we found transfer to the untrained location. In addition, performance was also improved in a fixation condition at the trained location tested in the periphery. We propose that VPL within an active perception framework might reflect mechanisms different from classic perceptual learning.

Mind the Eye: Confounding Eye Movements in Cognitive Neuroscience

Jordy Thielen[1,2], Sander Bosch[1,2], Tessa van Leeuwen[1,2], Marcel van Gerven[1,2] and Rob van Lier[1,2]
[1]Radboud University, Nijmegen, the Netherlands
[2]Donders Institute for Brain, Cognition and Behaviour, Nijmegen, the Netherlands

Already more than a decade ago, it was shown that stimulus orientation could be predicted from brain activity obtained by functional magnetic resonance imaging. However, even today, the neural mechanisms involved remain a point of discussion. Here, we investigated whether (fixational) eye movements and pupil dilation could explain orientation decoding. Participants' eye movements and pupil dilation were recorded, while they perceived orientated square-wave gratings under attempted fixation. Participants performed both a passive and an active session. In the passive session, participants were asked to passively view the stimuli, whereas in the active session, participants actively monitored the stimuli to detect infrequent and small deviations of the orientation. For both sessions, we trained a linear support vector machine to predict the stimulus orientations from eye movements. Our results show a clear effect of task instruction on decoding accuracy. In line with previous results, there was no evidence of systematic eye movements in the passive session as no decoding of stimulus orientation was possible. Instead, in the active session, orientation decoding was significantly higher than chance. This suggests that under specific task requirements, stimulus-dependent eye movements occur. Such eye movements form an important confound in neuroimaging studies using decoding across cognitive neuroscience.

Talk Session 30

Perceptual Organization

Gaze Adaptation Induced by the Bloodshot Illusion

Yumiko Otsuka[1], Colin Palmer[2], Katsumi Watanabe[3] and Colin Clifford[2]
[1]Ehime University, Matsuyama, Japan
[2]UNSW Sydney, Australia
[3]Waseda University, Tokyo, Japan

We examined the effect of adaptation to faces that evoke the bloodshot illusion (Ando, 2002, 2004), in which darkening of one side of the sclera induces a shift in the perceived gaze direction of the face toward the darker side. Twenty-four Japanese participants performed tasks measuring the magnitude of the illusion as well as an adaptation task. In the adaptation task, participants adapted either to the bloodshot illusion faces with 0° eye deviation or to normal faces with 25° eye deviation. We found that gaze aftereffects occurred in a manner consistent with adaptation to the illusory direction of gaze of the bloodshot illusion faces rather than their veridical 0° gaze, though the aftereffect magnitude was significantly smaller following adaptation to the bloodshot illusion faces compared with normal faces. Simulation analysis using a gaze adaptation model by Palmer and Clifford (2017) revealed that the aftereffect induced by the bloodshot illusion faces was greater than what would be expected from the measured magnitude of the illusion. Our results suggest that the gaze aftereffect reflects not only adaptation of high-level perceptual representations as previously shown (Palmer & Clifford, 2018) but also involves some adaptation of luminance mechanisms specialized for eye gaze perception.

A Compound Computational Model for Filling-In Processes Triggered by Edges: Watercolor and Alternating Afterimage Illusions

Hadar Cohen-Duwek and Hedva Spitzer
School of Electrical Engineering, Tel-Aviv University, Israel

The research goal was to offer a compound computational model that predicts filling-in effects that are triggered by edges. These effects can be simultaneous effects, for example, the assimilative and the nonassimilative watercolor effects, or they can be temporally alternating effects, for example, "filling in the afterimage after the image" and the "color dove illusion." The computational model is based on a filling-in mechanism, through the Poisson equation, where the color and intensity of the perceived surface are obtained through a filling-in process of color from the stimulus edges. The stimulus edges are calculated through oriented double opponent receptive fields and are applied as "heat source" to the Poisson equation. In the simultaneous effects, the modified stimulus gradients trigger the filling-in process, while in the alternating effects, the remaining contours play a role as a trigger for the filling-in process. Consequently, the same filling-in process has been applied for both the simultaneous and the alternating effects. In summary, our proposed computational model is able to predict most of the "conflicting" filling-in effects that derive from edges and thus supports the hypothesis that a shared visual mechanism is responsible for the vast variety of the "conflicting" filling-in effects that derive from edges.

Evidence of Independent Symmetry Representations in the Extrastriate Cortex From a Sequential Presentation Paradigm

Alexis David James Makin, Giulia Rampone, Yiovanna Derpsch and Marco Bertamini
University of Liverpool, UK

Psychophysical work has examined many questions about symmetry perception and its role in perceptual organisation. We also know that all types of symmetry activate a network of extrastriate regions and generate an event-related potential component called Sustained Posterior Negativity (SPN). However, it is unclear whether different symmetry types are coded by different neural mechanisms with these regions. We addressed this question with a novel sequential presentation paradigm. Experiment 1 found that sequential presentation of three reflectional symmetries lead to an increase in SPN amplitude. We term this increase SPN priming. Subsequent experiments replicated SPN priming but found that it did not transfer across unpredictable changes in axis orientation, retinal location, or symmetry type. However, SPN priming did survive orthogonal changes in axis orientation (i.e., horizontal to vertical or vice versa). This confirms the special relationship between orthogonal axes. We suggest that independent representations of symmetry are coded by independent integration mechanisms in the extrastriate cortex.

The Neural Response to Visual Symmetry Is Not Modulated by Visuospatial Attention

Yiovanna Derpsch, Giulia Rampone, Marco Bertamini and Alexis Makin
University of Liverpool, UK

Symmetry detection is effortlessly and fast, even within brief presentations of less than 100 milliseconds. Electroencephalographic studies have shown that the brain response to symmetry is automatic and not altered by participant's task. However, no studies have yet tested whether the symmetry response is altered by the current focus of spatial attention. We adapted the cueing paradigm (Posner, 1980) and recorded a symmetry-related event-related potential known as the sustained posterior negativity (SPN) which is relatively negative for symmetrical compared with random patterns at posterior electrodes. We predicted a stronger SPN when patterns would appear at the attended location than at the unattended location. Forty-eight participants discriminated symmetrical and random-dot patterns that were cued by an endogenous cue (arrow) presented at fixation. To control for covert attention, fixation, measured with an eye-tracking device, was maintained while patterns were presented to both the left and right side of fixation for 1,000 milliseconds. Surprisingly, we found that the SPN amplitude was independent of spatial attention, not changing significantly depending on whether symmetric patterns appeared in a cued or uncued location. This reinforces the understanding of the neural response to symmetry as automatic and stimulus-driven, unchanged by either task or spatial attention.

An Ideal Observer Model for Grouping and Contour Integration in Natural Images

Jonathan Vacher[1], Pascal Mamassian[2] and Ruben Coen-Cagli[1]
[1]Albert Einstein College of Medicine, New York, NY, USA
[2]Ecole Normal Supérieure, Paris, France

Spatial context in images modulates visual perception reflecting optimization to the statistics of natural images. Popular models based on divisive normalization (ratio between target and context features) offer a link between optimal coding principles and contextual modulation in cortex. Here, we apply this framework to perceptual grouping in natural images and more specifically to contour integration. First, we show that a successful model of image statistics based on normalization (termed Gaussian Scale Mixture [GSM]) learns dependencies between colinear features in natural images. We then show analytically that image regions with strong normalization are statistical outliers of the model and use this insight to distinguish high-salience regions due to high contrast from those corresponding to contours. To this aim, we extend the model to a mixture of GSMs, with each component encoding a specific orientation and curvature. Our model performs competitively on contour detection in natural images from the BSD500 database. We further evaluate our model by comparing its performance on iso-oriented Gabor elements embedded in Gabor noise ("snakes") to the psychophysics literature. Our model thus serves as an ideal observer for contour integration and a basis for future experiments on natural image segmentation.

Predicting the Design of Salient Features in Natural Environments

Olivier Penacchio[1], Christina G. Halpin[2], Matthew Wheelwright[2], John Skelhorn[2], P. George Lovell[3], Innes C. Cuthill[4], Candy Rowe[2] and Julie M. Harris[1]
[1]School of Psychology and Neuroscience, University of St Andrews, UK
[2]Institute of Neuroscience, Newcastle University, UK
[3]Division of Psychology, University of Abertay, Dundee, UK
[4]School of Biological Sciences, University of Bristol, UK

One of the strategies for the visual system to cope with the wealth of visual information it is exposed to is to deploy involuntary attention toward salient objects. Here, we aimed to understand what visual features are particularly salient in natural environments starting from the hypothesis that the process that delivers perceptual salience is maximal stimulation of neurons. We posited that visual features that elicit strong activity in the visual system are likely to be salient in natural environments. We developed a model visual system optimized to process natural images efficiently—that is, with reduced metabolism-, with V1-like receptive fields, and divisive normalization. We first tested our hypothesis using the tractable system of animal warning signals, an important type of defensive coloration whereby toxic species use conspicuousness to advertise their unprofitability. Warning signals from known unprofitable *Lepidoptera* species were associated with stronger model activity than colorations of undefended species or natural images. We next explored the predictive power of the hypothesis using a generative model to develop stimuli optimized to elicit the strongest activity possible in the model visual system. Patterns that emerged are reminiscent of classes of stimuli widespread in animal warning signals and recognized in vision science as causing visual distress.

Talk Session 31

Luminance, Flicker, Contrast

Theory Versus Data: The Empirical Characteristics of Human Pattern Vision Defy Theoretically Driven Expectations

Peter Neri
École Normale Supérieure, Paris, France

We can view cortex from two fundamentally different perspectives: a powerful device for performing optimal inference or an assembly of biological components not built for achieving statistical optimality. The former approach is attractive thanks to its elegance and potentially wide applicability; however, the basic facts of human pattern vision do not support it. We demonstrate this statement with relation to the most fundamental property of images: contrast. Current theories predict that vision should become broader (more low pass) at low contrast to protect from noise. We find that the opposite is true for human discrimination of elementary image elements, urging caution when attempting to interpret human vision from the standpoint of optimality and related theoretical constructs. Our direct measurements of this phenomenon indicate that the actual constraints derive from intrinsic architectural features, such as the coexistence of complex-cell-like and simple-cell-like components. Small circuits built around these elements can indeed account for the empirical results but do not appear to operate in a manner that conforms to optimality even approximately. We conclude that current theories of visually guided behaviour are at best inadequate, calling for a rebalanced view of the roles played by theoretical and experimental thinking about this function.

SSVEP Correlates of Luminance Contrast Perception

Laysa Hedjar[1], Jasna Martinovic[2], Soren Andersen[2] and Arthur G. Shapiro[1]
[1]American University, Washington, DC, USA
[2]University of Aberdeen, UK

In the contrast asynchrony paradigm, the luminance levels of two identical patches modulate together over time (i.e., dark, bright, dark, bright, . . .): one patch is surrounded by a bright field and the other is surrounded by a dark field. Previous studies have shown that observers perceive the patches to modulate in antiphase, corresponding to the alternation of the contrast between patch and the respective surrounds, yet also acknowledge that both patches get bright and dark at the same time, corresponding to the in-sync luminance modulation of the patches. Our aim was to link perceptual phenomena with steady-state visual-evoked potentials (SSVEPs) with the hope of identifying specific contrast and luminance signals. Our adaptation of this paradigm displays eight circles modulating sinusoidally from dark to bright on one of the three backgrounds (bright, midgray, and dark). Circle modulation (and backgrounds) for the first experiment spanned a large range (0–64 cd/m^2) at three frequencies (3, 5, and 7.14 Hz); for the second experiment, modulation range (30–34 cd/m^2) was reduced to levels no greater than VEP saturation (Weber contrast 15.5%) to see whether we would get similar results. With lower modulation, SSVEP amplitudes and phases correspond to the temporal signatures of contrast—not luminance—modulation.

Critical Flicker Fusion at Ultra-High Luminance: Beyond the Ferry-Porter Law

Maydel Fernandez-Alonso, Jenny Read and Christos Kaspiris-Rousellis
Institute of Neuroscience, Newcastle University, UK

The relationship between luminous intensity and the maximum frequency of flicker that can be detected defines the limits of the temporal-resolving ability of the human visual system. Characterizing this relationship has important theoretical and practical applications and it is best described by the Ferry-Porter law, which states that critical flicker fusion (CFF) increases as a linear function of log retinal illuminance. This law has been shown to hold for a wide range of stimulus over four orders of magnitude; however, beyond this, it is unknown if the CFF continues to increase linearly. We determined the flicker fusion threshold for five participants over six orders of magnitude at 35° eccentricity. Our results show that up to 104 Trolands, the data conform to the Ferry-Porter law with a similar slope as previously established for this eccentricity (22 Hz/decade) and a maximum average threshold of 77 Hz (±5 Hz); however, beyond this value and up to 106 Trolands, the CFF function flattens with a slope that falls within the error of the measurements (4 Hz/decade). We conclude that for 35° eccentricity the Ferry-Porter law holds over four orders of magnitudes, after which point, saturation is reached and the time constant no longer decreases with increasing luminous intensity.

Correlates in Visual Cortex of Pupil Constriction to Visual Change (But Not to Luminance)

Sebastiaan Mathôt[1] and Michael Hanke[2,3]
[1]Department of Psychology, University of Groningen, the Netherlands
[2]Research Center Jülich, Institute of Neuroscience and Medicine Brain and Behaviour (INM-7), Germany
[3]Institute of Systems Neuroscience, Heinrich Heine University Düsseldorf, Germany

The pupil constricts in response to motion, color change, or more generally to any change in visual input. This happens even when luminance remains constant, and pupil constriction to visual change is therefore distinct from the pupil light response. Pupil constriction to visual change is reduced after lesions to visual cortex, suggesting that it is mediated by a cortical pathway. However, this has so far not been directly studied. Here, we analyzed pupil size, eye movements, and functional magnetic resonance imaging data, recorded during unconstrained movie viewing (from http://studyforrest.org/). We found that visual-cortex activity was negatively correlated with pupil size, consistent with the notion that pupil constriction to visual change is mediated by visual cortex. This relationship was similar throughout visual areas (V1, V2, V3, and V4) and did not markedly depend on the population receptive field properties of the voxels. Crucially, the relationship was not driven by luminance of visual input (although luminance did strongly affect pupil size, likely through a different, subcortical pathway). Taken together, our results provide crucial support for the notion that pupil constriction to visual change is associated with activity in visual cortex, and that this response is distinct from the pupil light response.

Characterizing How Attention Alters Contrast Appearance Using Reverse Correlation

Antoine Barbot[1,2], Lucas Huszar[1] and Marisa Carrasco[1,2]
[1]Department of Psychology, New York University, NY, USA
[2]Center for Neural Science, New York University, NY, USA

Attention enhances contrast appearance, but the underlying mechanisms mediating these phenomenological changes are unclear. Using psychophysical reverse correlation, we assessed whether and how differences in energy sensitivity with exogenous (involuntary) attention mediate changes in perceived contrast. On each trial, two tilted Gabors embedded in Gaussian noise were presented simultaneously. The standard patch's contrast was 40%; the test patch's contrast varied (8%–100%). Participant reported the orientation of the higher contrast Gabor, while the test, standard, or both stimuli were cued. For each cueing condition, we computed the proportion of trials in which the test patch was reported as higher contrast and estimated the point of subjective equality (PSE). Using reverse correlation, we assessed whether and how signal-like fluctuations in noise predict observers' trial-to-trial variability in perceived contrast judgments. Cueing a stimulus enhanced its perceived contrast (reduced PSE). Attention increased energy sensitivity at the attended location via gain enhancement for both appearance and orientation discrimination judgments. Moreover, attention increased sensitivity to the energy difference between the two patches via an input-baseline shift. PSE changes correlated with both gain enhancement and input-baseline shifts. These results reveal how attentional changes in visual representation underlie perceptual changes in performance and appearance.

Neurocomputational Model of the Staircase-Gelb and Scrambled-Gelb Effects

Michael Rudd
University of Washington, Seatle, WA, USA

In the staircase-Gelb experiment (Cataliotti & Gilchrist, 1995), a series of papers is arranged in a spotlight from darkest to lightest. Observers judge the paper lightnesses with a Munsell match. Zavagno, Annan, and Caputo (2004) replicated this experiment and added conditions in which the paper order was spatially scrambled, which altered the matches. These experiments together reveal the existence of systematic distortions in the physical-to-perceptual reflectance mapping that are important to understanding lightness scaling. I here explain the patterns of lightness matches produced in these experiments with a neurocomputational model that sums weighted steps in log luminance at borders to compute surface lightness (Rudd, 2013, 2017, submitted). Luminance ratios at borders are first neurally encoded by ON- and OFF-cells having different response compression properties. The ON- and OFF-outputs are then log transformed and used to construct border signals that, in turn, drive a cortical filling-in of surface lightness. The model provides a simple quantitative explanation of lightness scaling in the staircase- and scrambled-Gelb experiments, and it challenges the standard interpretation of the Gelb effect in terms of lightness anchoring theory (Gilchrist et al., 1999), a theory based on concepts derived from Gestalt psychology (e.g., grouping by illumination).

Talk Session 32

Statistical Regularities

Statistical Regularities Across Trials Bias Attentional Selection

Jan Theeuwes and Aisu Li
Vrije Universiteit Amsterdam, the Netherlands

We demonstrated that through statistical learning, observers learn to activate a location that is likely to contain a target and suppress a location that is likely to contain a distractor (Wang & Theeuwes, 2018a,b). We also showed that even when these locations changed during the course of the experiment, participants learn this quickly and adapt their selection priorities. Here, we want to determine whether it is possible to learn sequential regularities (transitional relationships) between selection episodes. We used the additional singleton paradigm in which participates search for a diamond between circles (or vice versa). From trial to trial, the target appeared randomly at any of the eight locations, yet particular transitions between trials were built in: If the target appeared in one location in one trial, it would consistently appear at another location on the next trial (say if the target is at the top, it is at the bottom on the next trial). We show that observers learn these transitions when it concerns the target, if similar transitions are built in for search displays in which a distractor is present reduced learning is seen. These findings have important implications for theories of visual selection.

Testing the Temporal Integration of Information From Visual Ensembles: How Variance Modulates Recency Effects

Ömer Dağlar Tanrıkulu[1], Andrey Chetverikov[2,3] and Árni Kristjánsson[1]
[1]School of Health Sciences, University of Iceland, Reykjavik, Iceland
[2]Donders Institute for Brain, Cognition, and Behavior, Nijmegen, the Netherlands
[3]Radboud University, Nijmegen, the Netherlands

Integration of individual visual items into ensembles has been well studied; however, little is known about how different ensembles are integrated. If such integration is optimal, we can expect observers to weigh more reliable information more strongly, such as distributions with low variance. We examined how observers temporally integrate orientation ensembles randomly drawn from two different probability distributions that were interleaved in a visual search task. Participants performed streaks of sequential odd-one-out visual search for an oddly oriented line. On learning trials, distractor orientations were sampled from two different Gaussian distributions on alternating trials. We manipulated the variance and the distance (in orientation space) between the two distributions. Next, observers performed a test trial where the orientations of target and distractors were switched, resulting in slowed search due to role-reversal effects, revealing observer's internal model of distractor distributions. Participants were strongly biased by the last distribution they were shown; however, this recency effect was weakened when the variance of the last distribution was higher, but conversely it was stronger with smaller distance between the two distributions. These results suggest that variance and distance between distributions modulate the weighing of information during temporal integration, while there is also a strong recency effect.

Intertrial Effects in Visual Search Is Determined by Response-Defining Feature, Not by Motor Response

Fredrik Allenmark, Hermann J. Müller and Zhuanghua Shi
Ludwig Maximilian University of Munich, Germany

Previous studies have found that reaction times in visual search tasks are faster when the response defining feature (RDF) of the search display is repeated compared with when it changes between trials. In a previous study, we showed that such intertrial effects can be modelled as resulting from learning, through Bayesian updating, the prior odds of the responses, which determines the starting point of an evidence accumulation process (Allenmark, Müller, & Shi, 2018). However, it remains unclear whether this updating is based on the response defining perceptual feature or the motor response. Here, we tested this in a singleton detection task by cueing the stimulus-response mapping at the beginning of each trial and randomly swapping this mapping between trials, thereby independently varying repetition/switch of the RDF and the motor response. We found that reaction times were slowed by RDF-switch regardless of whether the S-R mapping was repeated or swapped between trials, indicating that response repetition benefit is based on the RDF, not the motor response. This was further supported by model comparison: The data were better explained by updating the starting point based on the RDF compared with on the motor response.

fMRI Reveals Visual Statistical Learning in Macaque V2

Victor Vergnieux and Rufin Vogels
Laboratorium voor Neuro-en Psychofysiologie, Departement of Neurosciences, KU Leuven, Belgium

Primates learn statistical regularities of their environment. Electrophysiological studies in macaques showed that after statistical learning (SL) of temporal regularities of stimulus sequences infero-temporal (IT) neurons show reduced responses to learned fixed sequences of visual images compared with random or unpredicted image sequences. We designed a block design functional magnetic resonance imaging (fMRI) experiment in macaques to assess which other parts of the brain manifest visual SL signals. During 6 weeks, two macaques (*Macaca mulatta*) were exposed to sequences of 20 images, presented as quartets. Within each quartet, image order was fixed, but the quartets themselves were displayed in a random order (Fixed Stream Condition[FS]). They were also exposed to 20 other images having a randomized order within a quartet (Random Stream Condition[RS]). Stimuli of FS and RS were switched between monkeys. After exposure, both monkeys were scanned with contrast agent-enhanced fMRI using three block conditions: FS, RS, and a fixation-only block (FX). After a whole-brain analysis, the contrast RS-FS showed activations in IT but also in early visual area V2. One monkey showed activation in the prefrontal cortex. These data suggest that statistical learning signals of complex images are already present in early visual areas of monkeys.

Talk Session 33

General Information Processing

The Magic Number 2 ± 1: Capacity-Limited Inference in Mid-Level Perceptual Properties

Christopher Tyler
City University of London, UK

It is an interesting property of perception that just a few of many available samples are sufficient for many perceptual tasks such as luminance-defined blob location, orientation-cluster centroid, disparity-defined object position, three-dimensional structure from motion, and perspective slant estimation, with extra samples producing no further improvement in performance. In George Miller's terms, there is processing capacity beyond which the system is unable to integrate further information, although these are tasks in which the information is inherently integral: Unselected random samples will not solve the problem. This performance is typically reported as a low level of efficiency in perceptual information processing for the larger sample cases but may instead be viewed as a "pyramidic" property of perception (analogous to the foveal specialization of primary vision) in which there is a focal peak of perceptual processing with continuity to more peripheral regions across the domains of perceptual variables. The implication is that the perceptual system meets the task requirements by defining a Bayesian model of the underlying stimulus distribution, based on experience with the task, with model fitting to the distribution of the relevant stimulus information corresponding to the peripheral context information, and the focal peak as the low-dimensional parameter estimation process.

Discrete Windows of Feature Integration

Michael H. Herzog[1], Adrien Doerig[1], Guido Marco Cicchini[2] and Leila Drissi Daoudi[1]
[1]EPFL, Lausanne, Switzerland
[2]CNR, Institute of Neuroscience, Pisa, Italy

A car drives through the night. It is hard to estimate its color from single photoreceptor activity because photoreceptor activation is short and noisy. An efficient way to estimate the color is to average photoreceptor activities along the car's motion trajectory. Here, we show that humans indeed integrate visual features along trajectories for substantial times. We presented a vernier followed by subsequent pairs of flanking lines, creating the impression of two expanding motion streams. When a flanking line is offset, its offset integrates with the central vernier offset. This integration is mandatory for about 450 milliseconds, that is, observers cannot report the two offsets independently. Integration is even mandatory when observers make an eye movement during this period. Integration is precise, that is, vernier offsets from the two streams never integrate—just as colors of two cars are not mixed. However, when vernier offsets are presented in subsequent integration windows, observers can report both offsets independently. For example, the central vernier integrates mandatorily with the flank offset at 330 milliseconds but not with one at 490 milliseconds. Surprisingly, the flank offsets at 330 milliseconds and 490 milliseconds do not integrate although they are in close temporal proximity. We propose that integration comes with perceptual quants.

Parsing Response Times in Multisensory Decisions: The Effect of Signal Strength and Motor Response

Thomas Otto and Bobby Innes
University of St Andrews, UK

Parsing the processing architecture of mental operations and understanding how different components contribute to response times (RTs) are fundamental questions in perception and cognition. For example, the psychological refractory period paradigm has contributed to propose sensory processing, decision-making, and motor response as consecutive stages. Here, we extend this approach to multisensory processing as tested in the redundant signals paradigm, which asks participants to respond with the same motor act to auditory, visual, or combined audiovisual signals. The RT speedup with combined signals is well explained by so-called race models, assuming parallel decision units coupled by a logic OR gate. Specifically, with experimental manipulations that target processing components either before or after the OR gate, the model distinctly predicts the speedup on the level of RT distributions. We tested these predictions in a 2×2 design with signal strength (low, high; "before") and motor response (hand, foot; "after") as factors. Both factors were highly effective leading to joint RT differences of around 200 milliseconds within unisensory conditions. Critically, the RT speedup in all four combined conditions followed the predictions remarkably well. We use these findings to propose that the assumed OR gate can be highly informative to parse the time between stimulus onset and response.

Reaction Times Versus Reaction Speeds

James Pomerantz
Rice University, Houston, TX, USA

The reaction time (RT) literature frequently mentions fast RTs and speed–accuracy trade-offs, but these terms refer to rates, not to durations of processing. Converting times to speeds is a nonlinear, reciprocal (power) transformation that can alter data patterns dramatically, making additive data become interactive. Factors like stimuli and tasks can affect the number of processing steps a task requires, as in the approaches of Donders and Sternberg. Other factors may affect the rate at which those steps are taken (e.g., fatigue, age, and medical conditions may alter neural conduction velocities or frequency bands), something researchers have largely ignored. Just as the time required to complete a walk depends both on the route's distance and our walking speed, computer CPU speeds vary with processing load, temperature, and so on, so the time required to complete computations depends both on clock speeds and the number of steps the calculation requires. We model simple situations in which independent variables affect RT either by influencing the amount of processing required or the speed at which processing proceeds. We then present data from tasks involving two factors: one affecting the number of steps required to respond and the other affecting stepping rate.

Poster Sessions

Monday, August 26, 2019

Poster Session 1

Simultaneous Retinotopic Adaptation to Opposing Distortions

Yannick Sauer[1], Siegfried Wahl[1,2] and Katharina Rifai[1,2]
[1]Institute for Ophthalmic Research, University of Tübingen, Germany
[2]Carl Zeiss Vision International GmbH, Aalen, Germany

Distortions as a visual impairment are inherent in many optical devices such as spectacles or virtual reality headsets. In such devices, the distortions can vary spatially across the visual field. In progressive addition lenses, for example, the left and right regions of the lens skew distort the peripheral parts of the wearers visual field in opposing directions. This study investigates simultaneous adaptation to opposing distortions in a retinotopic reference frame. Two oppositely skewed natural image sequences were presented to 10 subjects as adaptation stimuli at distinct locations in the visual field. To do so, subjects were instructed to keep fixation on a target. Eye tracking was used for gaze control. Change of perceived motion direction was measured in a direction identification task. By determining the point of subjective equality before and after adaptation, that is, the angle at which a group of coherently moving points was perceived as moving horizontal, the shift of perceived motion direction was evaluated. The results show a significant shift at both retinotopic locations in the direction of the skew distortion of the corresponding adaptation stimulus. This confirms the presence of adaptation to spatially varying distortions in a retinotopic reference frame.

Multiple Adaptations to Prisms in a Single Session of Neglect Rehabilitation: A Preliminary Study

Amalie Christine Skov[1], Thomas Alrik Sørensen[2] and Maria Nordfang[1]
[1]Department of Neurology—Rigshospitalet, Glostrup, Denmark
[2]Centre for Cognitive Neuroscience, Aalborg University, Denmark

Prism Adaptation Therapy (PAT) has shown to be a useful rehabilitation intervention for spatial neglect. Despite decades of research on PAT, the exact dose–response mechanisms of the adaptation remain unclear. Typically, the standard PAT is composed of a single prismatic exposure with about 50 to 200 pointing movements. However, the adaptation to the prisms often appears fairly rapidly with less than 50 pointing movements. We hypothesize that a multiple adaptation paradigm in a single session PAT is more effective than the standard PAT, as plural discrepancies may reinforce visuomotor plasticity. We tested 13 patients with spatial neglect in an initial exploratory study. The control group received standard PAT (1 $\times$ 90 pointing movements), while the experimental group received multiple PATs (3 $\times$ 30 pointing movements). Four standardized neuropsychological tests were used as outcome measures. Our preliminary data suggest that PAT with multiple adaptations generates larger aftereffects compared with the standard procedure. Surprisingly, neuropsychological outcome measures showed no consistent effects for either group. Further research is needed to validate the potential efficiency in multiple PATs as well as clarifying the null effect of PAT in neuropsychological tests.

Effect of Light Level on Visual Discomfort From Flicker

Sanae Yoshimoto[1], Fang Jiang[2], Arnold J. Wilkins[3] and Michael A. Webster[2]
[1]Hiroshima University, Japan
[2]University of Nevada, Reno, NV, USA
[3]University of Essex, UK

Uncomfortable images tend to have a spatial structure deviating from 1/*f* Fourier amplitude spectra or excessive energy at middle spatial frequencies. Flickering patterns with similar temporal structure also appear uncomfortable, but the discomfort is affected by not only the amplitude spectrum but also the phase spectrum. We examined whether these effects are robust at lower light levels at which temporal sensitivity shows low-pass characteristics. Participants rated discomfort for flickering uniform fields at various light levels from photopic to scotopic. The waveform of the flicker was varied with a squarewave or random phase spectrum and filtered by changing the slope of the amplitude spectrum relative to 1/*f*. At photopic levels, the squarewave phase flicker with a 1/*f* amplitude spectrum appeared most comfortable, whereas discomfort for the random phase flicker increased with shallower slopes. Analogous results were found at mesopic levels. These results suggest that the dependence of discomfort on the waveform remains constant over a wide range of light levels. At scotopic levels, however, discomfort was reduced and no difference was found between the squarewave and random phase spectra. This suggests that photopic and scotopic vision may respond very differently to flicker discomfort in ways related to their different contrast sensitivities.

Optogenetic Examination of the Origin of Repetition Suppression in Macaque Temporal Cortex

Francesco Fabbrini[1,2], Chris Vanden Haute[2,3], Marina DeVitis[1,2,4], Veerle Baekelandt[2,3], Wim Vanduffel[1,2,5] and Rufin Vogels[1,2]
[1]Laboratory for Neuro- and Psychophysiology, KU Leuven, Belgium
[2]Leuven Brain Institute, KU Leuven, Belgium
[3]Research Group for Neurobiology and Gene Therapy, KU Leuven, Belgium
[4]Department of Biomedical and Neuromotor Sciences, University of Bologna, Italy
[5]Harvard Medical School, Boston, MA, USA

Neurons in macaque inferior temporal (IT) cortex, the end stage of the ventral visual stream, show a decrease in the response with stimulus repetition, known as repetition suppression. Several mechanisms have been proposed to explain this form of adaptation in IT, from firing-rate-dependent fatigue to influences of other brain areas. We recorded spiking activity from IT cortex of two monkeys while simultaneously stimulating optically neurons previously transduced with a depolarizing opsin, ChrimsonR, and measured the effect of stimulation on their responses. Photostimulation could lead to both an increase and a suppression of a neuron's firing rate. In the first case, preceding photostimulation had no effect on the response to a subsequent visual stimulus with a typical contrast; we observed small suppression of the response to repeated photostimulation or when a low-contrast visual stimulus followed photostimulation. Units suppressed during photostimulation showed a strongly suppressed response to simultaneously presented visual and photostimulation (compound stimulus). Using this compound stimulus as adapter produced little or no effect on the response to a subsequent visual stimulus compared with repetition of the same visual stimulus. Together, these results suggest only a small if any contribution of firing-rate-dependent mechanisms to repetition suppression in IT.

The Prospective-Contrast and Retrospective-Assimilation Effects Within and Across Visual Hemifields

Saki Takao[1] and Katsumi Watanabe[1,2]
[1]Waseda University, Tokyo, Japan
[2]University of New South Wales, Sydney, Australia

While we do not experience the separation between left and right visual fields, the visual fields separately project

onto the contralateral hemispheres. We have recently found that our perception is repelled from the past and assimilated to the future in apparent motion (Takao & Watanabe, 2019 APS). This study examined whether these prospective-contrast and retrospective-assimilation effects would be different when appeared within a single hemifield or across hemifields. We prepared circles with different sizes and brightness. In each trial, one circle appeared in the left visual field and the other circle in the right field for 50 milliseconds. After an interval of 0 to 800 milliseconds, another set of two circles appeared for 50 milliseconds such that the circles underwent apparent motion within or across the hemifields. Thirteen participants reported the size or brightness of the circles predetermined for each trial. The prospective-contrast and retrospective-assimilation effects were replicated. However, the effects were significant only when the circles moved within a single hemifield but not across the hemifields. These results suggest that the effects are confined to or enhanced within a single hemifield, reflecting the anatomical constraints on visual processing.

Attentional Repulsion Effect: Its Neural Locus as Indicated by Meridian Modulations

Denise Baumeler and Sabine Born
University of Geneva, Switzerland

Disruptions in perceptual effects have previously been reported when stimuli were presented across the vertical meridian. These disruptions were explained by separate representations of the left and right visual hemifield, projecting to opposite anatomical hemispheres. Here we were interested in investigating similar hemifield representations in the attentional repulsion effect (ARE). The ARE is a bias induced by a covert shift of attention toward a flashed peripheral cue, which in turn repulses the perceived position of a subsequently presented probe (Suzuki & Cavanagh, 1997). Even though the ARE is typically examined through position estimations of a probe presented around the vertical meridian, no such hemifield asymmetries have so far been reported. By collecting absolute estimations of memorized probe positions instead of binary responses, we indeed found the ARE to be strongest when the attentional capturing cue and the subsequently presented probe were displayed in the same hemifield. At the same time, we discovered that the ARE is not only disrupted at the vertical, but also at the horizontal meridian. These disruptions could be an indicator that the ARE originates in visual neural areas with quadrantic representations of the visual field such as V2 and V3.

Factor Analysis of Individual Differences in the Tilt Illusion Reveals Separate Factors for Attraction and Repulsion Effects

Pieter Moors, Marijke Casteleyn and Johan Wagemans
Laboratory of Experimental Psychology, Department of Brain and Cognition, KU Leuven, Belgium

The tilt effect refers to a perceptual phenomenon where the perceived orientation of a central stimulus is biased by a surrounding stimulus with a different orientation. Depending on the orientation difference, the perceived orientation of the central stimulus is repelled away from the surrounding orientation or attracted to it. This general pattern of repulsion and attraction is well described by population-code models implementing divisive normalization of neural responses. In this study, we were interested in the structure of interindividual differences for the tilt effect. We asked a set of 78 observers to adjust a central stimulus such that they perceived it to be vertical. Our results indicated that everyone showed repulsion and attraction to a varying extent. Next, we applied principal components analysis to the pattern of correlations between biases elicited by different surround orientations. We extracted four different factors: two associated with repulsion and two with attraction. These results will be compared with simulations of interindividual variability in the parameters of population-code models eliciting these effects, to elucidate which combination of parameters best captures the structure of individual differences.

Hysteresis and Adaptation in Perceptual Categorization, Discrimination, and Similarity Judgment Tasks

Eline Van Geert and Johan Wagemans
Laboratory of Experimental Psychology, Department of Brain and Cognition, Faculty of Psychology and Educational Sciences, KU Leuven, Belgium

How we perceive a visual stimulus or the difference between two sequentially presented stimuli does not only depend on aspects of the presented stimuli but also on the temporal context in which they are presented. In data from a perceptual categorization, a perceptual discrimination, and a similarity judgment task with both recognizable and non-recognizable morph series, we analyzed the effects of signal strength and response in the previous trial on the response in the current trial. Attractive effects of the previous response (i.e., hysteresis) were found in all three tasks. Under certain conditions, indications of repulsive effects of signal strength in the previous trial (i.e., adaptation) were also present. In addition, these context effects were

stronger in tasks involving the nonrecognizable morph series, suggesting that stronger categorization led to reduced attractive and repulsive context effects. The results are in accordance with Bayesian accounts of perception, where current sensory information is combined with prior information. We will also discuss planned research regarding individual differences in hysteresis and adaptation effects with other stimuli and tasks.

Continuous Open-Loop Psychophysics: A Novel Method to Measure Temporal Dynamics of Body Extension

Robert Keys[1], David Burr[2] and David Alais[1]
[1]University of Sydney, Australia
[2]University of Florence, Italy

Precise action requires an accurate sense of body dimensions and location and must adapt to changes throughout development. During embodiment illusions, vision temporarily recalibrates proprioception, suggesting body models have short-term plasticity. To determine how rapidly changes occur, we used immersive virtual reality to dissociate perceived hand location from vision and proprioception to examine visuo-proprioceptive recalibration over time. We tracked hand movement and mapped actions onto a hand avatar which was extended in position to increase reach by $\sim$7 cm. We exposed participants to alternating adaptation and tracking trials. Adaptation (5 seconds): Participants pointed their index finger at an array of small targets with the extended hand avatar visible. Tracking (20 seconds): Participants followed a random-walking target with their index fingertip without seeing the avatar. Cross-correlating target and tracking paths, we used peak correlation lag to calculate Euclidean distance between target and (lagged) fingertip for each trial. Immediately after adaptation, estimated hand location was biased toward the extended avatar but drifted toward the veridical hand within a 20-second trial. This return drift decreased over 8 to 10 adaptation trials, suggesting that body-model extension begins after $<$1 minute of active feedback. These findings suggest resolving short-term visuo-proprioceptive conflict may recruit long-term body representations.

Numerosity Adaptation: Changes in Sensory Processes or in Decision-Making?

Paula A. Maldonado Moscoso, Roberto Arrighi and David C. Burr
University of Florence, Italy

Humans and other animals can make rapid but approximate estimates of the numerosity of items in a scene, an ability often termed as the number sense. Numerosity perception, like other senses, is susceptible to sensory adaptation: After a prolonged exposure to a patch containing many dots, subjects show a tendency to underestimate the numerosity of a second stimulus subsequently presented to the adapted region, with the opposite occurring for adaptation to small numerosities. Do these aftereffects arise from a change in the processing of sensory signals or from a shift of criteria at the decisional stage? We addressed this question by investigating the effects of numerosity adaptation in a two-alternative forced choice discrimination task on apparent numerosity (measured as point of subjective equality) as well as on subjective confidence and reaction time. Our results show that shifts in perceived numerosity are mirrored by shifts in both, confidence and reaction time, with the maximum uncertainty and longest response time occurring at the point of subjective equality rather than at the point of physical equality. These results are consistent with the hypothesis that numerosity adaptation aftereffects are perceptual in nature and not related to decisional processes.

How Does Numerosity Adaptation Affect Neural Numerosity Selectivity?

Andromachi Tsouli[1,2], Yuxuan Cai[2,3], Ben M. Harvey[1], Susan F. te Pas[1], Maarten J. van der Smagt[1] and Serge O. Dumoulin[1,2,3]
[1]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[2]Spinoza Centre for Neuroimaging, Amsterdam, the Netherlands
[3]Experimental and Applied Psychology, VU University, Amsterdam, the Netherlands

Perception of visual stimulus numerosity (i.e., the set size of a group of items) is an evolutionarily preserved ability found in humans and animals. Like other perceptual features, numerosity is susceptible to adaptation, allowing behavioral investigation of the neural underpinnings of numerosity perception in humans. Recently, we have shown numerosity-selective neural populations with a topographic organization in the human brain. Here, we investigated how numerosity adaptation affects the numerosity selectivity of these populations. We scanned participants with 7 Tesla ultra-high field functional magnetic resoncance imaging while they viewed stimuli of changing numerosity, mapping numerosity selectivity. We interleaved a low or high numerosity adapter stimulus with these mapping stimuli, repeatedly presenting 1 or 20 dots, respectively, to adapt the numerosity-selective neural populations. We analyzed the responses using custom-build population receptive field neural models of numerosity encoding. We replicated the network of

numerosity maps described in our previous studies. During numerosity adaptation, we found that the numerosity preferences within these numerosity maps change depending on the adaptor numerosity. We propose that the observed changes in numerosity preferences underlie perceptual effects of numerosity adaptation.

Ambivalence of Artistic Photographs Can Foster Interest and the Motivation to Engage

Claudia Muth and Claus-Christian Carbon
University of Bamberg, Germany

Ambivalence makes us shift in-and-out of interpretations with contrasting valence. With each interpretation, we face a yet unfulfilled promise of another. This semantic instability (Selns, Muth, & Carbon, 2016) can drive interest as we appraise uncertainty with coping potential (Silvia, 2005). In Study 1, participants rated the interestingness of photographs varying in ambivalence. During an elaboration-phase, they described positive and negative interpretations of a subset before rating all photographs again. Interest ratings were highest for ambivalent photographs, and they increased after the elaboration whereas for control (non-elaborated) stimuli, interest did not change. Explicit notions of interest could reflect motives of social distinction rather than actual motivation to engage. Therefore, in Study 2, participants selected one of the two photographs about which they "would like to learn more." Eye-tracking informed about duration of fixations to each photograph. After elaboration, participants chose highly ambivalent photographs more often than before and more often than control images. Our findings suggest that ambivalence can foster interest and the motivation to engage. This effect is increased when guiding awareness to multiple semantic facets. Not each context or processing-mode invites us to open up for Selns, but if images offer potentials for new insight, this can drive deep engagement.

Experiencing ASMR: About the Phenomenology of Video Sequences That Trigger Excitement and Subsequent Relaxation

Claus-Christian Carbon[1,2,3] and Vera M. Hesslinger[1,2]
[1]University of Bamberg, Germany
[2]Research Group EPÆG (Ergonomics, Psychological Æsthetics, Gestalt), Bamberg, Germany
[3]Bamberg Graduate School of Affective and Cognitive Sciences (BaGrACS), Bamberg, Germany

ASMR stands for Autonomous Sensory Meridian Response, which shall subsume experiences of tingling sensations and positive, sometimes orgiastic feelings with the potential of inducing sustainable relaxation. ASMR is mostly experienced via the consumption of special ASMR videos made available on web channels such as YouTube. The phenomenon has recently gained wide publicity— the eye-catching, highly aestheticized video contents get millions of views—but research on this topic is still sparse. We investigated experiences including sensations and insights elicited by ASMR-videos in people who are unversed with ASMR-content. In Study 1 ($N = 30$), we presented a wide variety of short ASMR-video-sequences; in Studies 2 ($N = 80$) and 3 ($N = 57$), we used full-length 1 hour+ videos consisting of several ASMR-sequences. Participants typically reported contrastive sensations with initial interest and arousal being followed by clear signs of relaxation. Overall, participants assessed ASMR videos as mostly noninteresting, even boring yet beneficial due to their distracting and relaxing character. Relaxation as measured by PANAS pre- and post-video was positively related to the duration of watching. Studying ASMR reveals mechanisms of how multisensory perception affects affective states.

Learning to Like: A Computational Account of How We Learn Visual Aesthetic Values

Hassan Aleem and Norberto Grzywacz
Georgetown University, Washington, DC, USA

We are all born with certain innate visual preferences, such as a preference for symmetry, contrast, and balance. However, there is tremendous diversity in visual preferences across the globe. For example, different cultures can have vastly different aesthetic values. At the same time, individuals within these cultures also maintain their own unique preferences. What neural mechanism may underlie all of this? One likely candidate is reinforcement learning. Over our lifetime, we may learn to value certain visual characteristics that bring us benefit, and this can vary greatly between cultures. Similarly, what is beneficial may change from person to person and from time to time, thus learning is highly dependent on context. Here, we present a neurobiologically inspired model for how we learn aesthetic values. In particular, we focus on how this learning is modulated by cultural values as well as by individual factors such as motivation. Our computer simulations show that both factors can have a considerable effect on learning of aesthetic values. In addition, our simulations shed light on other aspects of visual preference formation such as the time course of learning and competition between aesthetic variables.

Designing an EEG Paradigm for Naturalistic Engagement with Aesthetic Stimuli

Dominik Welke and Edward A. Vessel
Max-Planck-Institute for Empirical Aesthetics, Frankfurt, Germany

"Real-world" visual aesthetic experiences typically involve open-ended exploration of highly variable artistic objects. Yet uncontrolled gaze and stimulus variability are typically avoided in electroencephalographical (EEG) experiments due to the potential generation of artifacts and noise. We aimed to quantify EEG signal-to-noise ratio (SNR) during an aesthetic rating task of both static images and moving (video) stimuli in which participants were allowed to gaze freely. Observers viewed "artistic" video clips depicting nature scenes or dance performances plus randomly drawn still frames from these clips and were instructed to rate each stimulus for both subjective aesthetic appeal and degree of personal interest. 64-Channel wet EEG was recorded in a laboratory environment. To quantify SNR, a task-unrelated auditory stimulus eliciting a frequency-tagged EEG response (auditory steady-state response [ASSR]) accompanied each trial. An initial comparison of four different ASSR stimuli ($n = 5$) demonstrated that an ASSR-based SNR assessment can indeed be applied in our aesthetic rating paradigm, and that amplitude-modulated Pink Noise or Speech Noise lead to the most robust response across participants. Individual ratings of aesthetic appeal and personal interest spanned the entire scale, suggesting that the auditory stimuli did not prevent observers from aesthetically engaging with the visual stimuli.

Beauty Is One-Dimensional

Qihan Wu[1], Aenne A. Brielmann[1] and Denis G. Pelli[1,2]
[1]Department of Psychology, New York University, NY, USA
[2]Center for Neural Science, New York University, NY, USA

Can you compare the beauty of the Mona Lisa to Starry Night? Does the difference in beauty ratings of two images predict the rated beauty difference between them? Thirty participants were tested with 14 OASIS images and 6 self-selected images. In the relative task, each participant saw all possible two-image pairs twice, chose which image was more beautiful and rated by how much on a 1 to 9 scale. In the absolute task, they saw, 4 times, each of the 20 images randomly presented alone and rated how much beauty they felt from each. We find that participants made consistent absolute and relative beauty judgments (absolute: test–retest $r = .98$, standard deviation [SD] = 0.6; relative: test–retest $r = .86$, $SD = 1.17$). The difference in absolute beauty ratings predicts relative beauty ratings ($r = .79$, root mean square error = 2.58). Our model assumes that beauty is one-dimensional. Higher dimensional models produced by Multi-Dimensional Scaling do not improve the predictions. Thus, mean beauty-difference ratings are predicted by the difference in mean absolute-beauty ratings. Beauty is one-dimensional, rendering it a potential criterion for decision-making.

A Methodological Evaluation on Simultaneous Use of Wearable and VR Eye Tracking in Museum: A Comparative Case Study on Piet Mondrian's Room Design

Doga Gulhan, Szonya Durant and Johannes Zanker
Royal Holloway, University of London, UK

Empirical aesthetics aiming to investigate aesthetic experience of observers shares methodological aspects with vision science, including the measurement of eye movements. Moving on from screen-based systems, improvements in wearable eye-trackers, and emergence of eye-tracking in virtual reality (VR) led to mobile experiments outside laboratories. In our exploratory study, we utilised both mobile eye-tracking systems simultaneously for Piet Mondrian's room design from 1926—a physical installation entitled "a spatial appropriation" by artist Heimo Zobernig, side by side with a VR reconstruction developed by our team—in the Albertinum Museum (Dresden State Art Collections). Volunteer museum visitors engaged with these two reconstructions of the same artwork both in real-world and VR in counterbalanced design. Two data streams were collected, in addition to a questionnaire to record qualitative responses. This comparative study design allows us to quantitatively compare observer experience in two different settings and can utilise postprocessing with three-dimensional modelling or photogrammetry to generate gaze maps to enable one-to-one correspondence between physical and digital environment. A major limitation for both systems, as compared with desktop eye tracking, is the currently available sampling frequency (around 100 Hz), allowing mostly fixation-based analysis and disregarding saccades.

Constructing Piet Mondrian's Design of a "Salon for Ida Bienert" in VR

Johannes Zanker, Doga Gulhan, Jasmina Stevanov and Tim Holmes
Royal Holloway University of London, UK

The question why the design of Piet Mondrian commissioned by the arts collector Ida Bienert in 1926 for her villa in Dresden ("Damenzimmer") was never executed

during his lifetime is widely discusses in Arts history. A small number of life-size reconstructions have been attempted in exhibitions, but all encountered some difficulties. We followed up potential conflicts between the aesthetic theory of the Dutch DeStijl arts movement and perceptual properties of visual perception in three-dimensional (3D) spaces (Stevanov & Zanker, 2017). More recently, we compared Mondrian's plans with the actual room in Dresden and generated a 3D reconstruction of this design that could be explored in VR with an eye-tracking enabled HTC Vive headset. Here, we present some adjustments to the original plan to reconcile it with the architectural constraints of the intended physical space, which includes a correction of the proportions of the room, location and size of windows and doors, and some decisions about the colour palette. As a result, we suggest a "most likely" scenario in VR of how the "Damenzimmer" would have looked if it had been executed.

Generating Synthetic Images for Visual Attention Modeling

David Berga[1,2], Xavier Otazu[1,2], Xosé R. Fdez-Vidal[3], Víctor Leborán[3] and Xosé M. Pardo[3]
[1]Computer Vision Center, Barcelona, Spain
[2]Universitat Autònoma de Barcelona, Spain
[3]CiTIUS, Universidade de Santiago de Compostela, Spain

Visual saliency has long been evaluated with eye-tracking data from real image data sets. In contrast, we aim to evaluate eye movements through synthetically generated psychophysical patterns. In this work, we collected data from 34 participants with 15 distinct types of stimuli, and we tested it in Free-Viewing (for stimuli reproducing Corner Salience, Visual Segmentation, Contour Integration, and Perceptual Grouping) and Visual Search tasks (for stimuli reproducing singleton search in distinct conditions of Feature/Conjunctions, Asymmetries, Roughness, Brightness, Color, Size, Orientation, etc.). We found that saliency is predominantly and distictively influenced by feature type, feature contrast, temporality of fixations, task difficulty, and center biases. All these influences should be accounted as baselines for visual saliency modeling benchmarks, as not all fixations define saliency in the same way. We also quantified target–distractor feature contrast for each of these psychophysical patterns, providing an implementation to generate these (and many other) types of stimuli.

Posterior Parietal Cortex Involvement in the Prioritization of Objects Based on Features

Armien Lanssens[1], Ronald Peeters[2], Hans Op de Beeck[1] and Céline R. Gillebert[1,3]
[1]KU Leuven, Leuven, Belgium
[2]University Hospitals Leuven, Leuven, Belgium
[3]University of Oxford, Oxford, UK

We live in a dynamic world where stimuli continuously compete for our limited processing resources. Attention helps us to prioritize the information that is most relevant for our behavior. In this study, we aimed to investigate the neural mechanisms of prioritizing visual information based on features using functional magnetic resonance imaging (fMRI); 24 neurologically healthy participants performed a feature-based variant of a continuous performance task in which they were instructed to monitor either one or two streams of differentially colored gratings that were presented on the vertical meridian. They had to make a key press to each grating in the task-relevant stream(s), except to gratings with a horizontal orientation. Behaviorally, response times were increased by attending two streams of gratings simultaneously as opposed to selectively attending one. The analysis of fMRI data revealed that activity in both posterior parietal and visual cortical regions was modulated by distributing attention across one or two streams of stimuli. In summary, our results confirm the role of the posterior parietal cortex in remapping feature-based attentional priorities and suggest relevance-based modulations of visual cortical stimulus representations.

Identifying the Neural Correlates of Spatial Biases in Visuospatial Attention

Lulu Wang[1], Ronald Peeters[2], Dante Mantini[3,4] and Céline R. Gillebert[1,5]
[1]Department of Brain and Cogniton, University of Leuven, Belgium
[2]Radiology Department, University Hospitals Leuven, Belgium
[3]Research Centre for Movement Control and Neuroplasticity, University of Leuven, Belgium

Covert visuospatial attention enhances neural responses of visual cortical areas to stimuli presented at the attended location in the visual scene and improves their perception by enhancing spatial resolution, increasing contrast gain, and suppressing interference from other stimuli. When attention is not directed to a specific location, perceptual processing of stimuli is spatially biased: Stimuli are processed more accurately and faster when presented at the fovea compared with the periphery, the eccentricity effect, and in the left side of space compared with the right, the leftward bias. Here, we studied the neural basis of covert attention to stimuli at different eccentricities using a

probed change detection task and functional magnetic resonance imaging in 14 neurologically healthy individuals. When attention was distributed across the visual field, we observed an eccentricity effect, but no leftward bias. When attention was cued to one of the locations, performance did not differ between different eccentricities or hemifields. From the neuroimaging data, we expect to see that increases in task performance during covert visuospatial attention will be accompanied by an increased neural activation in contralateral areas in the early visual cortex as well as the frontoparietal attention network.

Synchronous Audiovisual Looming Signals Are Not Prioritized

Hanne Huygelier[1], Johan Wagemans[1], Raymond van Ee[1,2,3] and Céline R. Gillebert[1,4]
[1]Brain and Cognition, KU Leuven, Belgium
[2]Philips Research Laboratories, Department of Brain, Behaviour & Cognition, Nijmegen, the Netherlands
[3]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands
[4]Department of Experimental Psychology, Oxford University, UK

Previous studies showed that multisensory information is more likely to be attended than unisensory information. These studies typically show that brief auditory stimuli affect detection of visual stimuli. However, it is unclear whether multisensory stimuli affect attention when auditory and visual information are integrated based on temporal synchronicity. In this study, we assessed the effects of synchronous audiovisual looming signals on attention in four paradigms. In Experiment 1, we measured spatial attention allocation toward a synchronous versus asynchronous signal using a contrast change detection task. The results of 18 participants showed no difference in contrast change detection for the synchronous versus asynchronous signals. In Experiment 2, we replicated these results in 15 participants using a temporal-order judgement task. In Experiment 3, we measured spatial attention orientation toward synchronous versus asynchronous signals using an endogenous Posner cueing paradigm. The results of 25 participants showed no effect of audiovisual synchronicity on attentional orientation. In Experiment 4, we measured sustained attention for synchronous versus asynchronous signals using a sustained attention to response task. The results of 36 participants showed no effect of audiovisual synchronicity on sustained attention. To conclude, our data show that synchronous audiovisual signals are not preferentially attended.

The Looming Sound Benefit for Visuospatial Re-orienting and Its EEG/ERP Correlates

Christiane Glatz[1], Makoto Miyakoshi[2] and Lewis Chuang[1,3]
[1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany
[2]Swartz Center for Computational Neuroscience, UC San Diego, CA, USA
[3]LMU Munich, Germany

Looming sounds that indicate an approaching object, for example, those that grow louder with time, can enhance the visual processing of items that they accompany. This is often attributed to multisensory integration. Recently, we have demonstrated that looming sounds presented to one ear can also preferentially reorient spatial attention, away from a central manual tracking task to peripheral visual targets on the congruent side. Specifically, looming sounds induced a reaction time benefit for correctly discriminating the tilt of congruent targets that followed them, compared with static intensity sounds (Glatz & Chuang, 2019). Here, we report electroencephalography (EEG) results for this "looming benefit." Visual targets that appear after a congruent looming sound induced larger event-related potential (ERP) amplitudes at 159 $\pm$ 30 milliseconds and 280 $\pm$ 30 milliseconds that were more pronounced in the right hemisphere. Source localization analyses suggest that the earlier component (P159) is defined by a greater activity in the right cuneus, which is implicated in visual detection, and the later component (P280) by the right precuneus, which is implicated in spatial reorienting. Both components were also defined by less activity in frontal brain regions, for example, orbitofrontal cortex, which suggests that "looming" sounds reduced inhibition to interruptions to the manual tracking task.

Attentional Modulation of Audiovisual Interactions in Time: Temporal Ventriloquism in Visual Apparent Motion

Aysun Duyar[1,2] and Hulusi Kafaligonul[1,3]
[1]National Magnetic Resonance Research Center (UMRAM), Bilkent University, Ankara, Turkey
[2]Department of Psychology, Bilkent University, Ankara, Turkey
[3]Interdisciplinary Neuroscience Program, Bilkent University, Ankara, Turkey

To construct a coherent percept of the external world, the brain organizes spatial and temporal information provided by different modalities. The role of attention in this process has become a focus of multisensory research. Here, we aimed to understand the relationship between spatial attention and audiovisual interactions in time as well

as to investigate the capacity of audiovisual integration. We utilized a set of audiovisual stimuli that elicit an illusion demonstrating "temporal ventriloquism" in visual apparent motion and asked participants to perform a two-interval forced-choice speed discrimination task. In two sets of experiments, we oriented attention in the visual and auditory domains and also changed the number of visual events systematically. The manipulation of attention in the visual domain did not affect temporal ventriloquism. On the other hand, introducing an additional task in auditory space significantly increased the amount of temporal ventriloquism. However, task difficulty did not affect this increase. Moreover, the temporal ventriloquism was almost constant across different number of visual events and existed in all the experimental conditions. Although we found some evidence that auditory attention can modulate temporal ventriloquism, our findings mainly suggest that spatial attention may not be required for the audiovisual interactions in time to occur.

(Non-)Effects of Visual Spatial Attention on Auditory Multistability

Karl K. Kopiske[1], Wolfgang Einhäuser[2] and Alexandra Bendixen[1]
[1]Cognitive Systems Lab, Chemnitz University of Technology, Germany
[2]Physics of Cognition Group, Chemnitz University of Technology, Germany

A central question in auditory perception concerns how listeners can tell apart multiple sound sources in an auditory scene. Cues from other sensory modalities such as vision may help achieve this—for example, temporally coherent visual stimuli can enhance listeners' ability to detect tones. In the present experiment, we tested for a similar enhancement effect of spatial attention to visual stimuli on listeners' multistable perception of spatially separated auditory streams. Specifically, we asked $N = 24$ participants to report their subjectively perceived organization of two interleaved sequences of tones differing in pitch, presented in an ambiguous ABAB . . . pattern. Spatial separation was simulated by presenting each of the sequences with higher level to one ear than to the other. Concurrently, we asked participants to pursue a moving dot with their eyes. Gaze was verified using eye tracking. Contrary to our expectations, the proportion of either sequence being perceived as dominant was not affected by the dot's position or movement direction. This suggests that visual spatial attention's role in segregating sound sources is more limited than expected.

Contour Integration in Autism Spectrum Disorders

Tsvetalin Totev Totev[1], Milena Slavcheva Mihaylova[1], Miroslava Dimitrova Stefanova[1], Kalina Ivanova Racheva[1], Bilyana Zaharieva Genova[1], Svetla Nikolaeva Staykova[2] and Nadejda Bogdanova Bocheva[1]
[1]Institute of Neurobiology, Bulgarian Academy of Sciences, Sofia, Bulgaria
[2]Clinic of Child Psychiatry "St. Nikolas," University Hospital Alexandrovska, Sofia, Bulgaria

Besides impaired higher level cognitive and social abilities in autism spectrum disorders (ASD), atypical processing of low-level sensory information has also been described. A prominent feature in visual information processing is the enhanced discrimination of individual elements combined with difficulty in binding local elements into a global percept. We studied whether visual contour integration performance might be similarly characterized. Stimuli involved Gabor elements of random orientation positioned on a regular grid. On half of trials target line tilted at 60° was formed at middle of the screen with elements' orientation shifted by 0°, 10°, 20°, 30°, 45°, or 60° and standard deviation of 0.3 of these shifts. Twenty children and adolescents with ASD (aged 8–15 years) and 28 age-matched controls participated in a task to detect the target line presence/absence. Based on Signal Detection Theory d' values were calculated. Results showed that while at 0° the performance of the observers with ASD was insignificantly inferior, it deteriorates more strongly with shift increase than for typical observers. These findings imply lower efficiency of ASD observers in using stimulus information than typically developing controls due probably to difficulties in noise rejection and extraction of signal information from the noisy background.

Global Motion Direction Sensitivity in Autism Spectrum Disorder

Simeon Stefanov Stefanov[1], Nadejda Bogdanova Bocheva[1], Miroslava Dimitrova Stefanova[1], Ivan Milenov Hristov[1], Tsvetalin Totev Totev[1], Svetla Nikolaeva Staykova[2] and Milena Slavcheva Mihaylova[1]
[1]Institute of Neurobiology, Sofia, Bulgaria
[2]Clinic of Child Psychiatry "St. Nikolas," University Hospital Alexandrovska, Sofia, Bulgaria

This study is aimed at testing the hypothesis of increased neuronal noise in visual information processing in autism spectrum disorder (ASD). We used the method of

equivalent noise to evaluate the sensitivity to local motion direction related to internal noise and the ability to pool the local information. Two groups participated in the study: 15 children with ASD (aged 8–15 years) and 22 age-matched controls. The stimuli were patterns of band-pass elements with motion directions taken from normal distribution with standard deviations of 2°, 5°, 10°, 15°, 25°, and 35°. The variability of motion directions represent the added external noise level.The subjects' task was to determine whether the mean motion direction was to the left or to the right of vertical. The results show larger individual differences in the effects of external noise on motion direction thresholds and lower sensitivity to mean motion direction in ASD than in controls. These findings are not due to a greater inaccuracy in local direction estimation but to a lower efficiency in global motion integration. The data obtained suggest that ASD individuals have poor ability to integrate the local motion information rather than having increased internal noise.

Pupillometry Reveals Perceptual Differences That Are Tightly Linked to Autistic Traits in Typical Adults: A No-Report Paradigm Based on Stereopsis

Chiara Tortelli[1], Marco Turi[2,3], David Charles Burr[4,5] and Paola Binda[2,6]
[1]Department of Surgical Medical Molecular and Critical Area Pathology, University of Pisa, Italy
[2]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy
[3]Fondazione Stella Maris, Calambrone, Italy
[4]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Firenze (Italy)
[5]University of Sydney, School of Psychology, Sydney (Australia)
[6]CNR Neuroscience Institute, Pisa (Italy)

Many perceptual differences have been linked with personality traits. We recently showed that pupillometry can provide an objective index of local/global perceptual styles when viewing a bistable rotating cylinder, and that the index correlates strongly with autistic traits (estimated by the autistic quotient [AQ]). Here, we combine this approach with dichoptic viewing to simplify the paradigm and eliminate the need for active reports of perceptual states, to make it user-friendly for young children and clinical populations. Participants viewed a structure-from-motion cylinder formed by a front and a rear surface of white and black dots. While in the original study, the three dimesnional perception was illusory and bistable; here, we used disparity cues to define the front and rear surface, which switched every 5 $\pm$ 0.5 seconds. As with bistable motion, typical adults with high AQ scores showed strong pupil dilations or constrictions when the black or white dots were reported as front surface, whereas participants with low AQ showed no such oscillations. Pupil oscillations remained similar when participants watch the stimulus passively, without reporting the perceptual state. This simplified, report-free paradigm marks an important step toward applying pupillometry to measure perceptual styles in young and clinical populations.

Eye Movements in Developmental Prosopagnosia and Autism-Spectrum Conditions in Adulthood

Ebony Murray, Stephanie Chase, Nicola Gregory, Rachel Moseley and Sarah Bate
Bournemouth University, Poole, UK

Developmental prosopagnosia (DP) is sometimes misdiagnosed as an autism spectrum condition (ASC). This study aimed to investigate whether eye-movement patterns can differentiate between adults with DP, ASC, and control participants. Participants watched eighteen 30-second audio-visual clips. These clips varied in how interactive they were; a woman read and looked either straight down at a book (passive condition), at another person in the scene (passive–interactive condition), or straight at the viewer (interactive condition). Dwell times on the internal features of the face, external features including the hair and clothing, and the background, were analysed. Dwell times, specifically on the external features of the face and the background, differentiated the three groups. These patterns were more apparent when the videos were more interactive. As DP is sometimes misdiagnosed as ASC in childhood, the eye movements of younger DP, ASC, and control participants should be explored. Combining the findings from this study and from future research, eye-tracking may be a successful method to differentiate the two conditions. This could lead to more accurate diagnosis and, subsequently, suitable support and restorative options.

Pupillometry Provides New Insights on Figure-Ground Segregation and Its Covariation With Autistic Traits

Paola Binda[1,2], Chiara Tortelli[3], Elizabeth Salvagio[4], David C. Burr[5,6] and Mary A. Peterson[7,8]
[1]Department of Translational Research and New Technologies in Medicine and Surgery, Università di Pisa, Italy
[2]Institute of Neuroscience of the CNR—Pisa Unit, Italy
[3]Department of Surgical Medical Molecular and Critical Area Pathology, University of Pisa, Italy
[4]University of Arizona, College of Medicine
[5]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Firenze (Italy)

[6]University of Sydney, School of Psychology, Sydney (Australia)
[7]University of Arizona, Department of Psychology
[8]University of Arizona, Cognitive Science Program

We used pupillometry to investigate the processes of figure-ground segregation and its interindividual variability while minimizing interference with the observer's perceptual task. Twenty-five observers classified silhouettes as depicting meaningful real world or meaningless novel objects. The borders of half the novel objects suggested portions of meaningful objects on the ground side. Participants were directed to focus their attention on the central object for the full duration of the stimuli (2 seconds). Pupil constriction/dilation responses to the central figure (respectively, brighter/darker than its ground) were stronger when its borders suggested meaningful objects on the ground side. This is inconsistent with attention shifting away from the meaningless central figure toward the meaningful ground objects (which would have predicted the opposite pupillometry pattern) but may suggest active suppression of the meaningful figure on the ground. We investigated the interindividual variability of the responses and found a surprisingly strong correlation between the strength of pupillary light responses and autistic traits, estimated with the autistic quotient (AQ). Participants with stronger AQ have reduced pupil constrictions, particularly in response to silhouettes with meaningful objects on the ground side. This could be an index of autistic traits influencing figure-ground processing, which is revealed by the sensitive and objective pupillometric technique.

How We Perceive Pseudo-Haptics in Virtual Reality: Relationships to Autistic Traits

Kento Suzuki and Takao Fukui
Tokyo Metroplitan University, Japan

The aim of this study is to investigate whether and how we perceive pseudo-haptics in virtual reality (VR) space and how the subjective feeling of this perception relates to autistic traits. Participants wore head-mounted display and were required to place their own arm-hand at the location where the arm-hand model was presented in VR space. In each trial, a moving gray bar (5.7 deg/s) approached the arm-hand model, and, when the bar touched the surface of that model, the initial speed was rapidly slowed down. The ratios of speed change were manipulated (10 conditions). After each trial, participants scored the extent to which they perceive pseudo-haptics on a 5-point scale (5 indicating *very strong* and 1 [almost] *none*). Each participant's autistic traits were measured by the autism-spectrum quotient test. We found that stronger touch perception related to (a) larger speed change when the bar touched the arm-hand model and to (b) higher autistic traits.

Neural Correlates of James–Lange Hypothesis on Smile

Naoyuki Osaka[1], Ken Yaoi[2], Miyuki Azuma[3], Mizuki Kaneda[3] and Mariko Osaka[3]
[1]Kyoto University, Japan
[2]Kanazawa University, Japan
[3]CiNET Osaka University, Japan

We explored how facial feedback modulates emotional experience of smiling using functional magnetic resonance imaging. Although the James–Lange theory pertained to expressions throughout the body in addition to facial expression like smile, their theory led to the facial feedback hypothesis. We explored how facial expressions affects emotional experience in the human brain based on James–Lange facial feedback hypothesis in which emotion is experienced when the brain reacts to the information received via the body's nervous system. Contracting facial muscles (smile or frowning) could make emotions stronger even when one is unaware that one is modifying expressions (Strack et al.,1988). The neural correlates of emotional experience under strong/weak facial expressions are unknown so far. We asked participants to hold a straw with their teeth-only or lips-only to simulate facial expressions. Behavioral data suggested that a happier emotions associated with teeth-only condition during reading a funny comic strips. Results suggested activations in the medial prefrontal cortex, inferior frontal gyrus, and temporo-parietal junction regions under funny conditions.

Estimating the Average Speed of a Crowd Using Intact and Scrambled Biological Motion

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

How well can we judge the average speed of a crowd? Are judgements based on global dynamic structure or local motion? To answer these questions, we presented observers with test arrays containing a 4×3 grid of point-light walkers. Each of the 12 walkers had the same randomly determined depth orientation but a unique step-phase. Display duration was 3 seconds. The test array was immediately followed by a response array, which showed figures with speeds from very slow walking (40 steps/min; bottom left) to very fast walking (150 steps/min; top right) in 10 steps/min increments. Observers were required to click

on the stimulus that matched their estimate of the average speed in the test array. On critical trials, the test array contained a range of walking speeds, with the mean speed constrained to be either slow (60 steps/min), medium (90 steps/min) or fast (120 steps/min). Across trials, the walking figures could either be intact (Global) or were spatially and phase scrambled (Local). Initial results suggest that observers were able to estimate the average quite accurately under both Global and Local conditions, but the correlation between estimated and true average speed was stronger when walkers were intact.

Heading Bias Based on Conflicting Local Optic Flow and Biological Motion Confirms Independent Processing Paths of Heading Perception and Object Segmentation

Krischan Koerfer and Markus Lappe
University of Münster, Germany

Heading estimation is biased if independent object motion is present. The lack of compensation for object motion indicates different pathways of heading perception and object segmentation. In prior studies, independent object motion has been bound to the corresponding distortion of local optic flow, making it impossible to analyze the impact of object motion perception on heading estimation independently. Our study used a new stimulus that decouples independent object motion and local optic flow. The stimulus displays global optic flow due to heading combined with a specific area that changes position over time consistent with the biological motion of a human walker. Within this biological motion area, dots simulate motion which can be consistent with optic flow, consistent with biological motion, or neither. Results show that participants ($N = 12$) were able to detect biological motion and that heading estimation biases based on equidistant and approaching object motion reproduce earlier findings. Furthermore, they showed that the heading estimation bias is independent on perceived walker motion direction and solely depends on the local optic flow field, confirming independent pathways of heading estimation and object segmentation.

Neural Model for the Visual Recognition of Agency and Social Interactions

Martin A. Giese, Mohammad Hovaidi-Ardestani and Nitin Saini
HIH/CIN, University Clinic Tuebingen, Germany

Heider and Simmel demonstrated that humans can perceive intent or social interactions from strongly impoverished stimuli consisting of moving geometrical shapes. While it has been proposed that this capability requires high-level cognitive processes, such as probabilistic reasoning, we demonstrate that it might be explained by much simpler, physiologically plausible neural mechanisms. We propose a model that is a hierarchical neural network with two pathways that analyze form and motion features, consistent with the architecture of the visual cortex. The highest hierarchy level contains neurons that are selective for learned combinations of relative position-, motion-, and body-axis features. We tested the model exploiting a novel stimulus genrator that models classes of social intractions by modification of dynamic models for human navigation in space. The model reproduces that moving figures with defined body axis, like a rectangle, result in stronger perceived animacy than a moving circles, iff the body axis is aligned with the motion direction. In addition, the model classifies a variety of social interaction types from abstract stimuli, including categories that have been tested in the psychophysical literature. Simple neural circuits account for a variety of effects in animacy and social interaction perception.

Manipulation of Internal Representations of Physics Through VR Training in an Unnatural Physical Environment

Tjeerd Maarten Hein Dijkstra[1,2], Jindrich Kodl[1], Chung-Chiang Yu[1] and Martin Giese[1]
[1]University Clinic Tuebingen, Germany
[2]Max Planck Institute for Developmental Biology, Tübingen, Germany

It has been hypothesized that human motor cognition relies on an internal representation of physical laws. How fast do we learn novel laws of physics, and more importantly, do such laws transfer to novel tasks? We tested these questions by designing a virtual environment where 22 participants controlled a humanoid avatar by online-motion capture. Participants manipulated a ball in different physical environments. The virtual scene was presented to the participants as a virtual mirror on large projection screen. Participants first performed a ball bouncing task (training) and then a target aiming (transfer) task. In two separate groups, the training task was performed in a normal and in an unnatural position-dependent gravity field. The test task was performed by both groups in unnatural gravity. Both groups showed increased performance over time for both tasks, indicating successful task learning. We found only minimal differences in performance between the two groups during the transfer task. This result is inconsistent with learning of an abstract

internal representation of physics and rather indicates task-specific learning.
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Line of Sight and Brain Activity During Pursuit of a Moving Target With Constant Velocity

Ryo Koshizawa, Kazuma Oki and Masaki Takayose
Nihon University, Tokyo, Japan

Visual information processing in the brain and control of eye movements contribute to the ability to pursue a moving target. To clarify the line-of-sight adjustment process in the brain, high temporal resolution is required in order to obtain information on the target location, line of sight, and brain activity. We investigated this issue by analyzing line-of-sight and electroencephalography (EEG) data that were continuously recorded in 10 participants, while they pursued a downward moving target with constant velocity on a display. According to the results of our line-of-sight analysis, positional error increased until approximately 300 milliseconds after stimulus onset and decreased between approximately 300 and 800 milliseconds after stimulus onset. The results of our EEG time–frequency analysis showed that increased theta and alpha EEG activity in the parietal cortex may contribute to the ability to focus on a target. In addition, increased beta EEG activity in the premotor cortex may contribute to the conversion of visual information processed about the target in the brain into eye movements, making it so that the target can be pursued.

Eye Movements During Movie Viewing: An Annotated Data Set and a Benchmark for Algorithmic Eye Movement Detection

Mikhail Startsev, Ioannis Agtzidis and Michael Dorr
Technical University of Munich, Germany

Recently, many visual behaviour and perception studies have shifted towards naturalistic stimuli or real-world experimental setups. However, eye movement analysis for such data, unlike for artificial controlled stimuli, is compounded by moving targets that are unknown in advance and by eye–head coordination. Even expert annotation will encounter problems in the presence of, for example, camera motion. In this work, we systematically manually annotated fixations, saccades, and smooth pursuits in a 2-hour subset of a large data set of Hollywood movie excerpt viewing, accounting for the difficulties related to camera panning and zooming. All annotations were validated by an expert and reveal, for example, a much larger proportion of pursuits for such professionally created content (compared with naturalistic stimuli), often due to camera motion rather than the motion of the targets in the physical scene. In some of the clips, smooth pursuit percentage reaches as high as 62%, overtaking fixations by a large margin. Overall, our sample-level labels contain 63% fixations, 24% pursuits, and 9% saccades. We additionally evaluated several state-of-the-art eye movement classifiers on this data, establishing a large-scale benchmark for future algorithms. All data are publicly available https://web.gin.g-node.org/ioannis.agtzidis/hollywood2_em, enabling further research into dynamic content perception in the context of movie watching.

Stability of (C)overt Attention Strategies in a Digital CORSI Task—An Eye-Tracking Study

Gregor Hardiess, Lílian de Sardenberg Schmid and Hanspeter A. Mallot
Cognitive Neuroscience, Institute of Neurobiology, University of Tübingen, Germany

The Corsi block-tapping task (CBTT) is a classic and well-established spatial working memory task in humans which demands internal computations (memorizing of Corsi sequences, organizing and updating the memorandum, and recall processes) as well as (c)overt shifts of attention to facilitate externalized rehearsal serving to maintain the Corsi sequences during the retention phase. To understand the relevance of (c)overt attention in CORSI tasks, 28 participants had to solve different CBTT conditions (within-subject design), while eye position and pupil size were monitored. As CBTT, we introduced a novel and digital version in which (a) the difficulty of the memorandum (sequence lengths reaching from 3 to 10) was controlled, (b) the execution of (c)overt attention during the retention phase was manipulated, and (c) (c)overt shifts of attention were quantified. We present behavioral data showing and characterizing for the first time the interindividual variability but intraindividual stability as well as the range in deploying (c)overt attention strategies in CBTT.

Predicting Self-Rated Uncertainty From Eye Movements in a Natural Task

Brian Sullivan[1], Hazel Doughty[2], Walterio Mayol-Cuevas[2], Dima Damen[2], Casimir Ludwig[1] and Iain D. Gilchrist[1]
[1]School of Psychological Science, University of Bristol, UK

[2]Department of Computer Science, University of Bristol, UK

Everyday tasks can have sources of uncertainty that interact with cognition, memory, perception, and motor control. Task steps may be unclear and require problem-solving, visual stimuli may require careful inspection and manipulation, and instructions may need to be encoded in memory. Is it possible to infer when an individual is uncertain from their eye movement behaviour? We examined the relationship between eye movements and uncertainty, while participants assembled a tent outdoors wearing a mobile eye tracker. Setting up a tent is naturalistic, takes several steps to achieve, and can be challenging for naive participants. We operationalize uncertainty in two ways. First, participants viewed their first-person camera video and rated their level of uncertainty frame-by-frame during the task. Second, video data were annotated to delineate subtasks, including instruction reading, and assembly errors. Using neural networks, we are evaluating if eye movement features and scene camera video can predict uncertainty. Results thus far have not found useful behavioural predictors of self-rated uncertainty, and we discuss alternate methods. In addition, we demonstrate methods to recognize subtasks and errors from video data using neural networks, comparing performance either using the full scene camera or small image patch near the fovea.

Decomposition of Manual and Ocular Following Responses Into the Direct and Interaction Components

Hiroaki Gomi and Naotoshi Abekawa
NTT Communication Science Laboratories, Kyoto, Japan

Suddenly applied surrounding visual motion elicits ultra-short latency manual flowing response (MFR) and ocular following response (OFR), which are considered to a function in reducing corresponding errors in interaction with environments. Interestingly, response specificities of MFR and OFR for the stimulus size and location were dramatically distinct from each other. To quantitatively characterize the interactions among the visual fields, we tried to reconstruct MFR and OFR amplitudes experimentally obtained by applying a linear model having direct effects and interaction effects between the adjacent fields of concentrically divided retinal area. The direct effect to MFR was strongest at 0.2 c/deg among different spatial frequency in the visual center fields but was strongest at 0.05 c/deg in the visual periphery fields. In contrast, the direct effect to OFR was strongest at 0.2 c/deg in any visual fields. As for the adjacent interaction effect, strongest negative effect was found at 0.05 c/deg in the visual periphery for the MFR, while it was at 0.2 c/deg in any visual field interaction for the OFR. This result suggests that strong inhibitory interactions exist especially between the surrounding visual fields in generating MFR, possibly contributed by distinctive spatial integration process of visual motion distinctive for the MFR.

Different Effects of Pre- and Postsaccadic Stimulus Contrast on Displacement Detection Across Saccades

Satoshi Shioiri[1], Syuhei Takano[1], Kazumichi Matsumiya[1], Chia-huei Tseng[1], Yasuhiro Hatori[1], Ichiro Kuriki[1] and Heiner Deubel[2]
[1]Tohoku University, Sendai, Japan
[2]Ludwig-Maximilians-Universität München, Munich, Germany

The visual system is much less sensitive to the displacement of a visual stimulus during saccadic eye movements than during fixation (saccadic suppression of displacement). As temporarily blanking the target after a saccade improves displacement judgments (blanking effect), suppression is suggested to be an active process. We measured the effect of stimulus contrast to investigate how pre- and postsaccadic stimulus contrast influence displacement detection. Experimental results showed that an increase of presaccadic target contrast improved displacement detection. Interestingly, however, an increase of postsaccadic contrast deteriorated perception of displacement. We also measured the effect of a brief blanking of the target after the asaccade and found improvement in the detection performance also when the contrast of postsaccadic stimulus was high, which suggests that contrast sensitivity of the suppression mechanism is lower than that of the mechanism for detection. We propose a model that explains saccadic suppression by assuming that the magno-cellular parthway is suppressed by the contrast-dependent parvo-cellular pathway for displacement detection. The model explains our experimental results of both conditions with and without blanking target. The visual processing in the parvo-cellular pathway may play a crucial role for visual perceived stability across the saccade.

Focusing on the Center Bias: Resolving Biases From Content-Based Fixations

Rotem Mairon and Ohad Ben-Shahar
Ben-Gurion University of the Negev, Beersheba, Israel

Saliency computation has long been evolved into a mature field, with well-established benchmarks. However, only recently studies have begun to explicitly address fundamental issues in evaluating computational saliency models. Specifically, such studies focus on the inconsistency of different evaluation metrics. In this poster,

we address another important aspect of saliency evaluation that concerns ground truth generation. In particular, we focus on the center bias in human fixation maps and propose a simple technique to quantify fixations that stem from this bias. Based on our findings, we make practical recommendations for more accurate ground truth generation. Then, by using a temporal based evaluation of state-of-the-art saliency models, as well as more "traditional" models, we demonstrate the significance of our findings for saliency benchmarking and optimization.

Task-Dependent Increase of Beta Activity After Eye Blinks in Occipital Cortex

Franz Aiple, Armin Brandt, Julie Blumberg, Peter Reinacher, Markus Kern and Andreas Schulze-Bonhage
University Medical Center Freiburg, Germany

Intracortical local field potentials were recorded during a visual task in epilepsy patients implanted with electrodes in temporal and occipital brain regions. Images were presented for 500 milliseconds, followed by interstimulus intervals of 1,300 milliseconds in repetitive trials. Eye blinks were detected on the basis of electrooculography signals. Trials were analyzed with respect to stimulus onset times (STON) and eye blink occurrence times (BLINK). Eye blinks during trials typically occurred within 700 to 1100 milliseconds after STON. Event-related analysis was performed separately for different frequency bands in the delta to gamma range (0.5–256 Hz). STON-aligned averaging revealed visual-evoked potentials (VEPs); BLINK-aligned averaging revealed blink-related potentials (BRPs). In occipital electrodes (areas V1, V2, FG) of four of the five patients, beta activity (11–32 Hz) increased shortly after blinks. This was more pronounced for blinks within than outside of trials. On the other hand, STON was followed by a decrease in beta activity. Modulation of beta activity during visual tasks was already discussed in the literature in the context of attentional processes but without considering the role of eye blinks. Here, we report that during our task beta activity is decreased after the appearance of visual stimuli and increased after eye blinks.

Multiple Object Tracking in Noise Background

Filip Dechterenko and Jiri Lukavsky
Institute of Psychology, Czech Academy of Sciences, Prague, Czech Republic

People are able to successfully track four moving objects among four distractors. Many factors influencing tracking performance has been identified in the past, but surprisingly, the effect of object detectability have not been addressed yet. In this study, participants ($N = 25$) tracked Gabor patches (four targets and four distractors) in $1/f$ noise. Tracking period was 6-second long, and participants selected tracked targets with mouse. Gabor's detectability was manipulated in four within-subject contrast conditions (40 trials per condition). Same trajectories were used in each detectability condition and randomized across participants. Tracking accuracy was measured in number of correctly identified targets. Preliminary results suggests that the detectability influenced the tracking (number of correctly selected targets: 2.28 for lowest contrast to 3.05 for highest contrast). Our observations show that it is necessary to distinguish between detectability in static/dynamic conditions. When objects stopped, the targets blended with background, which resulted in increased higher number of clicks required to find the targets ($M = 10.3$ clicks in low detectability conditions). The decrease in performance is probably related to both decreased detectability of the objects and increased spatial uncertainty when objects stop moving.

Gaze Differences in Multiple Object Tracking Versus Multiple Identity Tracking

Jiri Lukavsky and Filip Dechterenko
Institute of Psychology, Czech Academy of Sciences, Prague, Czech Republic

People can track moving objects with their attention. The tracking is easy (multiple object tracking [MOT]) as long as people are not required to also keep track of individual identities (multiple identity tracking [MIT]). Do eye movements differ when we need to track object identities? Previous studies comparing fixation counts and durations reached inconclusive results. Here, we exploited the fact people frequently fail to distinguish repeated MOT trials, but their eye movements are similar in repeated presentations. We compared gaze similarity in repeated MOT-MOT trials, repeated MIT-MIT trials, and repeated MOT-MIT trials ($3 \times 2 \times 25$ trials). The similarity was evaluated using Pearson correlation in spatiotemporal scanpatterns smoothed with a Gaussian filter. Our preliminary results ($N = 16$) show the gaze patterns are most similar in repeated MOT trials (Pearson r estimate = .456, 90% credible interval [CI] = [.411, .501]). The similarity drops when we compare gaze patterns across MOT and MIT tasks ($r = .307$, 90% CI [.262, .352]). The gaze patterns in MIT task are more variable compared with MOT ($r = .337$, 90% CI [.293, .382]). Our results based on spatiotemporal similarity of scanpatterns indicate the gaze behaviour differs

when we need to track object identities (relative to positional tracking).

Rapid Scene Categorization: From Coarse Peripheral Vision to Fine Central Vision

Audrey Trouilloud[1], Louise Kauffmann[1,2], Alexia Roux-Sibilon[1], Pauline Rossel[1], Nathalie Guyader[2], Martial Mermillod[1] and Carole Peyrin[1]
[1]LPNC, Univ. Grenoble Alpes, France
[2]GIPSA-Lab, Univ. Grenoble Alpes, France

Studies of scene perception have shown that low spatial frequencies (LSF) are extracted first, allowing a coarse parsing of the scene, prior to the analysis of fine information in high spatial frequencies (HSF). However, the spatial resolution of visual information is not uniform across visual field but constrained by the properties of retinal cells. The density of cell used to process HSF is greatest in the fovea, while the density of cells used to process LSF increases with foveal eccentricity. Many studies suggest that scene gist recognition can be accomplished by the low resolution of peripheral vision. Our study investigated the influence of processing order of central and peripheral visual information during rapid scene categorization. We used large scene photographs (30° of visual angle) from which we built five circular rings of different eccentricities. Rings were assembled from Central to Peripheral vision (CtP sequence) or from Peripheral to Central vision (PtC sequence). Participants had to categorize the scene sequences (indoor vs. outdoor). Results showed that participants categorized PtC sequences more rapidly than CtF sequences. This study suggests that the low resolution of peripheral vision allows an initial coarse parsing of the scene prior to the finer analysis in central vision.

Detecting Affordances in Visual Scenes: Evidence From Rapid Serial Visual Presentation

Mark Robert Nieuwenstein and Ana Dugeniuc
University Groningen, the Netherlands

When people are asked to categorize pictures of visual scenes, they tend to group the scenes by the kind of activity they allow for (e.g., Greene et al., 2016). Although this suggests that affordances constitute an important feature in human scene categorization, little is known about the perception of affordances in visual scenes. In this study, we compared how well people could detect the presence of a target scene in Rapid Serial Visual Presentation when the target was defined in terms of its gist (e.g., a harbor), an affordance (e.g., sailing), or both. Replicating previous work (Potter et al., 2014), preliminary analyses suggest that detection of targets by gist was above chance even when the sequence was shown at a rate of 10 ms/picture. Interestingly, performance for affordance-based detection did not appear to be much different from gist-based detection at this rapid rate, whereas it was considerably worse at slower rates. Finally, when both target-defining features were combined, performance was equivalent to that for gist-based search, suggesting no added benefit of specifying affordances in addition to gist. A first, preliminary conclusion from this work is that people can determine the affordances of a scene after extremely brief viewing time.

Putting Together the Parts of a Social Scene: A Frequency-Tagging Electroencephalography Study

Parvaneh Adibpour, Jean-Remy Hochmann and Liuba Papeo
CNRS, Institut des Sciences Cognitives—Marc Jeannerod, Bron, France

Recent research shows that perceiving two interacting (vs. noninteracting) bodies induces inversion effect comparable to the inversion effect found for individual bodies. This suggests specialized mechanisms for perceiving dyadic interactions, similar to single body perception. How does the brain process a dyad relative to an individual body? And how is this process affected by the spatial relation between bodies within a dyad? We separated responses to dyads of facing/interacting or nonfacing/noninteracting bodies from responses to individual bodies, using a frequency-tagging paradigm, previously employed to separate responses to whole faces versus face parts. We recorded high-density electroencephalograms, while participants ($n = 20$) watched the stimuli presented upright or inverted. Each body constituting a dyad flickered at a different frequency ($F1$ and $F2$). $F1$ and $F2$ marked the neural responses to single bodies. A third response at the intermodulation frequency ($F1-F2$) and its subharmonic ($[F1-F2]/2$) was associated with the concurrent appearance of the two bodies (dyad). Inversion affected the responses to individual bodies over posterior sites, whereas the positioning of bodies (facing/nonfacing) within dyads affected the response at the subharmonic of intermodulation frequency over anterior areas. Body- and dyad-related activations tagged here may arise from faster perceptual and slower stages of processing, respectively. These results suggest that computation of interactions between bodies involves late processes relative to the early perceptual stages of body perception.

The Role of Object and Scene Orientation in the Scene Consistency Effect

Tim Lauer[1], Verena Willenbockel[2], Laura Maffongelli[1] and Melissa Le-Hoa Võ[1]
[1]Department of Psychology, Goethe University Frankfurt, Germany
[2]Department of Psychology, University of Victoria, British Columbia, Canada

In scenes, semantically consistent objects are typically recognized better than inconsistent objects (e.g., a coffee maker in a kitchen vs. a printer). What is the role of object and scene orientation in the so-called scene consistency effect? We presented consistent and inconsistent objects either upright (Experiment 1) or inverted (i.e., rotated 180°; Experiment 2) on three types of background scenes: upright, inverted, and scrambled (control condition). In Experiment 1, on upright scenes, consistent upright objects were recognized with higher accuracy than inconsistent ones. Moreover, N300/N400 event-related potentials known to reflect object-scene semantic processing were observed in response to the inconsistent objects on upright scenes, whereas no such effects were found for inverted or scrambled scenes. In Experiment 2, on both upright and inverted scenes, consistent inverted objects were recognized with higher accuracy than inconsistent ones. In addition, inconsistent inverted objects on upright scenes triggered N300/N400 responses. Interestingly, no N300 but only a N400 deflection was found for inverted objects on inverted scenes, while no effects were observed for scrambled scenes. These data suggest that inverted scenes can modulate semantic processing (but only for inverted objects), with contextual influences occurring later in time possibly driven by delayed or impaired gist processing.

Long-Term Visual Predictions While Viewing Familiar and Unfamiliar Real-World Streets

Matthew A. Bennett, Lucy S. Petro and Lars Muckli
University of Glasgow, UK

A prominent school of thought (Friston, 2010) proposes that the brain uses internal models to predict upcoming sensory input. Internal models may be based on personal familiarity (Penny, Zeidman, & Burgess, 2013) and statistical regularities. We investigated whether personal familiarity affected visual predictions during videos of real-world streets. We filmed several 15-minute walks from a head-centred point of view. Subjects saw a personally familiar route twice and an unfamiliar route twice. Frames from 1,000-millisecond intervals were presented successively (duration 500 milliseconds; interstimulus interval 500 milliseconds). Blank intervals (4,000 milliseconds) cued subjects to mentally simulate the walk. Subjects confirmed whether frames resumed behind-time (−3,000 milliseconds), on-time (+4,000 milliseconds), or ahead-of-time (+8,000 milliseconds). A repeated-measures analysis of variance of reaction times (RTs) showed a significant Accuracy × Time interaction, $F(2, 30) = 8.78$, $p < .001$, $\eta_p^2 = .37$, and an almost significant Accuracy × Familiarity interaction, $F(1, 15) = 4.43$, $p = .053$, $\eta_p^2 = .29$. Post hoc pairwise comparisons showed significantly faster RTs for correct confirmations versus incorrect rejections: only for on-time trials (270.58 milliseconds, $p < .0001$) and only during familiar routes (152.68 milliseconds, $p < .01$). Sensory inputs matching the prediction ("on-time" trials) are more sensitive regarding correct confirmations versus incorrect rejections, particularly during personally familiar routes. This suggests visual predictions are generated up to 4 seconds into the future and that predictive processing is richer for internal models based on extensive personal familiarity.

Do Sleep Slow Waves Modulate Information Processing Along the Visual Pathway?

Alexandra Y. Vossen and Sarang S. Dalal
Aarhus University, Denmark

Cortical slow waves (SW) generated during deep sleep reflect alternating phases of heightened or depressed cortical excitability which affect the magnitude of the brain's response to sensory information ("sensory gating"), at least in the acoustic and somatosensory domain. This study investigates if SW-phase also modulates the response to visual stimuli, and if this happens early (in the retina) or late (in the cortex) along the visual pathway. Whether humans have cortico-retinal feedback connections is controversial, retinal response modulation would provide evidence supporting their existence. Sixteen healthy volunteers were stimulated with alternating monocular light flashes (interstimulus interval 1–2 seconds) overnight while sleeping. Following one habituation night, cortical and retinal responses were measured on the second night using electroencephalography (EEG) and electroretinography (ERG). All volunteers were able to sleep and only mildly to moderately disturbed by the flash stimulation, although sleep onset was generally delayed and more frequently interrupted. Preliminary analyses confirm the presence of visual-evoked responses and SW-activity in the EEG. Flash-evoked ERG b–waves were demonstrated throughout the night in all participants; oscillatory potentials (100–160 Hz) were observed in a subset. Ongoing analyses of the relationship of these responses to

SW-phase will inform our understanding of sensory gating in the visual system during sleep.

Poster Session 2

Memory-Driven Attentional Capture Comprises Separable Stages of Feature and Object Levels

Koeun Jung, Suk Won Han and Yoonki Min
Chungnam National University, Daejeon, Republic of Korea (South Korea)

When we search for a prespecified target in a visual scene, a stimulus matching working memory is prioritized for attentional selection. This study aimed at clarifying whether this memory-driven attentional capture takes place in an object-based manner or a manner comprising separable stages of feature and object levels. In the experiment, participants performed visual search tasks while maintaining the color or shape of a colored shape. When participants were required to memorize the color of the memory sample, the shape of the sample is task-irrelevant feature and vice versa. Importantly, while irrelevant-memory matching stimuli were presented in visual search for on group of participants, relevant-memory matching stimuli appeared for the other group of participants. Furthermore, we varied stimulus onset asynchrony (SOA) between the memory sample and search items. As results, relevant-matching stimuli captured attention regardless of whether the SOA was short or long. However, the SOA affected the capture by irrelevant-matching stimuli; no capture was observed at the shortest SOA, but significant capture was found at longer SOAs, $p < .05$. These findings suggest that attentional guidance by memory-matching stimuli occurs in a manner comprising separable stages of feature and object levels rather than in a strict object-based manner.

Comparing the Effects of Feature-Based Attention on SSVEPs and Behaviour

Nika Adamian and Søren Krogh Andersen
University of Aberdeen, UK

Recent studies suggest that steady-state visual-evoked potentials (SSVEPs) can explain per-trial evidence accumulation and resulting behavioural decisions. Here, we aim to test whether changes in reaction times and SSVEP amplitudes in feature-based attention task could be explained by a common mechanism. Twenty participants observed two superimposed fields of randomly moving blue and red dots in order to detect coherent motion. When one colour was cued (attended condition), 75% of targets occurred in the attended dot field. When both colours were cued (neutral condition), the targets occurred equally frequently in both dot fields. Reaction time (RT) distributions in each condition and stimulus were analysed by estimating three parameters of a shifted Wald model: threshold, shift, and drift rate. Attentional modulation in early visual cortex was quantified by means of SSVEPs in 1-second time windows immediately preceding the onset of motion and the subsequent successful detection. The results suggest that attention modulates drift rate and shift parameters of the RT distribution but has little influence on the threshold. Regression analysis suggests a small but significant association between the parameters of fitted Wald distribution and SSVEP rates.

Correct Feature Binding Is Determined by the Speed of Attentional Engagement

Alon Zivony, Rebecca Nako, Nick Berggren and Martin Eimer
Birkbeck, University of London, UK

We tested whether the identification of targets in rapidly changing environments depends on the speed of attentional allocation processes. When a target and a distractor that share a target-defining attribute appear in close succession, participants often erroneously report the identity of the distractor. Previous studies showed that such distractor intrusion effects are mediated by attentional factors, but it remains unclear which attentional processes are responsible. We employed a task where two streams containing letters and digits appeared in rapid succession on the left and right side. Participants had to report the identity of a target digit enclosed in a predefined shape. The onset and offset of attentional episodes were tracked by measuring N2pc components, separately for trials where participants correctly identified the target and intrusion trials where participants reported the digit that immediately followed the target. N2pc onsets but not offsets were earlier on correct trials relative to intrusion trials. The subsequent Pd component that is associated with distractor suppression also differed between these trials. These findings suggest that variability in the speed of attentional engagement affects the level of feature activation and binding within attentional episodes, which in turn determines perceptual reports.

The Impact of Shape-Based Cue Discriminability on Attentional Performance

Olga Lukashova-Sanz[1], Siegfried Wahl[1,2] and Katharina Rifai[1,2]
[1]ZEISS Vision Science Lab, Institute for Ophthalmic Research, University of Tübingen, Germany
[2]Carl Zeiss Vision International GmbH, Aalen, Germany

Numerous studies investigated modulation of attention deployment when varying the target, distractors, or the task in attentional paradigm. Fewer, however, looked into modulation of the cue itself. Previously, it was shown that cue contrast manipulates exogenous attention at contrast levels where the cue is fully localized. We investigated whether manipulation of a shape-based endogenous spatial cue by varying discriminability modulates attentional performance in a gradual way as well, considering costs of shape decoding. Eleven naive observers performed an orientation-discrimination task. They were presented a shape-based direction indicating cue, followed by a display of two tilted Gabor patches. Thereafter, a response-cue at fixation location indicated the final response target location. Attentional performance was evaluated selectively for attended and unattended target locations as well as for two different cue-target interstimulus intervals. Results show improved performance in attended target locations and decreased performance in unattended target locations. Attentional benefits and costs increase with cue discriminability, thus, discriminability of an endogenous shape-based spatial cue modulates endogenous attention. On the basis of performance differences depending on the cue-target interstimulus interval, an influence of cue processing time is discussed.

Reward-Driven Capture Effect Is Region-Specific But Can Be Across Modalities

Bing Li and Zhuanghua Shi
General and Experimental Psychology, Department of Psychology, LMU Munich, Germany

It has been shown that reward-associated but task-irrelevant visual stimuli can capture attention in visual search. However, it is unclear whether reward-associated visual stimuli would capture attention across modalities. To investigate this, we designed three experiments using visual and visual-tactile search tasks. In Experiment 1, we used visual search paradigm with left-right search array and partially replicated previous findings (Anderson, 2011). Interestingly, we found the reward-associated distractor influenced search accuracy significantly only when the target and the rewarded distractor were on the same side. In Experiments 2 and 3, we used visual-tactile search and again found reward-associated capture effect (in accuracy) was only significant when the reward-associated distractor and the target were on the same side. The findings suggested that reward-driven capture effect was region-specific effect, and this effect could spread across modalities.

Distinct Modes of Reward-Related Modulation of Perceptual Sensitivity Depending on the Task Relevance

Jessica Emily Antono, Roman Vakhrushev and Arezoo Pooresmaeili
European Neuroscience Institute—Goettingen, Germany

Visual sensitivity can be enhanced through reward, attention, or both. They may engage different gating mechanisms to prioritize processing of information. However, the distinction between these factors has remained elusive. This study employs two paradigms involving different relationship of reward to the task at hand to dissociate reward and attention. Participants discriminated the orientation of a Gabor patch that was presented together with a visual or auditory reward cue. In the first paradigm, the cues were previously associated with monetary reward and during the task led to no reward (task-irrelevant), whereas in the second paradigm, they led to different amounts of reward after correct performance (task-relevant). We hypothesized that task-irrelevant cues involve reward modulation per se with minimal involvement of attention, whereas task-relevant cues engage reward and attentional modulation. Our preliminary results demonstrate that task-relevant reward cues of both modalities facilitate visual sensitivity. However, task-irrelevant cues facilitate performance in auditory cues but are suppressive in visual cues. We suggest that reward cues in the two paradigms act differently: Task-relevant cues engage endogenous attention to prioritize reward, whereas task-irrelevant cues rely on exogenous attention and could lead to suppression when they share the same processing resources as the target.

Basic Shapes Guide Visual Attention Based on Search Goals

Markus Grüner, Florian Goller and Ulrich Ansorge
University of Vienna, Austria

We investigated whether basic shapes can guide visual attention in a goal-directed manner. Participants searched for one specific target shape among different basic shapes (square, diamond, triangle, and pyramid) and reported the color of a dot within the target shape. Before the target

display was shown, we presented a matching or nonmatching cue among three circles. The matching cue had the same shape as the target, whereas the nonmatching cue was a hexagon, which was never part of the target display. We found faster reaction times when the matching cue appeared at the same position as the target (valid condition) compared with a different position (invalid condition), suggesting that the matching cue captured attention. However, the nonmatching did not capture attention (same reaction times in the valid and invalid condition), despite being a salient singleton. Results are discussed in terms of top-down contingent-capture theory.

Adaptation Facilitates Visual Search for Scenes

Qiu Jing Yong and Ahamed Miflah Hussain Ismail
University of Nottingham Malaysia, Semenyih, Malaysia

The "naturalness" of scenes (i.e., man-made or nonman-made) is a higher level feature that is believed to be selectively encoded by neurons. We examined the functional role of adaptation (i.e., prolonged exposure) to this feature. In a series of trials, 20 participants searched for a target scene that was randomly placed in one of the eight equidistant (peripheral) positions from the fixation point (a clock-like arrangement). The targets varied in their level of naturalness (25%, 50%, or 75%) and were placed among seven other distracting scenes that were all man-made (0% natural; e.g., a building) or were all completely nonman-made (100% natural; e.g., forest). Initially, all participants searched for targets with no adaptation. Subsequently, they performed the search task after adapting to a series of scenes of 0% and 100% naturalness (in separate blocks) presented at fixation. Compared with no adaptation, both adapting conditions reduced search durations for targets that slightly but not largely differing in naturalness from the adaptors (e.g., adapting to 0% scenes facilitated search for 25% but not 75% targets, placed among 0% distractors). Our findings suggest that adaptation serves to exaggerate feature differences between scenes and facilitate the search for scenes differing slightly from our temporal context.

Target–Distracter Similarity in Visual Search for Multiple Targets

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

Subsequent search misses is a second target omission after the first one was detected in visual search task (Adamo et al., 2013). In our experiment, we investigated the role of target–distracter similarity in second target omission. The experiment involved visual search task. Twenty stimuli were displayed within each trial. Targets were defined as the specific letters, presented among other letters. On each trial, there could be two, one, or no targets on the screen. Color and size of the stimuli were varied. Targets could be equal to distractors in color and size, differ in color or size, and differ in color and size. Participant's task was to detect all targets or to report their absence. Accuracy of the second target detection was analyzed for different levels of target–distracter similarity. Repeated measures analysis of variance revealed the significant effect of target–distracter similarity ($F = 34.137$; $p < .001$; $\eta^2 = 0.587$). The accuracy of second target detection increased with decreasing target–distracter similarity. Further investigations are required in order to understand whether this result is due to basic visual search patterns (Duncan & Humphreys, 1989) or related to the specific second target detection mechanism.

The Role of Categorical and Perceptual Similarity of Targets in Subsequent Search Misses

Olga Rubtsova and Elena Gorbunova
National Research University Higher School of Economics, Moscow, Russia

Subsequent search misses (SSM) effect is the reduction in accuracy of finding the second target after finding the first target. It has been shown that perceptual and categorical targets similarity leads to the decrease of SSM. Our study investigated the impact of both perceptual and categorical targets similarity on the SSM. We used a visual search task and letters of Russian alphabet as stimuli. Vowels were used as targets, and consonants were used as distractors. Each trial could contain two, one, or no targets. In case of two targets, they could have categorical or perceptual similarity: the first was determined by the letter name (A and A or A and E) and the latter was determined by the way of writing (uppercase and uppercase or uppercase and lowercase). A degree of targets similarity was varied (only categorical, only perceptual, both categorical and perceptual, and neither categorical nor perceptual). Accuracy and reaction time were analyzed. Analysis of variance revealed the significant impact of similarity, $F(3,74) = 13,231$; $p < .001$; $\eta^2 = 0.329$. SSM effect was observed only for categorically and perceptually different targets. Categorically similar vowels were found faster than perceptually similar, which supports the hypothesis of categorical superiority in emergence of SSM.

Search Efficiency Is Not Correlated Between Visual and Memory Foraging Tasks

Shunsuke Kumakiri and Jun Saiki
Kyoto University, Japan

Search behavior requires continuous and immediate decision-making by integrating visual and memory information. Previous studies have shown that the optimal foraging theory can account for both visual and memory search behavior with multiple targets. However, as visual and memory search have been investigated separately, the domain-specificity of decision-making in search remains unknown. A domain-general decision process predicts intertask correlation between visual and memory search. Sixty-four participants performed a visual foraging task and a semantic fluency task, with the similar task structure. In the visual foraging task, each search display contained unknown number of targets, and participants maximize the number of searched targets within the time limit by efficiently switching search displays. In the semantic fluency task, participants produced words belonging to seven categories (animal, food, etc.) and maximized the number of words by efficiently switching subcategories. The index of optimality was defined as the difference in search time distribution between observed data and prediction by the optimal foraging theory. Both visual and memory search tasks showed a significant correlation between the optimality index and the number of searched items. However, the optimality was not correlated between the two tasks, suggesting that decision-making in search behavior is task-specific.

Manipulating "Foraging Tempo" to Explore Temporal Constraints During Multiple-Target Visual Search

Ian M. Thornton[1], Tram T. N. Nguyen[1] and Árni Kristjánsson[2]
[1]Department of Cognitive Science, University of Malta, Msida, Malta
[2]Faculty of Psychology, University of Iceland, Reykjavik, Iceland

Recently, we suggested that the self-imposed speed ("foraging tempo") with which participants select consecutive items in multiple-target visual search tasks is a major factor for determining patterns of category selection (Thornton, Kristjánsson, & de'Sperati, 2019). Specifically, when consecutive responses occur very rapidly (e.g., 400 ms/item), additional attentional load (e.g., conjunction vs. feature search) strongly increases the tendency to select in "runs" from the same category. When consecutive responses occur at a slower rate (e.g., 800 ms/item), the same attentional manipulations have little or no effect. Here, we introduce a new task variant where we explicitly control foraging tempo. Only "patches" of eight items (four targets/four distractors) from the overall search array were visible at any one time, and a single response was required for each patch. Participants completed three blocks of feature and three blocks of conjunction foraging. Across blocks, we systematically varied the speed with which subsequent patches appeared, providing slow, medium, and fast tempo trials. Dependent variables were misses (no response to a patch), errors, and patterns of runs. Initial data indicate that, as expected, the rate of misses and errors increase as the tempo increases, and the rate of switching between categories decreases.

The Role of Categorical Grouping and Segmentation in the Subset Visual Search Task

Vladislav A. Khvostov[1], Igor S. Utochkin[1] and Jeremy M. Wolfe[2]
[1]National Research University Higher School of Economics, Moscow, Russia
[2]Visual Attention Lab, Brigham & Women's Hospital & Harvard Medical School, Boston, MA, USA

Efficient feature search for orientation or color targets seems to require coarse, categorical differences between targets and distractors (Wolfe et al., 1992). Interestingly, relatively efficient search for conjunctions of color and orientation are possible even if target and distractor features are not categorical (Utochkin et al., VSS, 2019). Top-down activation of the target features can effectively guide attention to the target location even if target and distractor features are not clearly segmented from one another. Here, we ask about the role of segmentation in "subset search" where top-down guidance is limited to one feature of a conjunction. Colors could be homogeneously red or blue (segmentable) or heterogeneously reddish or bluish (nonsegmentable). Orientations could be homogeneously steep (near vertical) or shallow (near horizontal) or heterogeneously steep/shallow. Observers searched for an odd orientation in the red (reddish) subset. All combinations of segmentable or unsegmentable color and orientation produced relatively efficient search. However, conditions where one or both features were unsegmentable were markedly slower (higher intercept). This suggests that it took longer to guide attention to, for example, reddish subsets than to red ones, but guidance remained possible. This could be useful in a world where guiding features are variable.

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Interindividual Variability of Short-Term Ocular Dominance Plasticity in Human Adults

Cecilia Steinwurzel[1], Silvia Animali[2], Maria Concetta Morrone[3,4] and Paola Binda[3,5]
[1]Department of Neuroscience, Psychology, Pharmacology and Child Health (NEUROFARBA), University of Florence, Italy
[2]Department of Surgical Medical Molecular and Critical Area Pathology, University of Pisa, Italy
[3]Department of Translational Research and of New Surgical and Medical Technologies, University of Pisa, Italy
[4]IRCCS Stella Maris, Calambrone (Pisa), Italy
[5]Institute of Neuroscience CNR, Pisa, Italy

Recent studies have revealed an unexpected residual plastic potential of the adult visual cortex by demonstrating a form of short-term ocular dominance (OD) plasticity, which has been linked with GABAergic inhibitory signalling in the visual cortex. To quantify this phenomenon and gather insight into its interindividual variability, we measured OD using binocular rivalry before and after 2-hour monocular deprivation (eye patching) in 35 human adults. All but two subjects showed the expected OD shift in favour of the deprived eye. Nearly 50% of the variance in this OD plasticity effect could be predicted from the dynamics of binocular rivalry before patching. More mixed percepts predict stronger OD plasticity, together with an interaction between the amount of mixed percepts and the rate of switch between eyes. We speculate that switch rate and mixed percepts reflect two types of inhibitory signals: specific interocular inhibition (promoting binocular fusion, hence mixed percepts) and generally related to the stability of perceptual representations (promoting slower switch rates). Switch rate and mixed percepts are relatively stable characteristics of each individual; the unexplained portion of variance in OD plasticity leaves room of intraindividual differences, which has been suggested to arise from factors like physical exercise and metabolism.

The Effect of Perceptual Learning in the Treatment of Anisometropic Amblyopia

Li Li[1], Wei Shi[1], Xiang Tan[2], Hang Chu[2], Shasha Pang[2], Yanping Lin[2] and Li Yan[2]
[1]Beijing Children's Hospital, People's Republic of China
[2]Research Center of National Healthcare Appliance Engineering Technology, People's Republic of China

An 15-years-old boy presented to our department with the diagnosis of anisometropic amblyopia. The corrected visual acuity of his right eye was 20/25, and left eye was 20/100. Visual perceptual learning and test were used by binocular polarized dichoptic viewing equipment. The result of perceptual examination showed that the binocular visual function was destroyed, and there was severe inhibition and no stereoscopic function. After 1-year perceptual learning (focus on the signal-to-noise ratio balance training and stereoscopic perception training), the corrected visual acuity of both eyes were recovered to 20/20. And followed up for 1 year, binocular vision was stable. The results supported that perceptual learning may be an effective therapeutic method to the anisometropic amblyopia.

Binocular Rivalry From Luminance-Only Contrast

Sharon X. Qiu, Catherine L. Caldwell, Jia Y. You and Janine D. Mendola
Depatment of Ophthalmology and Visual Sciences, McGill University, Montreal, Quebec, Canada

Binocular rivalry is the phenomenon that when two incompatible images are simultaneously presented, one to each eye, the two images compete with each other to be the dominant percept. Levelt's propositions, originally published over 50 years ago, are not only useful for characterizing the perceptual dynamics of binocular rivalry but can also provide a metric for comparing the mechanisms of binocular rivalry when diverse stimulus types are used. In this study, we conducted a battery of psychophysics experiments, where we compared the rivalry dynamics of two quite different types of stimuli. Orthogonal gratings, the most classic type of rivalry stimulus, were contrasted with luminance patches, a type of rivalry stimulus that is relatively novel and less studied. Our results showed that, similar to the orthogonal gratings, luminance-only rivalry was described by the modified Levelt's propositions (e.g., Brascamp et al., 2015), which supports the prevalent view in the literature that the modified Levelt's propositions can well describe the dynamics of different types of binocular rivalry stimuli. Moreover, our results suggested that the grating stimuli and the luminance patch stimuli shared common and differential neural mechanisms in the contexts of contrast normalization models and Wilson's "escape" model.

Glasses Without Binocular Parallax

Kazuhisa Yanaka, Takumi Sunaoshi and Toshiaki Yamanouchi
Kanagawa Institute of Technology, Japan

Most three-dimensional image display devices use binocular parallax, which is a physiological depth cue. However, monocular stereo vision without binocular parallax has been recognized, and split-depth GIFs are an example of this type. In this case, if a stimulus is observed with both

eyes, then a display, such as an LCD, is actually flat. Thus, the amount of illusion decreases. Looking with one eye only is desirable but is physically burdensome for a subject. Therefore, we create special glasses with no parallax between the left and right eye images, even with both eyes open. These glasses are made of passive optics only. The light that comes from the front of these glasses is split by a half mirror into two and then reflected by an ordinary mirror or prism and enters the right and left eyes. Thus, the right and left eyes see the same image. When these glasses are used to observe split-depth GIFs, the amount of optical illusion is lesser than when one eye is closed but is larger than when viewed with both eyes. These glasses will be useful for studying stereoscopic vision.

Comparing Bias and Precision of Stochastic and Bayesian Procedures for Disparity Threshold Estimation

Sandra Arranz Paraíso[1], José C. Chacón[1] and Ignacio Serrano-Pedraza[1,2]
[1]Faculty of Psychology, Complutense University of Madrid, Spain
[2]Institute of Neuroscience, Newcastle University, UK

Bayesian procedures are broadly used in vision science to estimate thresholds. However, they need to do certain assumptions about the parameters that characterize the subject's psychometric function. Incorrect parameters may increase bias and reduce precision in threshold estimation. Although fixed step size procedures do not require additional assumptions, these procedures have some flaws regarding asymptotic properties. However, using a stochastic approximation, both issues could be solved (Faes et al., 2007). Here, we have compared two stochastic procedures (Robbins–Monro procedure, 1951, and its accelerated version, Kesten, 1958) and a well-known Bayesian procedure (ZEST).We ran Monte Carlo simulations to measure bias and precision of threshold estimations for the three different procedures in a two-alternative forced choice disparity detection task. Two cumulative distributions (Weibull and Logistic) and different slope values were tested. Our results show that Bayesian staircases yield smaller bias and higher precision when the subject's psychometric function is known or if the parameters are chosen carefully (e.g., underestimation of the slope when it is approximately known). However, if the parameters or the shape of the assumed psychometric function are unknown, we recommend using the Robbins–Monro procedure or its accelerated version.

Comparison of Binocular Imbalance in Emmetropic and Myopic Volunteers Under a Nonimmersive Virtual Reality Platform

Jin Zeng
Guangdong Provincial People's Hospital, Guangzhou, People's Republic of China

The objective of this study is to compare the status of binocular imbalance between emmetropic volunteers and myopic volunteers and to explore the correlation between binocular imbalance and myopia and provide a new idea of the development and progression of myopia in clinic. A retrospective study recruited 97 volunteers (56 emmetropia and 41 myopia) whose uncorrected or corrected visual acuity are better than 0.8. Binocular visual function was tested in a nonimmersive virtual reality platform. The status of binocular imbalance, refraction, and degree of reflection measured by Hirschberg Test were analyzed. In the stimulation mode of vertical bar contrast sensitivity, the status of binocular balance between myopic and emmetropic subjects was statistically significant ($F = 4.803$, $p = .028$, $p < .05$) and myopic subjects showed more inhibition. In the high-frequency stimulation mode, the status of binocular balance between myopic and emmetropic subjects was statistically significant ($F = -2.497$, $p = .013$, $p < .05$), and emmetropic patients showed more binocular imbalance. Emmetropic volunteers showed more binocular imbalance. Physiological binocular imbalance allows the eyes to function alternately, helping to relieve visual fatigue. Long-term binocular fusion or monocular inhibition is more likely to aggravate visual fatigue of one eye, which may cause or promote progression of myopia.

Do We Use Different Gaze Strategies to Discriminate Extremely Similar Faces?

Isabelle Bülthoff[1] and Mintao Zhao[1,2]
[1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany
[2]University of East Anglia, Norwich, UK

When two faces are displayed next to each other under similar viewing conditions, we can easily judge whether they represent the same person or not. However, little is known about how well our visual system can differentiate between two faces with increasing levels of similarity. Even less is known about whether differentiating between similar or different faces induces different gaze patterns. To measure the limits of face discrimination ability, we used pairs of morphed faces that were created with an equal number of "parent" faces but never shared any parent faces. To manipulate similarity, we increased the number

of parents; the larger the number of parents the more similar the test faces were. Participants remained over guessing rate even when test faces were created out of 32 parents faces each, demonstrating remarkable face discrimination ability. To investigate whether the increased similarity between test faces affects how we compare them, participants' eye movements were tracked during the discrimination task. Increased face similarity elicits more gaze fixations overall. However, the gaze distribution pattern remained the same whether participants saw two highly similar or dissimilar faces. These results demonstrate that we use stable gaze strategies for discriminating two faces regardless of task difficulty.

Eye Movements During a Face Race Categorization Task

Benay Baskurt[1,2], Christian Wallraven[3] and Isabelle Bülthoff[2]
[1]International Max Planck Research School for Cognitive and Systems Neuroscience, University of Tübingen, Germany
[2]Max Planck Institute for Biological Cybernetics, Human Perception, Cognition and Action, Tübingen, Germany
[3]Department of Brain and Cognitive Engineering, Korea University, Seoul, Republic of Korea

In a previous study, we paired Asian to Caucasian faces and exchanged a single facial feature between both faces of a pair (e.g., the eyes). These manipulations resulted, for example, in a Caucasian face with an Asian nose. We could show that participants' race decision about such modified faces is mostly influenced by the ethnicity of the eyes and the skin, while the ethnicity of other facial features (shape, contour, nose, mouth) affected their decision less. Here, we repeated this study with an eye-tracker recording participants' gaze during the task. Our aim was to assess whether modifying the faces would alter participants' gaze distribution, in particular, whether exchanged features (i.e., displaying another ethnicity than all other facial components in the test face) would attract more fixations than when the features were unaltered. The categorization results of 24 Caucasian participants confirmed our previous findings; face ethnicity perception is strongly dependent on the eyes. The eye gaze results suggest that participants fixated the eyes more when other features than the eyes (especially shape, skin, or facial contour) were manipulated in Caucasian faces, thus when the perceived race of the face was less clear.

Early Visual Potentials Related to Extremely Fast Saccades Toward Faces From Joint Electroencephalography and Eye Movement's Data

Léa Entzmann[1], Anne Guerin Dugue[2] and Nathalie Guyader[2]
[1]CNRS, LPNC, Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, France
[2]GIPSA-Lab, Grenoble INP, CNRS, Univ. Grenoble Alpes, France

Previous studies have demonstrated using a saccadic choice task that we are able to elicit very fast and accurate saccades toward face images compared with other categories of images. With this study, we investigated the neural correlate of these extremely fast saccades toward faces using a joint recording of electroencephalographic activity and eye movements. Participants ($N = 26$) were presented simultaneously with two images and had to perform a saccade toward the target image (face or vehicle). Mean eye saccade-related potentials were analyzed depending on target category (face or vehicle) and saccade accuracy (correct saccade toward target or error saccade at the opposite direction of the target). Notably, target category and saccade accuracy appears to modulate the lambda wave at the fixation onset and the presaccadic activity at the saccade onset. Very interestingly, a higher presaccadic activity was found for error compared with correct saccades and for faces compared with vehicles ($p < .0001$). These last results show a distinction between the target and more interestingly the accuracy of the saccade even before saccade onset, suggesting a differentiation as early as the saccade programming period.

Fixation-Related Potentials Reveal Category Selective Activity, Upon First, But Not Second, Fixations on Faces

Carmel R. Asch[1], Oded Bein[2] and Leon Y. Deouell[1]
[1]Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Israel
[2]Department of Psychology, The Hebrew University of Jerusalem, Israel

Event-related paradigms (ERPs) provide control over experimental conditions yet ignore the natural dynamics of visual perception involving eye movements. Fixation-related potentials (FRPs) overcome this limitation yet require deconvolution of overlapping responses to temporally proximal fixations. We used EEG with simultaneous eye tracking in 12 subjects with two aims: (a) comparing the face-sensitive activity evoked by stimulus abrupt appearance (N170), with that evoked by self-controlled fixations and (b) explore whether such activity is apparent in ensuing fixations on the same object. We presented face and nonface stimuli in three conditions: (a) cued-saccade for analyzing guided eye

movement FRPs, (b) free-viewing for analyzing self-guided eye movement FRPs, and (c) control for analyzing classical ERPs. All FRP analysis was done using a multiple regression generalized linear model framework for activity overlap correction. The face-selective (faces minus nonfaces) FRP component elicited by the first fixation on stimuli and the classic ERP showed overall similar spatio-temporal characteristics. Major topographical differences between the responses emerged, however, within category, and we present source simulations to provide possible interpretation of the results. Second fixations did not elicit any category-specific activity in any of the three conditions. While this may be explained by adaptation, the unaltered perception remains a puzzle.

Investigating Association Between Viewers' Eye Movements and Face Recognition Performance With Hidden Markov Model

Shun Ohue, Ryoko Yamada and Shigeru Akamatsu
Hosei University, Tokyo, Japan

We applied a hidden Markov model (HMM)-based method to eye movements to investigate the association with face recognition from a machine learning perspective. We used a set of computer-generated faces that included both images of actual faces and synthetic images obtained by transforming the impressions of the original faces. With these visual stimuli, we conducted a simple face recognition experiment and participants judged whether they had seen the faces before. We obtained a quantitative hit rate score for each stimulus and subject. We also tracked their eye movements and recorded as temporal chains their gaze fixation points using an eye-tracking system. For each class of face stimulus and subject, we estimated the HMM parameters from the training samples of the eye movement. For the given eye movement data as test samples, we conducted a classification test among the predefined classes based on the differences of the log-likelihood values obtained from each HMM. Better discrimination of the subjects by HMM-based classification of the eye movement data corresponded to worse face recognition scores, suggesting that individually consistent eye movement patterns may lower the face recognition performance.

The Role of Tilt in Face Gaze Behavior

Nicolas Davidenko
University of California, Santa Cruz, CA, USA

It is well established that upright faces elicit a "left gaze bias"—a tendency to fixate and attend to left side of the face (defined from the observer's perspective). However, little is known about how the left gaze bias manifests in tilted faces in which the two eyes are vertically displaced. In three eye-tracking experiments, participants judged the expressions of upright and tilted faces ($\pm 45^\circ$ in Experiments 1 and 3, and a wider range of angles in Experiment 2), while their eye movements were monitored with a 60-Hz GazePoint eye tracker. Independent coders analyzed the locations of participants' first and second fixations during the 1,500-millisecond period each face was displayed on the screen. Across all three experiments, participants' fixations were robustly drawn to the upper eye in tilted faces. This "upper eye bias" was present for both clockwise and counterclockwise tilts, peaked around $\pm 45^\circ$ and quickly overrode the left gaze bias with as little as an 11.25° tilt. Furthermore, tilted faces elicited more overall eye-directed fixations than upright faces, a finding with intriguing implications for social cognition research.

Task-Related Gaze Control in Human Crowd Navigation

Roy S. Hessels[1,2], Andrea J. van Doorn[1], Jeroen S. Benjamins[1,3], Gijs A. Holleman[1,2] and Ignace T. C. Hooge[1]
[1]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[2]Department of Developmental Psychology, Utrecht University, the Netherlands
[3]Social, Health and Organizational Psychology, Utrecht University, the Netherlands

Human crowds provide an interesting case for the perception of people. Based on the literature on task-control of eye movements, one may expect that people are looked at if necessary for the task of navigating a crowd. Based on the literature on social attention, however, one might expect faces to be special and attract or maintain gaze more than necessary for task performance. We investigated how gaze is task-dependent during crowd navigation. Observers ($n = 11$) wore eye-tracking glasses and walked two rounds through hallways containing walking crowds ($n = 38$) and static objects. For Round 1, observers were instructed to avoid collisions. For Round 2, observers furthermore had to assess whether oncoming people made eye contact. Task performance (walking speed, absence of collisions) was similar across rounds. Dwell durations indicated that heads, bodies, objects, and walls maintained gaze comparably long. Only crowds in the distance maintained gaze longer. When eye contact was assessed, heads were fixated more often at the cost of looking at bodies. Gaze behavior in crowd navigation is task-dependent. Assessing eye contact while navigating crowds led observers to look at heads instead of bodies, which

suggests that not every fixation is strictly necessary for navigating crowds.

Eye Tracking During Interactive Face Perception: Does Speech Affect Eye-Tracking Data Quality?

Gijs A. Holleman[1,2], Roy S. Hessels[1,2], Chantal Kemner[1,3] and Ignace T. C. Hooge[1]
[1]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[2]Department of Developmental Psychology, Utrecht University, the Netherlands
[3]Brain Center Rudolf Magnus, University Medical Center Utrecht, the Netherlands

High-quality eye-tracking data are typically obtained when subjects are restrained with a chinrest or headrest while they passively perceive visual stimuli. However, during face-to-face interactions, people may talk, gesture, and move their head, body, and parts of their face. These conditions deviate from optimal eye-tracking conditions and may affect eye-tracking data quality but have hitherto not been investigated or quantified. In this study, we are interested in how speech affects eye-tracking data quality during interactive face perception. In a dual eye-tracking setup with a live video-connection, we measured gaze of two subjects simultaneously. Subjects ($n = 20$) were given several tasks to carry out in pairs: speaking, listening, turn-taking, staring, and chewing candy. We compared data loss (DL) and variable error (root mean square [RMS]-s2s deviation) for each task. Data loss and the variable error were highest when subjects were speaking (DL = 31.6%, RMS = 1.9°) and when subjects took turns speaking/listening (DL = 33.1%, RMS = 1.8°) and lowest when subjects were only listening (DL = 12.3%, RMS = 1.5°), staring (DL = 17.9%, RMS = 0.7°), or chewing candy (DL = 16.3%, RMS = 1.6°). Researchers interested in the study of face perception during social interaction need to be aware that speech and turn-taking behavior may decrease eye-tracking data quality, which affects eye-tracking data analysis.

The Extent of Gaze Following During Face-to-Face Conversation

Szonya Durant, Malgorzata Sobecka, Elicia Lobo, Sarah Devane and Vardah Mahmood
Royal Holloway, University of London, UK

The direction of gaze of others is often a powerful guide of our attention, potentially due to the social implications. However, to date, few studies have measured gaze following in the "real life" social situations. In our setup, the experimenter had a conversation with the participant who was wearing eye-tracking glasses. Two books on the table could be cued by the experimenter looking down left or right. We found that the probability of looking at the cued book was not increased after the gaze cue (on average 3% chance of looking at a book that has just been cued). To check whether the gaze cues were detectable, we used the (stabilized) eye-tracking glasses recordings of the experimenter and asked a new set of participants to look at the books after the gaze cues. For this task, the probability of looking at the cued book was 36.0%, averaged over all participants for each clip, a significant increase, suggesting the gaze cues were detectable. Our data suggest that during face-to-face conversation, gaze following does not necessarily occur. During conversation, other social information may be more important to attend to, rather than the object of the other person's gaze.

Neural Dynamics of Categorical Information in Visual and Auditory Signals

Polina Iamshchinina[1,2], Agnessa Karapetian[1], Daniel Kaiser[1] and Radoslaw M. Cichy[1,2,3]
[1]Department of Education and Psychology, Freie Universität Berlin, Germany
[2]Berlin School of Mind and Brain, Humboldt-Universität Berlin, Germany
[3]Bernstein Center for Computational Neuroscience Berlin, Germany

When we see an image of pineapple or hear somebody saying this word, we can rapidly and effortlessly understand what object is meant and categorize it (e.g., natural vs. manmade). It is unclear though how the brain extracts this categorical information from the sensory signals. In this study, we used electroencephalography ($N = 47$) and time-resolved multivariate pattern analysis to investigate the time course with which object identity and category information emerge in the visual and auditory modality, respectively. This analysis revealed two key results. First, representations differentiating between object exemplars emerged rapidly at around 70 milliseconds (sign-permutation test, $p < .05$) both in visual and auditory modality. Second, in the visual modality, categorical information (for divisions natural vs. artificial, small vs. large size, moving vs. nonmoving) emerged ~200 milliseconds after stimulus onset, concurrent with previous studies. By contrast, in the auditory modality, categorical information emerged markedly later, at ~400 milliseconds. Together, our results describe the temporal dynamics with which object representations and categorical distinctions emerge in the visual and the auditory modality. Further analysis will investigate whether conceptual

categorical knowledge is integrated across different sensory modalities.

The Intraparticipant Variability of Cross-Modal Synchrony Measurements

Tonja Machulla
LMU Munich, Germany

The perceived relative timing of two short events has been an active research topic since the 19th century. Measurements have application relevance in a large number of research domains such as multimodal perception, dyslexia, or interaction with novel technologies (teleoperation and virtual environments). Various psychophysical approaches exist, with temporal order judgments (TOJ) and synchrony/asynchrony judgments (SJ) being the most common. Often, the method of constant stimuli is used, and the number of repetitions per stimulus level is kept as low as 8 to 10 to limit the overall duration of the experiment. Here, we applied this approach to obtain estimates of the point-of-subjective-simultaneity (PSS) and the just-noticeable-difference (JND) for crossmodal TOJ and SJ. We tested 12 participants, each in three sessions administered across 2 days, and a further 2 participants in 20 sessions across 10 days. Our results show that the variability of individuals' PSS and JND estimates across sessions is high and, notably, larger than predicted from the variability observed within sessions. This suggests that either PSS and JND change between sessions (e.g., as a result of day–time-dependent factors) or that estimates are subject to variable response biases. Our findings exemplify the variability associated with measurements of relative timing.

Auditory and Visual Durations Load a Unitary Working-Memory Resource

Kielan Yarrow[1], Carine Samba[1], Carmen Kohl[2] and Derek H. Arnold[3]
[1]City, University of London, UK
[2]Hong Kong Polytechnic University, Kowloon, Hong Kong
[3]The University of Queensland, Brisbane, Australia

Items in working memory are defined by various attributes, such as colour (for visual objects) and pitch (for auditory objects). Item duration has received relatively little attention. While specialist stores (e.g., the phonological loop and visuospatial sketchpad) are often asserted in the wider working-memory literature, the interval-timing literature has more often implied a unitary (amodal) store. Here, we combine two modelling frameworks to probe the basis of working memory for duration; a Bayesian observer, previously used to explain behaviour in duration-reproduction tasks, and mixture models, describing distributions of continuous reports about items in working memory. We modelled different storage mechanisms (slots and a continuous resource) in order to ask whether items from different sensory modalities are maintained in separate stores. Participants had to memorise between one and eight items before reproducing the duration of a randomly selected target. In separate blocks, items could be all visual, all auditory, or an alternating mixture of both. Certain kinds of slot models, resource models, and combination models of both mechanisms could account for the data. However, looking across all plausible models, the decline in performance with increasing memory load was most consistent with a single store for event durations regardless of stimulus modality.

The Effect of Surface Properties on Avoidance Behaviour During Reaching

Constanze Hesse[1], Martin Giesel[1], Anna Nowakowska[1] and Julie Harris[2]
[1]University of Aberdeen, UK
[2]University of St Andrews, UK

In this study, we investigated how surface properties affect hand movements in a reach-to-grasp task. Participants ($N = 19$) reached over a surface to grasp an object. We tested five surfaces varying in granularity and density (cardboard, sandpaper, sugar granules, rock salt, and Astro Turf) but were matched in height and colour. All grasping movements were performed either visually open loop with vision being occluded at movement onset or closed loop with vision being available during movement execution. Vision conditions were blocked and the presentation of the different surfaces was randomised within conditions. Finger and arm movements were measured using an infrared motion tracking system. After grasping, participants rated the roughness, smoothness, and pleasantness-to-touch of each surface. Movement parameters were computed relative to those measured for the least rough surface (cardboard). We found that the area under the z-trajectory of the forearm, representing movements of the arm in the vertical direction, was positively correlated with the roughness ratings in both vision conditions suggesting that we keep a larger distance from a rougher surface when moving over it. In addition, actions were also executed more slowly when moving across rougher surfaces in the open-loop condition. Findings indicate that avoidance responses are finely tuned to surface variations.

Developmental Trajectory and Visual Dependence in the Use of Different Features in Haptic Object Perception

Krista Overvliet[1,2], Albert Postma[2] and Brigitte Röder[1]
[1]Department of Biological Psychology and Neuropsychology, University of Hamburg, Germany
[2]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands

To investigate the developmental trajectory and the influence of visual experience in the use of spatial and nonspatial features for haptic object recognition, we used a haptic ambiguous odd-one-out task in which one object had to be selected as being different from two other objects. The odd-one-out could be selected based on four characteristics: size, shape (spatial), texture, and weight (nonspatial). We employed a prospective approach to assess the developmental trajectory by testing sighted children from 4 to 12 years old as well as sighted adults; complimentary, we employed a retrospective approach to assess the influence of visual experience by testing congenitally blind, late blind, and visually impaired adults. Given the lengthy developmental time course and the unique role of vision for spatial perception, we expected congenitally blind individuals and young children to show preference for nonspatial features, such as texture and weight, as compared with visually impaired, late blind and sighted older children and sighted adults. The results revealed that the spontaneous use of size—but not shape—develops late and is hampered by the lack of visual experience. These data suggest that some spatial features develop surprisingly early and independently of visual experience in haptic object perception.

Visual and Haptic Softness Dimensions

Müge Cavdan[1], Knut Drewing[1] and Katja Doerschner[1,2,3]
[1]Justus Liebig University Giessen, Germany
[2]Department of Psychology, Bilkent University, Ankara, Turkey
[3]National Magnetic Resonance Research Center, Bilkent University, Ankara, Turkey

When investigating visually or haptically perceived softness of materials researchers have typically equated softness with compliance. However, softness entails more aspects than this single dimension: A rabbit's fur is soft in a different way than sand on Siesta beach and both's softness is not necessarily related to the materials' compliance. Here, we investigated the dimensionality of perceived softness in visual and haptic domains. We asked participants to rate various materials on different adjectives. In the haptic experiment, participants were blindfolded and rated materials after haptically exploring them, whereas in the visual experiment they made the same ratings while looking at close up images of the same materials used in the haptic experiment. Principal component analyses revealed that both haptic and visual perception of softness are similarly organized in perceptual space, both containing dimensions of granularity, viscoelasticity, and deformability. However, furriness existed only in the haptic experiment. Moreover, the explained variance was higher in the haptic experiment, which suggests that the perceived dimensions of softness might be more accessible through haptic exploration than by looking at images of materials. Overall, these results contribute to our understanding of how visual and haptic information about material properties are processed and integrated.

Navigation of Digitally Rendered Haptic Spaces

Ruxandra I. Tivadar[1,2], Astrid Minier[1,2], Tom Rouillard[3], Cédrick Chappaz[3], Carine Verdon[2], Fatima Anaflous[2] and Micah M. Murray[1,2,4,5]
[1]The LINE (Laboratory for Investigative Neurophysiology), Department of Radiology and Clinical Neurosciences, University Hospital Center and University of Lausanne, Switzerland
[2]Department of Ophthalmology, Fondation Asile des Aveugles, Lausanne, Switzerland

It is unknown whether individuals can create and manipulate spatial representations based on simulated haptic sensations. To address this, we introduced a new technology that digitally renders haptic feedback by modulating the friction of a flat screen through ultrasonic vibrations. We reasoned that participants should be able to create mental representations of a "living-lab" apartment presented haptically and manipulate them while navigating trained and untrained trajectories. Normally sighted, blindfolded participants were trained on the basic layout of the apartment, as well as on one of two trajectories. We then tested participants' ability to reconstruct the haptically learned labyrinths. Participants' hands were also filmed during exploration of the labyrinths. These data were analyzed using a deep neural network running on Tensorflow 1.0 (http://www.mousemotorlab.org/deeplabcut/). Preliminary tracking results indicate different individual exploration strategies, based either on exact road following or on exclusion. Preliminary behavioral analyses indicate a trend for training to improve performance on the more difficult trajectory. Our findings significantly extend research in sensory substitution by indicating that simulation of active haptic sensations can support the encoding of spatial mental images and may thus be a valuable tool in the rehabilitation of spatial functions and mitigation of visual impairments.

Brain Networks: From Vision to Movements and Beyond

Silvio Ionta
University of Lausanne, Switzerland

Traditional models of visuo-motor coordination consider vision as a "passive" planning or monitoring tool. Contrariwise, current perspectives suggest a more "active" role of visual input on motor output and higher cognitive functions. Animal electrophysiology showed that some neurons in the motor cortex respond to visual stimulation. Nevertheless, in humans, the neural basis of the interaction between (healthy and impaired) vision and movement still remains largely unexplained. To fill this gap, we present evidence from a series of experiments using high-definition brain stimulation (high definition transcranial direct current stimulation), cortical inhibition (repetitive transcranial magnetic stimulation [TMS]), corticospinal excitability (single pulse TMS), brain mapping (functional magnetic resonance imaging), and psychophysics about the influence of neuromodulation in visual areas on the neural activity in motor areas and beyond. The obtained results unravel the neural counterparts of our ability to organize visual perception and motor routines, shedding new light on the ways the brain represents the body as a function of the available visual information. The described findings will be enclosed in a broad theoretical model of modes and operations of visuo-motor processing.

Somatosensory Processing on Grasping Digits

Dimitris Voudouris, Maximilian Davide Broda and Katja Fiehler
Department of Experimental Psychology, Giessen University, Germany

When grasping, it is advantageous to estimate object properties relevant for the action. When people can do so, for instance based on visual or prior information, they tailor their movements for an efficient action. These accurate predictions come also with hindered processing of somatosensory signals on the moving hand, in line with the notion that predicting the sensory consequences of the movement decreases sensory sensitivity on the moving limb. Here, we examine whether somatosensory suppression is also influenced by increased sensory noise that may mask afferent signals. We used an inverted T-shaped object with predictable symmetric or asymmetric mass distributions (left, right). Participants had to grasp the object on two small points, with thumb and index finger at its left and right, respectively, and lift it straight up. To probe somatosensory sensitivity, participants detected a vibrotactile stimulus on their thumb or index finger at the moment of contact. Stronger forces were applied by the thumb and finger for left and right mass distributions, respectively. Somatosensory sensitivity dropped when grasping compared with rest, and this was stronger for the thumb. However, we see no evidence for increased suppression with stronger forces, suggesting that suppression is not sensitive to increased sensory noise.

The Goal of the Action Modulates Adherence to Weber's Law in Grasping

Aviad Ozana and Ganel Tzvi
Ben-Gurion University of the Negev, Israel

Grasping trajectories toward real objects violate Weber's Law, a fundamental principle of perception. It has been therefore suggested that highly skilled visuomotor actions such as precision grasps and perceptual processing are subserved by dissociable mechanisms. However, grasping an object also carries a purpose, which could differ in terms of its precision demands. In three experiments, we examined whether the required level of precision in an upcoming object manipulation can modulate the violation of actions to Weber's law. The demanding-goal task involved precision grasp-to-lift (lifting) movements. The nondemanding tasks were similar in all aspects, but now participants were asked to either slide the objects or rotate them on the surface of the tabletop without picking them up. Thus, grasp properties prior to interception were kept equal while the precision demands of the goal task were manipulated. In agreement with previous studies, the results showed that grasping trajectories prior to the grasp-to-lift violated Weber's law. In contrast, grasping trajectories prior to the nondemanding tasks adhered to Weber's law. The findings suggest a direct link between task demands and the violation of Weber's law in grasping. These findings converge with previous results to highlight the role of the movement's goal in determining its nature.

Role of Body Cues in Intent Perception During Ball Catching in VR

Jindrich Kodl, Tjeerd Dijkstra, Nick Taubert and Martin Giese
Universitätsklink Tübingen, Germany

Correct perception of biological motion enables humans to take appropriate action. We studied the perception of full-body cues during catching of a ball in a virtual environment. In a fully immersive virtual reality environment, displayed using HTC Vive, participants were asked to catch a ball thrown by highly realistic human avatars. The throwing

movements were derived from motion captured human underhand throws. The throws were left in their genuine form or modified to be deceptive. The thrown ball was occluded at various stages during the flight phase. Spatiotemporal error between ball trajectory and start of catching action determined the success of ball interception. As expected, catching performance drops with increased ball trajectory occlusion ($p < 10^{-8}$). Higher level deception during throws also has negative effect on catching performance ($p < 10^{-8}$). While fully occluded, the participants' catching success was higher for genuine throws compared with deceptive throws. Hence, not only ball trajectory but also thrower's body cues play an important role in ball catching performance.

How to Get Stable Number Lines in the Mind's Eye

Mario Pinto[1], Michele Pellegrino[2], Fabio Marson[2], Stefano Lasaponara[2] and Fabrizio Doricchi[1,2]
[1]Fondazione Santa Lucia, IRCCS, Rome, Italy
[2]Dipartimento di Psicologia, University La Sapienza, Rome, Italy

Humans mentally organise the ascending series of integers in accord with reading habits, so that in western cultures small numbers are positioned to the left of larger ones on a mental number line (MNL). Here, we show that MNLs are not "all or none" phenomena and that they can be more or less stable, as a function of the way an observer uses spatial and numerical-magnitude codes to operate on numbers. Using unimanual Go/No-Go tasks with intermixed central Arabic digits and left/right pointing arrows targets, in six experiments, we explored whether left/right spatial codes used in isolation evoke the left-to-right representation of numbers, that is, Space-to-Number (StoN) congruency, and whether numerical-magnitude codes used in isolation evoke the activation of left/right spatial codes, that is, Number-to-Space (NtoS) congruency. In Experiments 1 to 4, participants were asked to provide Go/No-Go responses based on instructions that activated only spatial or magnitude codes. In Experiments 5 and 6, both codes were used jointly, though in Experiment 6, one code was activated through sovraordinate knowledge. Significant and stable StoN and NtoS were found only in Experiment 5. We conclude that contrasting left/right spatial and small/large magnitude-numerical codes must be used jointly to evoke stable MNLs.

The Influence of Visual Perspective Taking on the SNARC Effect: A Pilot Study

Valter Prpic and Patrick Cullen
Institute for Psychological Science, De Montfort University, UK

The Spatial-Numerical Association of Response Codes (SNARC) effect consists in faster left (vs. right) hand responses to small (vs. large) numbers. This effect is considered evidence of humans' tendency to represent numbers along a left-to-right oriented mental number line. Visual perspective taking (VPT) can be broadly defined as the ability to "put yourself in someone else's shoes." More specifically this consists in computing the viewpoint of other individuals, an ability that several studies found to be spontaneous. As the SNARC effect is clearly bound to participants' spatial coordinates, our aim was to test whether a VPT manipulation could influence the direction and size of the SNARC effect. Participants completed a magnitude classification task with visual dot patterns in two conditions. In one condition, only dot patterns were displayed, while in the second one a picture of a person mirroring the participants' perspective appeared together with the dots. In this pilot study, dot patterns were preferred to symbolic numerals because the former are viewpoint invariant. Our results seem to suggest that VPT did not influence the SNARC effect, which remained consistent through the conditions.

Sound-Free SMARC Effect: Pitch-Space Association Without Sound

Atsunori Ariga and Shiori Saito
Hiroshima University, Japan

Pressing a key higher (lower) on the keyboard to a high-pitched (low-pitched) sound is quick, compared with the opposite configuration. This so-called spatial–musical association of response codes (SMARC) has been considered to reflect the spatial coding of sound pitch rather than to be an artifact of illusory sound localization in response to pitch height. This study completely excluded the latter possibility, that is, the directional effects of illusory sound localization on the corresponding response, by examining whether the SMARC effect occurs without sound. We investigated whether the effect would be elicited by written pitch names alone. We found that when musically trained participants judged pitch height labeled by visually presented word stimuli, the SMARC effect occurred. This also happened among musically naive participants when the height of the pitch was explicitly comparable to that of a referential pitch. We also found that musically trained participants exhibited the SMARC effect in response to pitch names even when the indicated pitch height was

irrelevant to the task they were asked to perform. These results suggest that the SMARC effect can occur at the semantic level in the absence of sound, clearly excluding the directional effects of illusory sound localization.

Quantifying Overlap Between Topographic Maps for Numerosity and Visual Event Timing in Human Association Cortex

Jacob M. Paul and Ben M. Harvey
Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands

Topographically organised maps representing continuous variations in sensory quantities are ubiquitous in early visual cortex but have more recently been identified throughout human association cortex. How are maps corresponding to different visual quantities organised within the same cortical locations? Using ultra-high field 7T functional magnetic resonance imaging, we measured responses in eight human adults to stimuli that varied in numerosity (the set size of visual objects) or visual event timing (event duration and period). We analysed these responses using population receptive field models tuned to numerosity, or visual event timing, respectively. We identified nine widely distributed, bilateral event timing maps that overlap at least partially with six bilateral numerosity maps. All maps showed a gradual topographic organization of preferences for both types of quantities, as confirmed by multiple quantitative indices of distance and topological correlation. Vector field analyses further showed the amplitude and orientation of overlapping numerosity and event timing maps closely aligned, or were opposing, depending on their location in the visual processing hierarchy. Our results support the suggestion that overlapping topographic maps may allow for efficient neural coding and transformation of quantitative information. We discuss the implications of our findings for theories regarding related and interacting cognitive magnitude representations.

Relationships Between Perceptual Judgments of Number, Time, and Distance

Frank H. Durgin and Shelby Billups
Swarthmore College, PA, USA

In everyday experience, time, distance, and number are frequently correlated conceptually (e.g., during travel). We often see metaphoric uses of language extending from one domain to another. Some have reported asymmetric contamination of perceptual time judgments by irrelevant distance information, but this may be parameter-specific Garner interference. We observe that surprisingly little leakage is present between perceptual estimates of temporal duration and these other dimensions when an appropriate analytic test is used. The amount of contamination observed between them seems to be related to perceptual uncertainty (i.e., increasing both with reduced discriminability of the target dimension and increased discriminability of the irrelevant dimension). However, it may also be related to inattention (contamination is greater for participants showing poorer matching overall). Overall, perceptual estimates of nonsymbolic number, temporal duration, and spatial extent seem to involve mode-specific magnitude encodings which are relatively independent. Cognitive interference between these dimensions (which can occur in both directions) takes place primarily at the margins, and may be only weakly related to hypothesized amodal magnitude representations, and relatively unrelated to the utility of spatiotemporal metaphoric borrowing in natural language.

Perceived Duration in Viewing RSVP Display Depends Upon the Cognitive Load Rather Than Number of Perceived Frames

Makoto Ichikawa and Masataka Miyoshi
Chiba University, Japan

We examined whether failure to detect targets in RSVP (Rapid Serial Visual Presentation) display, which indicates the reduction of perceived frames, causes the reduction of perceived duration by the use of attentional blink paradigm. In each trial, two series of RSVP display were presented; in the first sequence, two, one, or no numerals were presented as targets within a series of alphabets while, in the second sequence, only alphabets were presented. The lag between two numerals in the first sequence ranged from one to three. Each of the first and second sequences included 17 to 20 frames, and the frame difference between the sequences was either of -1, 0, or $+1$. In each trial, participants reported target numerals for the first sequence, and then judged whether the duration of the first sequence was longer than that of the second sequence. We found that perceived duration increased with the number of subjectively detected targets increased while number of objectively presented frames had no effect on the perceived duration. These results suggest that perceived duration in viewing RSVP sequence is determined by the cognitive load which is required in target detection, rather than by the number of perceived frames.

Attention Modifies the Width of Temporal Window for the Reconstruction of Temporal Structures

Hiroyuki Umemrua
National Institute of Advanced Industrial Science and Technology, Tokyo, Japan

Previous studies suggested that the brain reconstructs the temporal relationship of events considering expectations or causal relationships between them within a certain width of temporal window. However, whether the width of the temporal window is fixed or not is unclear. This study investigated whether the width of the temporal window is affected by attention. In the experiment, participants required to judge the temporal order of two timings in a visual stimulus, contact of a ball fallen from above on a floor and start of objects' movement on the floor. It has previously been reported that the perceived order of these events was modified so as to accord with causal relationship; the impact of ball contacting the floor caused the movement. Contribution of attention was controlled by conducting a secondary auditory task or not. The results showed that the temporal order judgement was more strongly affected by the causal context when the attention was divided by the secondary task, that is, the temporal window widened. This would suggest that attention increases the reliability of signals in the reconstruction process of temporal structures and relatively decreases the contribution of prior knowledge.

Automaticity in Processing of Spatial/Temporal Stimuli Affects the Degree of Cognitive Interaction Between Space and Time

Chizuru Homma[1] and Hiroshi Ashida[2]
[1]Ritsumeikan University, Japan
[2]Kyoto University, Japan

Judgements of line length and its exposure duration affect each other: the longer the line length is, the longer the exposure duration tends to be judged, but not as much vice versa. In our previous studies (Honma & Ashida, 2015), participants judged the spatial lengths of a line stimulus that varied in exposure duration or the exposure duration of a line that varied in spatial length, showing that the saliency of stimuli affects the extent of cognitive interaction. A possible problem, however, was that the trials were blocked by the target dimension and the participants knew it in advance. In this study, the target dimension was blind during stimulus presentation, while the other conditions were similar. The results showed a larger effect from temporal on spatial cognition than in the previous study. With the high automaticity in spatial information processing, participants can make a judgement soon after the stimulus onset for the spatial task when they know the target dimension. In such a case, they do not need to wait to the end of presentation and the temporal influence on spatial cognition could have been underestimated. With our new method, the interactions can be more symmetric.

Space Is Used to Infer Time in Deaf Individuals

Maria Bianca Amadeo[1,2], Caludio Campus[1], Francesco Pavani[1] and Monica Gori[3,4]
[1]Istituto Italiano di Tecnologia, Genoa, Italy
[2]Department of Informatics, Bioengineering, Robotics and Systems Engineering, Università degli Studi di Genova, Italy
[3]Center for Mind/Brain Sciences, CIMeC, University of Trento, Italy
[4]Department of Psychology and Cognitive Sciences, University of Trento, Italy

When visual experience is missing, complex spatial representation is impaired and temporal representation of events is used to build spatial metrics. Given the superiority of audition over the other sensory systems for time perception, we hypothesized that when audition is not available, complex temporal representations could be impaired, and spatial representation of events could be used to build temporal metrics. To test this hypothesis, 17 deaf and 17 hearing subjects performed a visual temporal task: They saw three stimuli and judged whether the second stimulus was temporally closer to the first one or the third one. The second stimulus was randomly and independently delivered at different spatial positions with different temporal lags, giving rise to coherent (i.e., identical space and time) and conflicting (i.e., opposite space and time) spatiotemporal information, as well as independent spatiotemporal information (i.e., space not informative about time). As predicted, we observed a strong deficit of deaf participants when only temporal cues were useful and space was independent with respect to time. However, the temporal deficit disappeared when coherent spatiotemporal cues were presented and increased for conflicting spatiotemporal stimuli. These results highlight for the first time that spatial cues influence time estimations in deaf participants.

Limited Evidence for Transfer Effects in the Temporal Preparation of Auditory Stimuli

Emily Crowe and Christopher Kent
University of Bristol, UK

How quickly participants respond to a "go" after a "warning" signal is partly determined by the time between the two signals (the foreperiod) and the distribution of previous foreperiods. According to Multiple Trace Theory of Temporal Preparation (MTP), participants use memory traces of previous foreperiods to prepare for the upcoming "go" signal. If the processes underlying temporal preparation reflect general encoding and memory principles, transfer effects (the carry-over effect of a previous block's distribution of foreperiods to the current block) should be observed regardless of the sensory modality in which signals are presented. To date, transfer effects have only been documented in the visual domain. We present four experiments using auditory stimuli. In acquisition phases, two groups of participants were exposed to different foreperiod distributions and, in transfer phases, groups received the same foreperiod distributions. Experiments 1 and 2 used a simple-RT task and found no evidence for long-term transfer (i.e., across sessions), although there was some evidence for short-term transfer (i.e., within session). Experiments 3 and 4 used a filled foreperiod and choice-RT task, respectively, but again found no evidence for transfer effects. Together, these results indicate modality specific memory differences in temporal preparation that MTP must account for.

The Influence of Variance of Prior on Behaviour—An Investigation Using a Temporal-Reproduction Task

Reny Baykova[1], Christopher Buckley[1,2,3], Anil Seth[1,4] and Warrick Roseboom[1]
[1]Department of Informatics, University of Sussex, Brighton, UK
[2]Evolutionary and Adaptive Systems Group, University of Sussex, Brighton, UK
[3]Centre for Computational Neuroscience and Robotics, University of Sussex, Brighton, UK
[4]Sackler Centre for Consciousness Science, Brighton, UK

According to many Bayesian brain theories, the effect of prior expectations on perception depends on the precision (variance) of the prior distribution—perception will be biased more by precise compared with broad priors. However, existing studies examining how priors affect perception confound the effects of distributional variance with concurrent changes in other distributional characteristics such as skewness, central tendency, and range. To establish the specific effect of distributional variance on time perception, we will conduct a duration-reproduction experiment in which the to-be-reproduced temporal intervals will be drawn from two distributions that have the same central tendency, skewness and range, differing only in distributional variance. Data simulated using a Bayesian ideal observer model suggests that the responses of a Bayesian actor are more biased toward the mean of the stimulus distribution when the distribution has a smaller variance, providing preliminary support for our hypothesis. We will use this model to generate predicted responses for each human participant and determine whether the behavioural data are consistent with the model-predicted responses using Bayesian paired *t* tests. Our findings will help determine the extent to which Bayesian accounts of perception provide an accurate reflection of the mechanisms governing human perception and behaviour.

Self-Relevance Influences Temporal Estimation

Arash Sahraie, Aleksandar Visokomogilski, Karolina Tothova and C. Neil Macrae
University of Aberdeen, UK

Self-relevant stimuli have been demonstrated to lead to faster detection of own name/face, more accurate episodic memory, and higher efficacy in attracting attention. Using a shape-label association task, Sui et al. (2012) demonstrated that the enhanced processing of self-relevant stimuli can extend to conditions where associations were made with arbitrary geometric shapes and person-labels, such that matching self-shape combinations led to faster reaction times and higher detection accuracies than those related to friend- or stranger-shape associations. Here, we explored the effects of self-relevance on perceptions of time. In a temporal bisection task, targets were presented at a range of durations between 300 and 900 milliseconds. Participants reported a higher proportion of "long" durations for matching shape-label trials compared with mismatching trials. In addition, the proportion of "long" self-matching trials was higher than friend-matching trials across all time intervals. In a second experiment in which participants completed the self-association task, but the subsequent time-bisection task only included shapes (no label), no effect of self-relevance in temporal perception was observed. We propose that overt shape-label evaluation is a prerequisite for the influence of self-relevance on estimates of time, indicating that the effect of self-relevance on temporal perception is underpinned by decisional rather than perceptual processes.

Electrophysiological Correlates of Temporal Integration in Metacontrast Masking

Alexander Tobias Andreas Kraut and Thorsten Albrecht
University of Göttingen, Germany

In metacontrast masking, the visibility of a target stimulus is reduced by a subsequent masking stimulus presented in close spatiotemporal proximity to the target. Although never presented at the same time, target and mask can either appear as a segregated, masked or integrated percept. Therefore, several theories incorporate temporal integration and segregation in the visual system as crucial processes involved in masking. We tested this hypothesis by searching for electrophysiological correlates of temporal integration and segregation in a metacontrast masking paradigm. Under constant stimulation parameters, participants indicated on each trial whether they perceived the target-mask sequence as an integrated, segregated, or masked percept, while their EEG was recorded. In the pretarget interval, we found greater beta-power for the integrated compared with the segregated percept (−200 to −50 milliseconds), and opposing phases for both percepts in the alpha band (−350 to −50 milliseconds). Both effects concur with findings of previous studies on temporal integration/segregation. In the posttarget interval, ERPs differed only after 200 milliseconds with more positive amplitudes for the segregated compared with the integrated percept suggesting that the different percepts under metacontrast do not arise from differences in early (perceptual) stages but rather from later (evaluative) stages of visual processing.

Tuesday, August 27, 2019

Poster Session 3

Hypothyroidism Can Compromise Spatial Summation and Resolution Acuity for S-Cone Selective Stimuli

Kalina Ivanova Racheva[1], Margarita Boyanova Zlatkova[1,2], Tsvetalin Totev Totev[1], Emil Slavev Natchev[3], Milena Slavcheva Mihaylova[1], Ivan Milenov Hristov[1] and Roger Sproule Anderson[2]
[1]Institute of Neurobiology, Bulgarian Academy of Sciences, Sofia, Bulgaria
[2]School of Biomedical Science, University of Ulster, UK
[3]Departament of Endocrinology, Medical University Sofia, Bulgaria

Hypothyroidism affects visual development in rats, causing a thinning of retinal layers, delays to nerve myelination, and reduced opsin production. The visual changes associated with hypothyroidism in humans have received little attention, in particular colour vision. We measured acuity at the resolution limit and the area of complete spatial summation (Ricco's area), known to be related to ganglion cell density, for patients with hypothyroidism and age-matched controls. Stimuli were chromatic isoluminant gratings and spots of variable size, presented at 20° in the temporal retina. We used silent substitution with modulation from an achromatic background to 90°, 270°, 0°, and 180° in DKL space, loosely called blue, yellow, red, and green. Resolution acuity was significantly lower in hypothyroid patients compared with controls only for blue gratings (0.54 c/deg vs. 0.77 c/deg, $p < .05$). Similarly, Ricco's area was significantly enlarged only for blue stimuli (0.25 deg^2 vs. 0.036 deg^2, $p < .05$) in the hypothyroid group. Similar tendencies were observed for yellow stimuli, but not reaching statistically significance. The results suggest that hypothyroidism affects blue-yellow spatial characteristics more than red-green. The observed acuity impairment and Ricco's area enlargement may be a result of S-cone driven ganglion cell loss or dysfunction in hypothyroidism.

A Multilayer Computational Model of the Parvocellular Pathway in V1

Xim Cerda-Company[1], Xavier Otazu[1] and Olivier Penacchio[2]
[1]Computer Vision Center, Universitat Autonoma De Barcelona, Spain
[2]School of Psychology and Neuroscience, University of St Andrews, Scotland

We defined a novel firing rate model of color processing in the parvocellular pathway of V1 that includes two different layers of this cortical area: layers 4Cβ and 2/3. Our dynamic model has a recurrent architecture and considers excitatory and inhibitory cells and their lateral connections. To take into account laminar properties and the variety of cells in the modeled area, the model also includes both single- and double-opponent simple cells, and complex cells (a pool of double-opponent simple cells). Moreover, the lateral connections depend on both the type of cells they connect and the layer they are in. To test the architecture, we used a set of sinusoidal drifting gratings with varying spatiotemporal properties such as frequencies, area of stimulation and orientation. We showed that to reproduce electrophysiological observations, the architecture has to include nonoriented double-opponent cells in layer 4Cβ, but no lateral connections between single-opponent cells. We also tested the configuration of lateral connections by studying their effect on center-surround modulation and showed that physiological measurements are reproduced: Lateral connections are inhibitory for high-contrast stimuli and facilitatory for low-contrast stimuli. Finally, we mapped the spatiotemporal receptive fields

using reverse correlation and showed that the selectivity of cells' polarity is time-dependent.

Spectral Difference Between the Ambient Light Flows Reaching the Extreme Peripheral Retina Through the Pupil and Through the Exposed Scleral Surface

Alexander Belokopytov[1], Galina Rozhkova[1], Elena Iomdina[2] and Olga Selina[2]
[1]Institute for Information Transmission Problems (Kharkevich Institute), Russian Academy of Sciences, Moskva, Russia
[2]Moscow Helmholtz Research Institute of Eye Diseases, Moscow, Russia

Color constancy conception implies that perceiving object coloration as invariable requires taking into account spectral characteristics of the ambient light illuminating the observed scene. There is a hypothesis that the characteristics of ambient illumination are mainly assessed on the basis of photoreceptor responses at the extreme retinal periphery where the following two light flows could be distinguished: (a) the light that entered the eye through the pupil and scattered by the eye structures (pupillary flow) and (b) the light that came to the receptors from the illuminated surface through all the eye tunics (diascleral flow). As it seems problematic to investigate living human eye in this respect, we performed preliminary experiments on rabbit eye ex vivo. Using the spectrophotometer Eye One (X-Rite) and the plastic optical fiber, we recorded the input light (Lo), the light leaving the eye through the optic nerve window (L1) and the light crossing all eye tunics (L2). As was anticipated, the ratios L1/Lo and L2/L1 revealed a significant difference between the spectra of the pupillary and diascleral flows showing that the second one was more reddish. This result seems natural in view of the optical parameters of the two light paths.
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Color Constant Representations in Early Visual Cortex

Anke Marit Albers, Elisabeth Baumgartner, Hanna Gertz and Karl R. Gegenfurtner
Justus-Liebig-Universität Giessen, Germany

The light entering our eyes is the product of the illumination and the surface reflectance of an object. Although it changes considerably when the illumination changes, we perceive objects as stable in color. To investigate how the brain achieves color constancy, we measured blood oxygen level-dependent functional magnetic resonance imaging, while 19 participants either observed colored patches (yellow, blue) under a neutral illuminant or neutral gray patches under simulated blue and yellow illumination conditions. Under bluish illumination, the gray patches appeared yellow; under yellowish illumination, they appeared blue. We trained a classifier to discriminate between the blue- and yellow-colored patches based on the activity pattern in V1 to V4. Blue and yellow patches could reliably be discriminated (54.76%–57.73%). The classifier could also discriminate between the apparent yellow and blue (59.14%–60.63%). Crucially, we then trained the classifier to discriminate between blue and yellow patches, but tested whether it could distinguish between blue and yellow induced by the colored illuminants. Apparent blue and yellow resembled colorimetric blue and yellow in V1 (54.30%), V3 (52.57%), and V4 (52.46%). These findings suggest that not only colorimetric but also apparent color is represented to some degree in retinotopic visual cortex, as early as in V1.

Evaluation of Color-Vision Deficiency Test Based on Pupil Oscillations

Yuta Suzuki[1], Kazuya Onodera[1], Tetsuto Minami[1,2] and Shigeki Nakauchi[1]
[1]Toyohashi University of Technology, Japan
[2]Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology, Japan

The Pupil Frequency Tagging (PFT), pupil oscillations by modulating stimulus luminance level of objects, has been used in the tracking of an attentional shift. We advanced the PFT for an evaluation of color-vision deficiency in order to use color changes in equiluminant displays instead of luminance changes. Here, we used the flickering stimuli imitated from Ishihara pseudo-isochromatic plates, each of which contains three luminance levels of green- or red-colored dots on the color confusion lines; the stimulus out of five types of color contrast within green/red was selected from the subject's subjective color discrimination threshold plus two fixed contrast levels (i.e., seven different distances on the color confusion lines). The stimulus was flicked at 1 Hz from green to red pattern and vice versa while monitoring participant's pupil changes with an eye-tracker. The color-vision deficiency threshold was predicted by the similarity between the pupil oscillations to the fixed contrast level and each variable contrast. The predicted threshold was significantly related to subjective color discrimination. This novel classification method based on the photoreceptors dependence pupillary oscillations characterized subject's color-vision deficiency as well as the extent, without any subjective tests.

How Many Component (Unique) Hues Can Dichromats See?

Alexander Logvinenko
Glasgow Caledonian University, UK

According to the model of dichromatic colour vision proposed recently (Logvinenko, 2014), the dichromatic hue palette differs significantly for object and light colours. This may explain why there is no consensus on what colours dichromats see. We explored the object hue palette. A set of Munsell chips was chosen, which should be equally perceived by dichromats and trichromats. These chips clearly contain the red, green, and blue component hues. As to green, it was tinged with such an amount of white that it was hard to judge its presence even for trichromatic observers. We used the hue scaling method to evaluate the amount of all six component hues for each chip in the sample. Trichromatic observers were asked to evaluate, in percentage, how much of each component hue they saw in the chip. We found that although the amount of green was low, its presence for some chips was statistically significant. Thus, all the six component hues are present in the hue palette of dichromats. We also confirmed the opponency of black and white, which were never present together in any chip. This is contrary to the generally accepted view that grey is a mixture of black and white.

The Screening Program for Detecting Color Vision Deficiencies Based on a Color Blindness Simulator: Preliminary Study

Paul V. Maximov[1], Maria A. Gracheva[1], Anna A. Kazakova[1,2] and Alexander S. Kulagin[3]
[1]Institute for Information Transmission Problems of the Russian Academy of Sciences (Kharkevich Institute), Moscow, Russia
[2]Pirogov Russian National Research Medical University, Moscow, Russia
[3]Moscow State Budgetar Educational Institution "School 1501", Moscow, Russian Federation

We have developed the screening program for color vision deficiencies. The program is based on the color blindness simulator presented earlier (ECVP, 2018). Three images—full color one, simulated "deuteranopic" and "protanopic" images—are displayed simultaneously. The task for the subject is to pick the most different image among the set of three images. Normal trichromats select the original picture as the most different one, protanopes select "deuteranopic" image, and deuteranopes select "protanopic" image. In addition, 81 children (9–17 years old, 26 males and 55 females) and 2 adults (males) were tested. We assessed color vision with Rabkin polychromatic test plates, and with our program. For the program we used ASUS UX305 with anti-glare IPS-screen. In both tests, we assessed subjects who make zero mistakes in all images as "normal," others—as "abnormal" (anomalous trichromats and dichromats). Seven subjects were identified by the Rabkin test as "abnormal." Comparing to the Rabkin test, the screening program has sensitivity—71%, specificity—100%. It seems that increasing the number of test images for each subject (we used 11) may increase the sensitivity. Our screening program seems to be a promising new method for detecting color deficiencies, though further studies on bigger samples are needed.

Perceptual Accuracy of a Spectrally and Physically Based Rendered Cornell Box Versus a Real Cornell Box

Gareth V. Walkom, Peter Hanselaer and Kevin A. G. Smet
Light & Lighting Laboratory, KU Leuven, Ghent, Belgium

The Cornell box has been used throughout computer graphics to show the interaction of light in computer renderings. However, it is currently unknown how this corresponds to that of a real Cornell box. In this project, test subjects will visually compare a real Cornell box to a simulated box and rate the perceived differences for the different materials in terms of brightness, colorfulness, and hue. The real Cornell box will be built based on characteristics reported in the literature, with walls and objects layered with uniformly colored paper. The real box and its materials will be optically characterized. A colorimetric accurate simulation of the box will then be rendered in Mitsuba, a state-of-the-art spectral and physical based renderer (SPBR). Colorimetric accuracy will be checked using XYZ tristimulus maps obtained with a TechnoTeam LMK-5 Color Luminance Camera and by measuring the spectral irradiance at several locations using a GigaHertz Optik BTS256E spectral irradiance meter. Considering the colorimetric accuracy, perceptual accuracy, determined in the visual experiment, will be characterized. Determining the perceptual accuracy of the current state-of-the-art SPBR could greatly advance research in lighting visualization and also other fields such as computer graphics.

Critical Luminance to Perceive an Object as a Light Source or a Reflective Object: Can It Predict Spatial Brightness?

Ching-Wei Lin, Peter Hanselaer and Kevin Smet
KU Leuven, ESAT/Light&Lighting Laboratory, Ghent, Belgium

Depending on surround conditions, a dim light source can be perceived as a reflective object, and vice versa, a bright reflective object as a light source. The critical luminance for an object to be perceived as self-luminous instead of reflective is defined as GL. However, there are no good models to predict GL as far as we know. We assume that the critical luminance is affected by spatial brightness and will conduct a series of experiments to test our assumption. A uniform, diffuse, luminance-tuneable sphere, and several colourful semitranslucent pictures illuminated from the back with a tuneable light source will be used as probes to test the critical luminance in various types of rooms. Spatial brightness perception as well as the room's luminance distribution as seen from the observer's position will be collected at the same time. With this data, we aim to determine and model the relationship between the luminance distribution, GL, and the perceived room brightness. Detailed results and conclusions will be reported in the full paper. It is hoped that new insights will be gained on the factors driving perceived room brightness, and whether GL can be a good predictor and how it can be best modelled.

Visual Perception in Automotive: Testing the Glare Effects of New Car Headlamps

Lucie Viktorová[1] and Ladislav Stanke[2]
[1]Department of Psychology, Faculty of Arts, Palacký University Olomouc, Czech Republic
[2]Hella Autotechnik Nova, S.R.O., Czech Republic

With the argument of increasing traffic safety by better road illumination, halogen bulbs in modern car headlamps are replaced by xenon arc lamps and most recently by LEDs. Yet at the same time, more drivers seem to complain about being glared, which might be a risk factor for safe driving. The studies of glare effects performed so far usually suffer from low number of participants and only taking subjective statements about being glared into account. The aim of this research is to study subjective as well as objective physiological/psychophysical effects of glare by different light sources on the observer in the context of traffic safety. The poster introduces the proposed experimental research design and presents the process of creating a special laboratory—a darkroom simulating two-lane traffic with different car headlamps. Multiple light sources and headlamp designs will be used, including modifications that are not seen on our roads, to simultaneously assess current status and prove whether changes in headlamp design can lead to improved user experience. The assessment will be supported by special measuring instruments, both commercially available and of open-source design.

Influence of Local Chromatic Configuration on Gloss Perception

Tatsuya Yoshizawa[1] and Haruyuki Kojima[2]
[1]Department of Human Sciences, Kanagawa University, Yokohama, Japan
[2]Department of Psychology, Kanazawa University, Yokohama, Japan

Our previous studies showed no difference between yellow and gold in the performance of color perception such as color detection and color search, and even ERPs for those colors. However, it has been known that in general the perception of glossiness is influenced by statistical features. This implicitly indicates that color perception of shiny objects like gold is described by them rather than local cooccurrence of spatial configuration of its image such as luminance and chromaticity of adjacent areas in a glossy-object image. We therefore psychophysically tested whether the color perception of glossy objects is affected by such local information of adjacent regions of a glossy-object image. Observers with normal color vision judged whether glossiness was perceived in an object-image with which some pixels were randomly shuffled with 20% to 80%. As a control condition, we asked the observers the same examination for an image of nonglossy objects as a function of pixel randomizing rates and of the spatial resolution of the image. The observers perceived little glossiness for a glossy-object image with 80% randomization at a low resolution, indicating the statistical features is relatively robust, although local luminance and chromaticity information also have an influence on glossy color perception.

Comparing Scaling Methods in Lightness Perception

Shaohan Li[1], Bernhard Lang[1], Guillermo Aguilar[2], Marianne Maertens[2] and Felix A. Wichmann[1]
[1]Eberhard Karls Universität Tübingen, Germany
[2]Technische Universität Berlin, Germany

Psychophysical scaling methods measure the perceptual relations between stimuli that vary along one or more physical dimensions. Maximum-likelihood difference scaling (MLDS) is a recently developed method to measure perceptual scales which is based on forced-choice comparisons between stimulus intervals. An alternative scaling

method that is based on adjusting stimulus intervals is equisection scaling. In MLDS, an observer has to answer which of two shown intervals is greater. In equisection scaling, the observer adjusts values between two anchoring points such that the resulting intervals are perceived as equal in magnitude. We compared MLDS and bisection scaling, a variant of equisection scaling, by replicating a lightness scaling experiment with both methods. Bisection scaling is attractive because it requires less data than MLDS. We found that, qualitatively, the lightness scales recovered by each method agreed in terms of their shape. However, the bisection measurements were more noisy. Even worse, scales from the same observers but measured in different sessions sometimes differed substantially. We would therefore not advise to use equisection scaling as a method on its own. But we suggest that it can be usefully employed to choose more favourable sampling points for a subsequent MLDS experiment.

Illusory Contrast Enhancement by a Dark Spot in Skin-Like Color Gradation

Soyogu Matsushita[1], Sakiko Kikunaga[2], Junya Aoyama[2] and Tsuyoshi Nomura[2]
[1]Osaka Shoin Women's University, Japan
[2]Pias Group Central R&D Laboratory, Osaka, Japan

A dark spot illusory enhances the perceived contrast of sinusoidal gratings of the adjacent area. While previous studies tested this illusion with grayscale stimuli, this study investigates the illusion with a human skin-like color. The brightest and darkest colors of the sinusoidal gratings were sampled from the skin of a portrait photograph of an actual person. The color of the spot as a contrast enhancer was selected from possible colors for human facial parts or usual cosmetics. The results replicated the illusory contrast perception also when the stimulus consisted of a skin-like color. We speculate that some facial parts with a darker luminance such as the eyebrows and lips could influence the perception of shading of faces, thus affecting perceived masculinity and maturity.

When Articulation Does Not Enhance Lightness Contrast

Giuseppe Alessio Platania[1], Sabrina Castellano[1], Tiziano Agostini[2], Giulio Baldassi[2] and Alessandro Soranzo[3]
[1]Università degli Studi di Catania, Italia
[2]Univesità degli Studi di Trieste, Italia
[3]Sheffield Hallam University, UK

Simultaneous lightness contrast (SLC) is the condition whereby two equal grays look different when they are placed one against a dark background and the other against a bright background. Adelson (1993) noticed that the SLC magnitude increases when the homogeneous backgrounds are replaced with more articulated ones. In Adelson's display, all darker patches are on one side of the stimuli while the brighter are on the other. The aim of this research is to test whether this regularity causes the SLC magnitude to increase. On a paper-based experiment, participants were requested to match on a Munsell scale two grays placed against a dark and a white background while the luminance of additional elements was manipulated: Dark and bright elements could have been added to either side. Results show that when bright elements where added to the darker background and bright elements where added to the darker background the SLC magnitude reduced. Vice versa, when bright elements were added to the bright background, and dark elements were added to the dark background, the SLC magnitude increased. It is concluded that the photometric relationships in the stimuli determine the SLC magnitude, not the level of articulation per se.

Transparent Layer Constancy in Naturalistic Rendered 3D Scenes

Charlotte Falkenberg and Franz Faul
Universität Kiel, Germany

In previous work on the perception of thin coloured transparent layers, we observed only relatively small degrees of constancy across illumination changes. This may partly be due to the fact that we used strongly reduced two-dimensional (2D) stimuli, as it is known from other domains of perception, for example, size or object colour perception, that an enriched context often leads to an increase in constancy. To test this hypothesis, we used an asymmetric matching task to measure transparent layer constancy (TLC) in scenes with varying levels of complexity: We presented filters in differently illuminated parts of "naturalistic" rendered three-dimensional (3D) scenes, which contained multiple illumination cues like scene geometry, surface shading, and cast shadows. To isolate the effects of specific cues on the degree of constancy, we stepwise omitted single cues. In the most reduced condition, a simple 2D colour mosaic remained, which

was colourimetrically identical to the corresponding 3D scene. The results suggest that TLC is indeed enhanced in naturalistic scenes, which is in line with findings of comparable investigations in the domain of colour constancy. An explanation for this increase in TLC might be that the perceptual affiliation of a filter to a particular illumination framework is enhanced in naturalistic scenes.

Measurement of the Perceived Size of the Face by the Cheek Color

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

Previous study showed that the perceived size of the face image by means of the line-straight shape of the cheek blush was smaller than other shapes (Nakato & Shirai, 2017). Although Kobayashi et al. (2017) revealed that lip color influenced the perceived facial skin lightness, there are very few studies which examine how facial color by other cosmetics causes the perceived size of the face images. This study investigated whether cheek color influences the perceived size of an illustrated face. Illustrated facial images with four kinds of cheek color (red, pink, purple, and brown) were used as standard stimuli and an illustrated facial image without cheek color as the comparison stimulus. Participants were instructed to manipulate a computer mouse and to stop the computer mouse when they judged that the facial size of the comparative stimulus was perceived to be the same as that of the standard stimulus by the method of adjustment. The results showed that the facial size with brown cheek color was perceived to be smaller than without cheek color. This finding implies that the darker cheek color is a determinant of the appearance of perceiving a smaller face.

The Effect of Context in Judgements of Face Gender

Alla Cherniavskaia, Valeria Karpinskaia and Natalia Romanova-Africantova
St. Petersburg State University, Russia

Although the characteristics of individual faces, such as identification of gender, have been studied extensively, questions remain about the effect of context in judgements of face gender. We examined how the perception of an ambiguous, composite face (an image morphed between a male and a female face) is influenced by the context of a surrounding group of faces. Seventy-four naive participants evaluated the gender of each morphed image using a 6-point scale. We calculated a context effect measure by subtracting the gender rating of a particular face when seen in the context of a group of male faces from the gender rating when seen in the context of female faces. Our results showed that there was a context effect in the gender judgements of the composite faces for 35% of participants. Of those participants, 79% showed an assimilation effect, in which the gender rating of the ambiguous face was shifted toward the gender of the surrounding faces and 21% showed a contrast effect, in which the gender rating of the ambiguous face was shifted away from the gender of the surrounding faces. Moreover, 90% of those shifts involved a perceived gender shift from female to male (or vice versa).

A Divided Visual Field Approach to the Categorical Perception of Faces

Ana Chkhaidze and Lars Strother
University of Nevada, Reno, NV, USA

The perception of boundaries between stimuli that exist along a graded continuum of physical properties is referred to as categorical perception. Categorical perception is often interpreted as evidence that language influences perception. Consistent with this, divided field studies of color and shape perception showed a relationship between categorical perception and cerebral laterality for language. Unlike color and shape perception, face recognition is associated with right-lateralized circuits in visual cortex and beyond. We hypothesized that the well-known left visual field (LVF) advantage for face recognition would show modulation by categorical versus noncategorical face perception. In three experiments, we used a divided field method in which observers performed a visual search task on arrays of faces split between the LVF and the right visual field (RVF). The search tasks required visual discrimination of faces by virtue of either identity, gender, or both. Our results confirmed the existence of categorical face perception in all three types of task. Crucially, however, we found greater categorical perception of identity for LVF faces and the opposite (RVF) for categorical perception of face gender. Our findings show that categorical effects on face recognition depend on opponent cerebral laterality for language and the visual processing of faces.

Face or Flower? Hemispheric Lateralisation for the Perception of Illusory Faces

Mike Nicholls[1], Ashlan McCauley[1], Owen Gwinn[1], Megan Bartlett[1] and Simon Cropper[2]
[1]Flinders University, Bedford Park, Australia
[2]Melbourne University, Australia

Pareidolia is the illusionary perception of faces in meaningless stimuli. This study investigates whether the predisposition to see faces, when there is none, is lateralised to the right cerebral hemisphere. It was predicted that the right hemisphere would be more prone to false positives than the left hemisphere. Normal right-handed undergraduates participated in a forced choice signal detection task where they determined whether a face or flower was present in visual noise. Information was presented to either the left or right hemispheres using a divided visual field procedure. Experiment 1 involved an equal ratio of signal to noise trials. Experiment 2 provided more opportunity for illusionary perception with 25% signal and 75% noise trials. There was no asymmetry in the ability to discriminate signal from noise trials for both faces and flowers. Response criterion was conservative for both stimuli, and the avoidance of false positives was stronger in the left- than the right-visual field. These results were the opposite of that predicted, and it is suggested that the asymmetry is the result of a left hemisphere advantage for rapid evidence accumulation.

Face Me to Remember You! Effect of Viewpoint on Male and Female Memory for Faces

Aneta Toteva[1] and Ivo D. Popivanov[1,2]
[1]New Bulgarian University, Sofia, Bulgaria
[2]Medical University of Sofia, University Hospital "Alexandrovska," Sofia, Bulgaria

Several studies have shown that women outperform men in tasks involving memory for faces. This effect has been demonstrated in children and adults for en face photographs of faces from the same or different ethnic groups. On the other hand, some studies reported male advantage in spatial tasks, such as mental rotation. In this study we assessed 27 male and 23 female participant's memory for 24 frontal, semiprofile and profile views of faces in attempt to check whether viewpoint may interact with the gender difference in face memory. The memory for faces was assessed in a recognition task including 24 new faces 10 minutes after a learning phase, presenting the faces twice. In addition, we estimated the mental rotation and face discrimination abilities of the participants. The results showed that although nonfrontal views were less remembered in general, women had a marked advantage in face recognition in comparison to men. Neither own- or other-sex bias were demonstrated. Interestingly, in our sample, man and women did not differ in their mental rotation abilities; however, female participants showed better face discrimination performance, estimated with the Benton Face Recognition Test. Thus, more optimal face encoding might result in female face memory advantage.

The Orientation Inversion Effect for 3D Concave Faces Extended to Convex Faces

Thomas V. Papathomas, Steven Silverstein, Attila Farkas, Hristiyan Kourtev, John Papayanopoulos and Brian Monteiro
Rutgers University, New Brunswick, NJ, USA

The hollow-face illusion (HFI) refers to the phenomenon of perceiving three-dimensional hollow faces as normal convex faces. HFI is much stronger for upright than upended stimuli (orientation inversion effect [OIE]). We displayed stereoscopic pairs of 11 face stimuli: photographs of people, realistically painted masks or unpainted masks; each was shown in four combinations (ux, dx, uv, and dv): 2 Orientations [upright (u)/upended (d)] $\times$ 2 Geometries [convex (x)/concave (v)]. Participants reported the perceived geometry using five choices: concave, somewhat concave, flat, somewhat convex, and convex. We processed the data to obtain six figures of merit: (a) the strength of the HFI for concave stimuli (uv, dv, v); (b) the ability to correctly perceive convex stimuli (ux, dx, x). Beyond confirming OIE for concave stimuli, the novel finding is that there is also an effect of orientation for convex stimuli: correct responses are higher for upright faces. One possible explanation is that the influence of stored knowledge—that faces are convex—accounts for the paradoxical results that humans are better at obtaining the true geometry of hollow masks for upended stimuli, whereas they are worse at obtaining the true geometry of convex masks for upended stimuli.

Face Adaptation Effects on Nonconfigural Information

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

Previously inspected faces can affect the perception of faces seen subsequently. The underlying mechanisms of these face adaptation effects (FAEs) have been considered to be based on sensory adaptation processes. This sensory oriented, short-term view on such adaptation effects was challenged by recent studies employing famous faces which show very reliable and robust adaptation over longer periods of times

(hours and days). After 20 years of intense research on FAEs, our knowledge is still quite limited in terms of which qualities of a face can be adapted as most studies used configurally manipulated stimuli (i.e., mostly addressing second-order relations). Here, we investigated less understood adaptation effects on nonconfigural face information by utilizing alterations which do not change configural aspects of a face by manipulating color brightness and saturation. Results of our studies provide evidence for nonconfigural color adaptation effects which seem to be unique within the context of faces. This supports the view that FAEs are not limited to configural qualities of a face.

Face Processing in V1: Coarse-to-Fine?

J. P. Schuurmans[1], T. Scholts[2] and V. Goffaux[1,2,3]
[1]Psychological Sciences Research Institute (IPSY), UC Louvain, Louvain-la-Neuve, Belgium
[2]Department of Cognitive Neuroscience, Maastricht University, Maastricht, the Netherlands
[3]Institute of Neuroscience, UC Louvain, Brussels, Belgium

Coarse-to-fine models propose that primary (V1) and high-level visual regions interact over the course of processing to build-up progressively finer representations. We previously observed that a high-level face-preferring region integrates face information in a coarse-to-fine manner. Whether V1 contributes to coarse-to-fine processing remains to be determined. To address this, we reanalysed the data of our past functional magnetic resonance imaging experiment, in which intact and scrambled faces were presented in three spatial frequency (SF) ranges (low, middle, and high) for three durations (75, 150, and 300 milliseconds). We localized individual V1 based on an anatomical atlas combined with a functional localizer. Next, we conducted a univariate analysis of the average response in this region and submitted the beta values to a repeated measure analysis of variance. Overall, V1 response decayed as a function of exposure duration. The response to the coarse low SF input drastically decayed between 75- and 150-millisecond poststimulus onset and bounced back to initial response level at 300 milliseconds of exposure. The decay of V1 response to middle and high SF was shallower and more linear. V1 response was comparable across between intact and scrambled stimuli. Multivariate pattern analyses are needed for a finer-grained investigation of the spatiotemporal dynamics of SF integration in the V1.

Beyond Binary Face Recognition Tasks: The Effects of Familiarity on Sensitivity to Subtle Face Changes

Rosyl Selena Somai and Peter Hancock
University of Stirling, UK

Recently, Abudarham and Yovel [preprint] found that there are no differences in feature hierarchy between familiar and unfamiliar faces in a face identity task. Although the feature hierarchy is not affected by familiarity, the memory accuracy of the features in the hierarchy might be. Theoretically, familiarity could aid or disrupt face perception. Familiarity could aid the comparison of two faces by using the memory of familiar face to enrich the image currently in visual working memory (VWM) with more details to compare. Alternatively, this "enrichment" has the potential to disrupt the comparison, by overwriting VWM content of the presented image with the visual information retrieved from the memorized face. This study proposes a novel experimental design that allows participants to gradually adjust the appearance of a face to match the original image, allowing us to measure the accuracy of face perception. We studied effects of familiarity on sensitivity to two types of adjustments, eyebrow and lip thickness (high perceptual sensitivity according to Abudarham & Yovel) and eye distance and mouth width (low perceptual sensitivity). Preliminary results indicate that both perceptual sensitivity and familiarity have an influence on the accuracy of our face perception.

Metacognition of Face Identification: Perspective From Multiple Face Processing

Luyan Ji and William G. Hayward
The University of Hong Kong, Hong Kong, S.A.R. (China)

Individuals can extract summary statistics from multiple items. However, the metacognition of ensemble perception is largely unstudied. In this study, we used a member identification task to explore whether observers have insight into implicit average face processing. Participants first saw a group of four faces presented for either 2s or 5s, then they were asked to judge whether the following test face was present in the previous set. The test face could be one member of the set, the matching average of the four studied faces, an unstudied face, or the nonmatching average of four unstudied faces. After each response, participants rated their confidence. Replicating previous results, there was substantial endorsement for matching average faces, even though they were never present in the set. Metacognition, operationalized as the correlations between accuracy and confidence, improved with increasing duration for identifying unstudied but not studied faces.

Importantly, participants were confident when judging the unseen matching average faces to be present, with confidence–accuracy relations at similar levels to that when endorsing matching member faces. The results suggest that average faces might be stored in sensory memory along with individual faces, and metacognition of face identification was different between target-present and target-absent conditions.

Visual Search With Deep Convolutional Neural Network

Endel Põder
University of Tartu, Estonia

Visual search experiments with human observers have revealed that simple features (luminance, color, size, orientation) can be detected in parallel across the visual field, independent of the number of objects in a display. Detection of combinations of simple features is more difficult and may need serial processing. Deep convolutional neural networks follow roughly the architecture of biological visual systems and have shown performance comparable to human observers in object recognition tasks. In this study, I used a pretrained deep neural network Alexnet as an observer in classic visual search tasks. There were four simple tasks, with targets of either different luminance, color, length, or orientation, and one complex task (rotated Ts), where target differs from distractors by spatial configuration of two bars. Set-size (number of displayed items) and difficulty level (target-distractor difference or size of stimuli) were varied. The results were different from usual human performance. It appears that there is no difference between searches for simple features that pop out in experiments with humans, and for feature configurations that exhibit strict capacity limitations in human vision. Both types of stimuli revealed moderate capacity limitations in the neural network tested here.

Unsupervised Learning of Viewpoints

Frieder Hartmann, Katherine R. Storrs, Yaniv Morgenstern and Roland W. Fleming
Justus-Liebig-Universität Gießen, Germany

How does the visual system represent relationships between different views of three-dimensional (3D) objects, when it only has access to two-dimensional (2D) projections? We rendered a data set of 2D silhouettes of 3D shapes from different viewpoints, and evaluated and contrasted different strategies (unsupervised machine learning vs. pixel-based metrics) on how well they capture similarity relationships among the images. We trained a variational autoencoder (VAE) on the data set and derived a metric of viewpoint difference from the resulting latent representations of pairs of images. We find that this metric meaningfully represents differences in viewpoint such that different viewpoints of the same 3D shape are organized in a structured way in the VAE's latent code. We contrast this with a simple pixel-based image similarity metric. Results indicate that the pixel-based metric is prone to artifacts introduced by inconsistent rates of image change between viewpoints. We compare both metrics to human judgments. Using a rank order task and a multiarrangement task, we investigate which model best predicts how humans perceive viewpoint differences. We discuss the implications of the results on human representation of 3D shape.

Modelling Human Recognition of Glossy Highlights With Neural Networks

Konrad E. Prokott and Roland W. Fleming
Justus-Liebig-Universität Giessen, Germany

With recent advances in machine learning, there have been many claims about the similarities between human perception and the computations and representations within neural networks. At the same time, there have been many observations of the striking differences. We aim to use machine learning to imitate human perception in the context of highlight recognition—that is, determining whether a bright point on a surface is a specular highlight as opposed to a surface texture marking. We created a data set of 165,000 computer-rendered grayscale images of perturbed surfaces that are textured but also display glossy highlights. We generated predictions based on the ground truth of the specular component of these images and a simple model that used only an intensity threshold. We identified individual locations in the images that distinguish between the models and asked human observers to judge whether these points depicted texture or a highlight. We compared responses of human observers to the two predictors across different spatial frequencies of surface geometries as well as different texture patterns. We then searched for neural networks that show a similar pattern of responses. Over a range of conditions, the networks predict human judgments better than the threshold model does.

Classification of Spatially Modulated Textures by Convolutional Neural Network

Denis Yavna, Vitaly Babenko and Kristina Ikonopistseva
Southern Federal University, Rostov-on-Don, Russia

Our work is devoted to the modeling of second-order visual mechanisms that detect spatial modulations of brightness gradients. We investigated the ability of neural networks with different convolutional parts to distinguish spatial modulations in textures. Networks were trained on images commonly used in psychophysical studies. These are textures synthesized from Gabor micropatterns modulated in contrast, orientation, and spatial frequency with randomly varied parameters. 15,000 images belonging to three classes were produced: 70% for training, 15% for validation, and 15% for testing. Networks were implemented using Keras library. A fully connected part always included a hidden layer of 32 elements and an output layer of three neurons. The learning capabilities of the networks with three to five convolutional layers were tested. At the moment, only the network with a five-layer convolutional part has demonstrated learnability (testing accuracy is 98.37%). There are 64 filters in each layer; filter sizes are 3×3 pixels in Layers 1 to 2, 5×5 in Layers 3 to 4, 7×7 in Layer 5. Each convolutional layer is followed by 2×2 max pooling layer. There is a similarity between the heatmaps of gaze-shifting data obtained previously in texture identification tasks and the class activation maps visualized using Grad-CAM procedure.

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Modelling Human Time Perception Based on Activity in Perceptual Classification Networks

Warrick Roseboom
University of Sussex, UK

Knowledge and experience of time are core parts of conscious, complex behaviour. Popular approaches to understanding human time perception focus on describing putative neural mechanisms to track objective time. In contrast, experience is characterised by deviations from veridicality—"time flies when you're having fun." We recently proposed a model of time perception built on tracking salient changes in perceptual classification. Saliency was defined as relatively large changes in network activation across layers of a deep convolutional image classification network. Similar to human vision, lower network layers are selectively responsive to less complex features, such as edges, while higher layers are selective for more object-like patterns. Against human reports regarding dynamic videos (1–64 seconds), model time estimates reproduce several qualities, including regression to the mean, variance proportional to magnitude, and dependency on scene content. Ongoing work further validates model performance using functional magnetic resonance imaging to track changes in blood oxygen level-dependent activity in visual processing areas (V1->IT) while participants view dynamic videos. Preliminary analyses support our primary presupposition that more activity across these perceptual processing areas is related to longer duration estimates, with further, specific model-based hypotheses currently under evaluation. These convergent lines of evidence support this new approach to understanding time perception.

Frequency-Based Object Identification: Exploring Spectral Analysis as a Means of Simulating Human Perception in Visual Systems

Jonas Martin Witt[1] and Claus-Christian Carbon[1,2,3]
[1]University of Bamberg, Germany
[2]Research Group EPÆG (Ergonomics, Psychological Æsthetics, Gestalt), Germany
[3]Bamberg Graduate School of Affective and Cognitive Sciences (BaGrACS), Germany

In spite of the striking successes of applied artificial intelligence, learning algorithms themselves remain wide off the mark with respect to human perceptual processing. Autonomous machine vision lacks fast feature extraction, is unable to effectively generalize learning across domains, and depends on vast data sets for training. To overcome some of these limitations, theories of human information processing are worth studying closely. We explore their application to existing computer vision processing through the methods of spectral analysis. With this approach, we outline core concepts behind human generalization capabilities regarding visual object recognition. Emphasis is placed on a psychological model of feature detection and its realization in form of periodic wave structures. We propose visual classification in spectral fully connected layers. The procedure is evaluated within a supervised learning task for the classification of traffic signs in the Belgium Traffic Sign data set for Classification. The results support the assumptions of a frequency-based representation of visual information in machines ($R^2 = .67$), compared with a pixel-based representation ($R^2 = .35$). The system's performance highlights the importance of an adaptive manipulation of the frequency domain in modern visual agents.

A Neural Network Model of Object-Based Attention and Incremental Grouping

Dražen Domijan
University of Rijeka, Croatia

A model of the recurrent competitive map is developed to simulate the dynamics of object-based attention and incremental grouping. The model is capable of simultaneous selection of arbitrary many winners based on top-down guidance. In the model, local excitation opposes global inhibition and enables enhanced activity to propagate within the interior of the object. The extent of local excitatory interactions is modulated in a scale-dependent manner. Furthermore, excitatory interactions are blocked at the object's boundaries by the output of the contour detection network. Thus, the proposed network implements a kind of multiscale attentional filling-in. Computer simulations showed that the model is capable of distinguishing inside/outside relationships on a variety of input configurations. It exhibits a spatial distribution of reaching times to points on the object that is consistent with recent behavioral findings. This means that the speed of activity propagation in the interior of the object is modulated by the proximity to the object's boundaries. The proposed model shows how elaborated version of the winner-take-all network can implement a complex cognitive operation such as object-based attention and incremental grouping.

Neural Dynamics of the Competition Between Grouping Organizations

Einat Rashal[1,2], Ophélie Favrod[1] and Michael H. Herzog[1]
[1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne, Switzerland
[2]Department of Experimental Psychology, University of Ghent, Belgium

Neural dynamics of the competition between grouping organizations have been studied to a limited extent. The paradigms used so far confounded grouping operations with task demands, using explicit reports of the predominantly perceived organization and biasing attention toward one grouping principle. This study explored the effect of grouping strength on ERPs elicited for conflicting grouping principles using a primed-matching paradigm, where the grouping display was irrelevant to the task. In Experiment 1, proximity was pitted against brightness similarity in a conflicting columns/rows organization. Competition level was manipulated by increasing grouping strength of one principle or the other. In Experiment 2, proximity was presented alone or in a weak/strong competition with size similarity. If conflicting organizations result in a hybrid representation, modifications would be evident for different degrees of grouping strength at early perceptual components. However, a competition-related component would appear in a later stage of processing, showing a difference between conflict and non-conflict conditions. We found no evidence for a competition specific component but did find modulations to the ERP waveforms at around 100 to 250 milliseconds from target onset. These results suggest that when grouping principles are in conflict, they produce a hybrid representation of the dominant and nondominant organizations.

Proximity-Induced Perceptual Grouping of Random-Dot Patterns in the Presence of a Tilting Frame

Arefe Sarami[1], Johan Wagemans[2] and Reza Afhami[1]
[1]Department of Arts, Tarbiat Modares University, Tehran, Iran
[2]Department of Brain & Cognition, University of Leuven (KU Leuven), Leuven, Belgium

The objective of this study was to investigate the effect of a tilted frame on the proximity-induced perceptual organization of random-dot patterns. Ten random patterns of nine dots were generated. For each pattern, a rectangular frame was tilted at seven angles around the dots. In ongoing experiments, for each set of 70 randomly ordered stimuli, 10 observers indicate the groups of dots in each stimulus, and each observer completes four sets of stimuli. This results in 28 grouping reports per dot pattern per observer. We randomly split the reports in two report sets and within each report set, we calculate the frequencies with which each dot-pair was placed in the same group. Chi-square and correlation independence tests between frequencies from the two sets of reports are used to measure the within-subject consistency of grouping. For all the 28 reports from each participant, we also calculate the frequency with which all dot-pairs were placed in the same groups. Independence tests between frequencies from each participant and those from other participants are used to measure the between-subject consistency of grouping. Replication with patterns of 18 points is conducted to explore the effect of dots density on the grouping consistency.

Perceiving 3D Mirror- and Rotational-Symmetry

Maddex Farshchi and Tadamasa Sawada
National Research University, Higher School of Economics, Moscow, Russia

The human visual system is very sensitive to the three-dimensional (3D) mirror-symmetry of an object's shape. This is fortunate because 3D mirror-symmetry serves as

the critical a priori constraint for perceiving a shape veridically. Note that this beneficial effect of 3D mirror-symmetry on visual perception can be attributed exclusively to its geometrical properties. Also note that 3D rotational-symmetry has geometrical properties analogous to those possessed by 3D mirror-symmetry. This makes it possible to postulate that 3D rotational-symmetry may also affect human perception in the same way. This possibility was studied by comparing a human observer's perception of 3D mirror-symmetry with perception of 3D rotational-symmetry. We required our observers to discriminate 3D symmetric and 3D asymmetric pairs of contours under both monocular and binocular viewing conditions. We found that only the 3D mirror-symmetry discrimination was reliable. With monocular viewing, the discrimination of 3D rotational-symmetry was near chance-level. Performance was slightly better with binocular viewing for both 3D mirror- and 3D rotational-symmetry, but performance with 3D rotational-symmetry was not sufficiently reliable to be taken seriously. These results suggest that the human visual system processes these two types of symmetry very differently despite the fact that they are geometrically analogous to one another.

Synergy of Spatial Frequency and Orientation Bandwidth in Texture Segregation

Cordula Hunt and Günter Meinhardt
Johannes Gutenberg-Universität Mainz, Germany

For a multitude of visual features, synergy has been shown, among those spatial frequency and orientation in Gabor random fields. We used noise textures filtered with a Gabor kernel controlled in base frequency and with random orientation to study the bandwidths of frequency and orientation. In a detection and identification experiment, we increased bandwidth in a target or the background by manipulating the Gaussian window of the Gabor. Our results show that both bandwidths exhibit feature-typical behavior as well as synergy if modified jointly. For detection, the d' difference between double-cue performance and prediction of orthogonality (DO) is very similar irrespective of whether target or background were modified (DO of 1.0 or 0.89; Cohen's d of 2.69 or 2.19). Interestingly, for identification, there is a marked difference in DO depending on the actual bandwidth of the target (DO of 1.29 or 0.59; Cohen's d of 2.53 or 1.37). Our results indicate that the salience of the target does not seem to depend on the absolute bandwidth, but the absolute difference between target and surround bandwidth. Target identification, however, is strongly influenced by absolute bandwidth.

Overlapping Surfaces Are Not Necessary for Overestimation of the Number of Elements in a Three-Dimensional Stimulus

Saori Aida[1], Yusuke Matsuda[2] and Koichi Shimono[2]
[1]Tokyo University of Technology, Japan
[2]Tokyo University of Marine Science and Technology, Japan

Elements in a stereoscopic three-dimensional stimulus that depicts parallel, overlapping, and transparent surfaces is perceived to be more numerous than those in a stereoscopic two-dimensional stimulus that depicts a single flat surface, even when both have the same number of elements. We investigated, via two experiments, the hypothesis that the visual system takes into account elements that are "potentially" occluded by the front surface and exists between the overlapping surfaces in estimating the number of elements contained as a whole. We used three types of random-dots stereoscopic three-dimensional (3D) stimuli: a stereo-transparent stimulus, which depicted two parallel-overlapping surfaces, a stepwise stimulus, which depicted two nonoverlapped surfaces each at different depths, and a "lump" stimulus, which depicted a volume but not surfaces. Experiment 1 revealed that when the disparity of elements was small, the number of elements in a stepwise stimulus was overestimated in the same manner as in a stereo-transparency stimulus. Experiment 2 revealed that the total number of elements in the lump stimulus was overestimated irrespective of the disparity size. The results indicate that overestimation of the number of elements in a 3D stimulus can occur irrespective of whether two stereo-surfaces overlap or not, being inconsistent with the hypothesis.

Influence of Disparity and Motion Cues on the Shape Perception of Transparent Objects

Nick Schlüter and Franz Faul
Institut für Psychologie, Christian-Albrechts-Universität zu Kiel, Kiel, Germany

Image regularities that could be used to estimate the shape of transparent objects arise from background distortions due to refraction, changes in chromaticity and intensity due to absorption, and mirror images due to specular reflection. Our previous findings show that although the presence of these regularities can contribute positively to shape perception in certain situations, the shape of transparent objects is judged less accurately than that of opaque ones. Here, we investigate how the overall performance and the contribution of individual shape cues change when information from disparity is removed or when information from dynamics is added. We presented subjects with images

of randomly shaped transparent objects and asked them to indicate their local surface orientation (gauge figure task). Our results show that omitting disparity information by using monoscopic stimuli impedes shape perception, but to a much lesser extent than for opaque objects. On the other hand, adding dynamics by oscillating the camera around the object substantially improves the performance, and much more so than in the opaque case. Moreover, the results suggest that this performance increase cannot be attributed solely to the concomitant increase in shape information conveyed by the contour of the object.

Preattentive Ensemble-Based Segmentation of Multiple Items: Evidence From the Mismatch Negativity

Anton Lukashevich, Maria Servetnik and Igor Utochkin
National Research University Higher School of Economics, Moscow, Russia

Our visual system is capable of rapid categorization and segmentation of multiple briefly presented items, even when they are spatially intermixed (e.g., seeing a set of berries among leaves vs. just leaves of various shades in autumn). We have previously shown that the statistics of feature distribution can be used for rapid categorization, namely whether the distribution has a single or several peaks. If the several peaks are present with large gaps between, the set can be split into relatively independent categorical groups. Here, we tested the automaticity of rapid categorization in an ERP study. We looked at the mismatch negativity (MMN), considered an ERP correlate of automatic processing (Naatanen, 1998). Our observers performed a central task diverting their attention from sequentially presented background textures with different combinations of length and orientation. The oddball event was the change in the sign of length-orientation correlation. We found evidence for an MMN to oddballs in the time window of 150 to 200 milliseconds. Critically, MMN was the strongest when lengths and orientations had two-peak rather than a smooth uniform distribution, which allows us to consider rapid categorization having an automatic, preattentive component.
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Age Judgements of Faces: Evidence for Ensemble Averaging

Deema Awad[1], Colin Clifford[2], David White[2] and Isabelle Mareschal[1]
[1]Queen Mary University of London, UK
[2]University of New South Wales, Australia

Previous work has shown that age estimates of faces are biased, with an average estimation error of 8 years. Here, we sought to examine whether the presence of other faces influences age judgments of a target face. To do this, we used a database of standardized passport photos and asked participants ($n = 136$) to estimate the age of a target face that was viewed on its own or surrounded by two different identity flanker faces. The flanker faces had the same age and differed from the target's age by $\pm$ 15 years. We find that age estimates are systematically biased toward the age of flankers, $F(2, 746) = 27.86$, $p < .001$. The target face appeared younger when it was flanked by younger faces, and appeared older when flanked by older faces, than when it was viewed alone. These effects were modulated by the stimulus age, with the largest biases occurring when the target face was similar in age to the participants'. We also tested different target:flanker ages and find similar results, although this effect was strongest for flankers differing by $\pm$15 years with the target. These results suggest that age judgments may be subject to ensemble averaging.

Filling-in of Two Antagonistic Features Into Artificial Scotoma by MIB

Hiroki Yokota and Seiichiro Naito
Tokai University, Japan

We investigated "Filling-in" at artificially created scotoma (AS) by Motion-Induced Blindness (MIB), in which the disappearing areas were surrounded by two antagonistically featured backgrounds. The features were (a) brightness, (b) color, (c) texture, (d) dynamic random dots, (e) afterimage, (f) motion, and (g) depth. Several white test discs were arranged circularly around the fixation point at equieccentric loci. For each test disc, MIB inducer was applied one disk or two at a time in turn. The inducer was the expanding rings surrounding the test disc. The observer noticed the disappearance of the test disc and reported that the two background textures were filled in, as if the subjective border line was extended and crosslinked over the disappeared test disc. Our "filling-ins" were quite consistent with that of the natural blind spot. The filling-ins of uniform texture such as (a) to (e) above have been studied; however, the filling-ins of two antagonistic features into a common area have not yet been fully investigated. The "filling-ins" of (f) and (g) were novel. Natural blind spot does not have (g). Our AS was similar to natural blind spot. The relevant nature of the border which instigate the "filling-in" should be highly abstract integrating all of (a) to (g).

Thinking Around the Corner: How to Process Sharp Bends in Contour Integration

Alina Schiffer[1], Udo Ernst[1] and Malte Persike[2]
[1]Institute for Theoretical Physics, University of Bremen, Germany
[2]Center for Teaching and Learning Services, Aachen, Germany

Contour Integration (CI) links disjoint image segments to identify the physically contiguous boundaries of global shapes or objects. Usually, contour salience deteriorates down to the point of invisibility when contour curvature increases. However, it was shown recently that the deterioration of contour visibility due to sharp changes in curvature can easily be remedied by inserting corner elements at the points of angular discontinuity (Persike & Meinhardt, 2016, 2017). Hence a question arises: What defines a "proper" corner and how do small changes in the configuration of a corner element influence the visibility of contours? We designed an experimental series analyzing the effect of corner-like elements placed at points of angular discontinuity consisting of two line segments with varying distances. These distances varied from disconnected line segments (_) as in classical CI paradigms, over line segments forming corners (∟), to overlapping line segments forming crosses (+). These experiments confirmed the stabilizing effect of corners on contour visibility. They showed that this effect is strongest for proper corners and decreases symmetrically with larger distance into both directions for classic segments as well as crossings. We currently perform model simulations to identify putative integration mechanisms explaining the experimental data.

Interaction of Convexity and Implied-Closure in Figure-Ground Organization

Tandra Ghose and Ananya Mukherjee
Uni Kaiserslautern, Germany

In figure-ground organization, a convex shared-contour implies closure, because extending it on the convex side will lead to the formation of a closed region. We investigated how convexity and implied-closure interact for determining figure-ground organization, in case of conflict. Conflict stimuli were created by manipulating the top and bottom part of the shared-contour that slightly curves around to intersect the perpendicular-borders of the bipartite image. These manipulated segments were cropped and flipped along an axis parallel to the shared contour, in order to reverse the direction of curvature. In congruent conditions, small segments of the shared contours were flipped close to the middle, so that net convexity is matched to the incongruent condition while convexity and implied-closure remained on the same side of the shared contour. Stimuli consisted of 256 bipartite black-white images with circular/triangular shared-borders in congruent and incongruent variations. Data from 18 participants show that in case of conflict, convexity has lower influence on figure-ground judgment compared with congruent cases. Data were noisier in conditions where the shared-border was horizontal and participants made up/down "figural" judgments due to the strong interference by "lower region figural" cue.

Link Ownership Assignment—A Psychological Factor in Knot Magic

Vebjørn Ekroll
University of Bergen, Norway

Many magic tricks involving knots and ropes are surprisingly effective, suggesting that unknown psychological factors are involved in creating the experience of magic (i.e., the illusion of impossibility). Here, I describe a novel perceptual principle which seems to bias our conscious reasoning about links between ropes, and thus may explain why many of these tricks are so effective. A link between two loops, such as the one created by two interlinked rings, is a shared property of the two loops. Depending on the current geometrical shape of two linked pieces of rope, however, we tend to perceive the link as belonging to only one of them. This phenomenon of link ownership assignment is reminiscent of the well-known phenomenon of border ownership assignment in figure-ground perception and can be regarded as an example of Bregman's principle of exclusive allocation. I illustrate how link ownership assignment is involved in several magic tricks and puzzles and argue that it may be an example of a more broadly applicable psychological principle, according to which the current geometrical shape category of a flexible object is so prominent in our immediate visual imagery that blocks imagery of other possible shape categories.

The Illusion of Absence in Magic Tricks

Mats Svalebjørg, Heidi Øhrn and Vebjørn Ekroll
University of Bergen, Norway

A recent analysis of the role of amodal completion in magic revealed a curious illusion of absence, where the space behind an occluder is compellingly experienced as empty. Informal observations suggest that this illusion is similar to illusions based on amodal completion in the sense that it refers to occluded portions of a visual scene and seems to be largely impervious to conscious knowledge.

Interestingly, however, this illusion cannot be explained based on extant models of amodal completion, because it does not involve directly visible parts of objects that can be used as a starting point for completion processes. The aim of the present experiment was to test the hypothesis that the illusion of absence is cognitively impenetrable in the same way as amodal completion. Participants viewed magic tricks based on attentional misdirection, amodal completion, or the illusion of absence and tried to infer the secret behind the tricks after one, two or three presentations. The results show that the tricks based on the illusion of absence are very difficult to debunk, even after repeated presentations. In this regard, they are similar to tricks based on amodal completion, but different from tricks based on attentional misdirection.

Occlusion Illusion Without Occlusion

Tom Scherzer
Kiel University, Germany

A partially occluded object is usually perceptually completed to a whole, whereby the added parts have no visual qualities such as brightness or color ("amodal completion"; Michotte, Thinès, & Crabbé, 1964/1991). Interestingly, however, under certain conditions not only an amodal but also a partial modal completion occurs ("occlusion illusion"; Palmer, Brooks, & Lai, 2007). The data presented here suggest that such a partial modal completion occurs not only with opaque but also with semitransparent screens. This would mean that the occlusion illusion cannot be attributed to occlusion itself. Rather, the effect seems to occur when there is clear evidence regarding the shape and quality of the continuation of a visible element. The findings are largely consistent with the theoretical idea that the phenomenal presence of visual qualities, as in the case of modal completion, represents a strong conclusiveness of sensory evidence ("conclusive-sensory-evidence hypothesis"; Scherzer & Faul, in press).

The Effect of Occlusion on "Tool Effect"

Hidemi Komatsu
Keio University, Japan

This study investigated the effect of occlusion on "tool effect" (without intermediary object). "Tool effect" is one of the "perceived causality" that had been examined by Michotte (1951). Object A (launcher), I (intermediary), and B (target) were arranged horizontally from the left. These objects began to move in the order of Objects A, I, and B. Then Object A was perceived to be the cause of all other objects' motions. Even if Object I was omitted, "tool effect" could be perceived. Some amodal "tool" was perceived to push Object B. As the stopping position of Object A was nearer Object B, the "tool effect" tended to be perceived. In these experiments, by examining the relationship between the stop position of the Object A and the reported rate of causality, the difference of the causal impression under with or without occluding object condition was compared. In without occluding object condition, the rate of "tool effect" had a negative correlation to distance between the stopping position of Object A and the starting position of Object B ($y = -4.22x + 79.57$, $R^2 = .97$). However, if the stopping point of Object A was occluded, it was increasing as the distance was longer. The relation of them approximated sigmoid curve ($y = -0.90x^3 + 13.05x^2 + 57.03$, $R^2 = .99$).

Anticipating Object Trajectories in the Presence of a Goal

Andrea Frielink-Loing, Arno Koning and Rob van Lier
Cognition and Behaviour, Donders Institute for Brain, Radboud University, Nijmegen, the Netherlands

We investigated whether attention allocation during Multiple Object Tracking (MOT) is influenced by the presence of a goal. We used adaptations of MOT paradigms to determine the allocation of attention near tracked objects as they moved toward a goal. In Experiment 1, participants tried to "catch" targets by controlling a goal. A vertical line centred on the screen acted as a wall off which objects bounced. Target bounces triggered the appearance of a probe in either the bounce direction (i.e., real future object location) or linear direction. Participants detected probes better when the target subsequently reached the goal as compared with no goal. In Experiment 2, participants additionally controlled the permeability of the vertical wall, allowing objects to move through or bounce off. Again, probes appeared when targets reached the vertical wall. Two corners of the screen were designated fixed goals, one "good" and one "bad." Only when a target moved toward a "good" goal, probes were detected better when the probe location was in the path toward that goal. The opposite was true for targets moving toward a "bad" goal. We conclude that the presence and valence of a goal influences how attention is allocated during object tracking.

The Influence of Perspective of an Inanimate Object on the Boundary Extension Phenomena

Giada Sangiorgi[1], Gabriele Pesimena[2], Elena Commodari[1], Marco Bertamini[3] and Alessandro Soranzo[2]
[1]University of Catania, Italy
[2]Sheffield Hallam University, UK
[3]University of Liverpool, UK

One of the most compelling phenomena in visual memory is the Boundary Extension (BE) which is the tendency to remember close-up scenes as if they include more information than that was seen. Intraub and Richardson (1989; JEP: LMC), suggested that this phenomenon is due to a filling in process: we fill the scene with information around the boundaries based on our knowledge. For the BE to occur, the scene must be perceived as part of a continuous environment. This project investigated whether the BE can be implicitly affected by the directional information provided by a camera. In the learning phase of a recognition experiment, participants were presented with an image on a computer screen that could have been cropped either to the left or to the right, while a camera could have been positioned either to their left or right. In the testing phase, the image was then presented again, and participants were asked to judge if it was the same. Results showed that the BE magnitude reduces when the camera is in the same side of the cropped images. It is concluded that implicit directional cues can affect our ability to visually memorize images.

Corepresentation of the Features of Objects in the Processes of Perception and Assessment of the Chances of Joint Events

Sergei L. Artemenkov
Moscow State University of Psychology and Education, Russia

Perceptual processes include co-existence of different alternatives providing the flexibility needed by multifunctional perceptual and cognitive system. According to the perceptual reality for any object, it is more reliable to have many defined and related features than just one feature. Thus, perceptual processes (unlike thinking processes) show that an object with many simultaneous and related features that belong to it is in fact more valid and actual than an abstract object with just a few random features. This assumes that the nature of perceptual cognition is complex and quite different from common probability logic of joint independent events considered by probability theory. The transcendental psychology approach to perception makes it possible to substantiate corepresentative mathematical probability model, which is compliant with human perceptual psychology and heuristic judgment under uncertainty. This model establishes other rules for combining probabilities and shows that the probability of joint events may exceed the probability of any of the events separately. Cross-cultural experiment on the perception of the likelihood of joint events showed the possibility of influencing a person's decision-making in a predictable direction, by varying perceived and semantic situational parameters in accordance with the theoretical assumptions associated with the new model for estimating probability.

Phenomenal Causality and Sensory Realism

Sebastian Alexander Bruijns[1], Kristof Meding[1,2], Bernhard Schölkopf[2] and Felix Wichmann[1]
[1]Universität Tübingen, Germany
[2]Max-Planck-Institute for Intelligent Systems, Stuttgart, Germany

One of the most important tasks for humans is the attribution of causes and effects—in diverse contexts, including visual perception. Albert Michotte was one of the first to systematically study causal visual perception using his now well-known launching event paradigm. Launching events are the collision and transfer of movement between two objects—featureless disks in the original experiments. The perceptual simplicity of the original displays allows for insight into the basics of the mechanisms governing causal perception. We wanted to study the relation between causal ratings for launching in the usual abstract setting and launching collisions in a photo-realistic setting. For this purpose, we presented typical launching events with differing temporal gaps, as well as the same launching processes with photo-realistic billiard balls, and also photo-realistic billiard balls with realistic physics, that is, an initial rebound of the first ball after collision and a short sliding phase of the second ball. We found that simply giving the normal launching stimulus realistic visuals lead to lower causal ratings, but realistic visuals together with realistic physics evoked higher ratings. We discuss this initially perhaps counterintuitive result in terms of cue conflict and the seemingly detailed (implicit) physical knowledge embodied in our visual system.

Perception of Temporal Dependencies in Autoregressive Motion

Kristof Meding[1,2], Bernhard Schölkopf[2] and Felix A. Wichmann[1]
[1]Neural Information Processing Group, University of Tübingen, Germany

[2]Department of Empirical Inference, Max Planck Institute for Intelligent Systems, Tübingen, Germany

Understanding the principles of causal inference in the visual system has a long history, certainly as the seminal studies by Michotte. During the last decade, a new type of causal inference algorithms has been developed in statistics. These algorithms use the dependence structure of residuals in a fitted additive noise framework to detect the direction of causal information from data alone (Peters et al., 2008). In this work, we investigate whether the human visual system may employ similar causal inference algorithms when processing visual motion patterns, focusing, as in the theory, on the arrow-of-time. Our data suggest that human observers can discriminate forward and backward played movies of autoregressive (AR) motion with non-Gaussian additive independent noise, that is, they appear sensitive to the subtle temporal dependencies of the AR-motion, analogous to the high sensitivity of human vision to spatial dependencies in natural images (Gerhard et al., 2013). Intriguingly, a comparison to known causal inference algorithms suggests that humans employ a different strategy. The results demonstrate that humans can use spatiotemporal motion patterns in causal inference tasks. This finding raises the question of whether the visual system is tuned to motion in an additive noise framework.

Poster Session 4

The Impact of Multifocal Attention on Population Receptive Fields in Human Visual Cortex

Susanne Stoll[1], Elisa Infanti[1] and D. Samuel Schwarzkopf[1,2]
[1]University College London, UK
[2]The University of Auckland, New Zealand

How the brain allocates attention to multiple task-relevant visual objects remains unclear. To address this question, we used functional magnetic resonance imaging to estimate population receptive fields (pRFs) while human observers performed a focal rapid serial visual presentation (RSVP) task at central fixation (baseline), in the upper-right visual field (unifocal condition), at fixation and in the upper-right visual field, or in the upper-right and lower-left visual field (multifocal conditions, respectively). Using the pRF position estimates from each condition, we back-projected the corresponding pRF size estimates into visual space and summarized them spatially via a searchlight procedure. For each condition, pRF size increased from the central to the peripheral visual field in early visual cortex, replicating previous research. When contrasting the unifocal condition to our fixation baseline, however, pRF size in early visual cortex increased predominantly in the upper-right visual field and decreased in the remaining visual field. Surprisingly, similar differential patterns emerged for both multifocal conditions (vs. baseline). We speculate that our findings reflect visual field asymmetries. Specifically, performing a RSVP task in the parafoveal upper-right visual field might be more challenging than in the lower-left visual field, necessitating increased spatial pooling and improved visual field coverage.

Cuing Spatial Attention in the Praying Mantis

Vivek Nityananda[1], Dune Ganot[1,2] and Jenny Read[1]
[1]Newcastle University, UK
[2]University of Rennes 1, France

Most studies of attention have focussed on vertebrates, yet other animals, including insects, must also select targets or spatial regions in their environment. We designed an experiment to investigate spatial attention in the praying mantis. We used a spatial cuing paradigm to elicit attention towards two different spatial areas. A target was then presented in either the same location as the cue or the opposite location, and we measured the difference in the probability of the mantis striking at a target in each of these cases. By varying the contrast of the targets, we further investigated the effect of spatial cuing on the contrast sensitivity of mantis striking behaviour. We present initial results from this cuing paradigm and discuss its usefulness for studies of attention in insects.

The Role of Social Mechanisms in Modulating Attentional Interference

Gabriele Pesimena[1], Marco Bertamini[2] and Alessandro Soranzo[1]
[1]Department of Psychology Politics and Sociology, Sheffield Hallam University, UK
[2]Department of Psychological Science, Liverpool University, UK

Spatial cueing of attention occurs when attention is oriented by the onset of a stimulus at a location signalled by a cue, creating an expectation that a stimulus will appear in that location (Posner, 1980; QJEP). To study this phenomenon, Samson et al. (2010; JEP: HPP) created a computer task consisting in a visual scene with a cue (a human avatar) pointing toward some targets. Participants were prompted to assume either their own or the avatar's perspective with the pronouns YOU and S/HE, respectively. Participants had to judge how many targets were visible. Authors found that the cue interferes with participants

reporting what they see and suggested that this interference is due to the social characteristics of the cue. To test whether social characteristics are necessary to generate this interference, we replicated Samson's experiment by systematically manipulating the social characteristics of (a) the cue: avatar, camera, and arrow; and (b) the pronoun used to prompt the perspective: social (e.g., YOU) vs. nonsocial (e.g., TOTAL). Results showed that the interference persisted when social components were removed from both the cue and the prompt. It is concluded therefore that the directional information of the cue is sufficient to orient attention and to generate interference.

The Influence of Depth of Field on Visual Attention in Moving Images

Christina Soderberg[1], Oliver Christiansen[2] and Szonya Durant[1]
[1]Royal Holloway, University of London, UK
[2]Cinefade Londen, UK

Depth of field changes are often utilised within cinematography with the intention of directing the viewer's visual attention. To empirically assess the effectiveness of differing depths of field on guiding attention in moving images, participants were eye-tracked while observing a series of video clips. The clips depicted two actors walking laterally across a scene, with either a static shallow depth of field, a dynamic depth of field change from deep to shallow, or a static deep depth of field—which acts as a control as both actors were continually in focus. Across the two conditions with a shallow depth of field, there was a significant main effect on total fixation duration; the actor who was continually in focus was fixated upon for a longer period of time, $F(1, 28) = 7.96$, $p < .01$. The largest effect was found in the fixed depth of field condition; viewers fixated upon an in-focus actor an average of 22.19% longer compared with when the actor was out of focus. Thus a strong preference was found in viewers to attend toward the actor who is in focus when free viewing moving images, which supports the use of depth of field in cinematography to guide attention.

Functional Magnetic Resonance Imaging Evaluation of the Effect of Visual Attention for Self-Controlled Moving Object—Psycho-Physiological Interactions and Dynamic Causal Modelling

Qiaobo Qu and Takako Takako Yoshida
Tokyo Institute of Technology, Japan

Recent discussions indicate the influence of the efference copy of intentional motor command on visual attention in the sense of agency model. To determine the association between attention and sense of agency, we developed a wearable pneumatic robot, evaluating passive hand movements inside the magnetic resonance imaging scanner, and compared brain activity under two visual stimulus conditions elicited by active and passive hand movements. (a) Functional magnetic resonance imaging results indicated the activation of the cerebellum and contralateral supramarginal gyrus when attention was directed at the active hand motion-controlled visual object. (b) Psychophysiological interaction analysis revealed functional integration among the visual cortex, primary motor cortex, cerebellum, and contralateral supramarginal gyrus. (c) A PPI analysis-based novel, action-triggered attention system may be devised utilizing the dynamic causal modelling analysis. These results suggest that attention plays a role in the facilitation of sensory feedback relying on cerebellar and supramarginal gyrus functions.

Exploring Dimensions of Perceived Visual Complexity in Natural Textures

Andreas Gartus and Helmut Leder
University of Vienna, Austria

While at first glance, visual complexity may appear to be an objective property of an image, it is known that different visual and psychological factors are contributing to the perception of complexity. We presented 476 texture images of the Salzburg Texture Image Database to 74 participants who rated the images for visual complexity on 5-point scales. Surprisingly, we found that some of the participants showed substantial negative correlations with other participants. Thus, these participants did not just disagree, but systematically produced opposing judgments of visual complexity. Using hierarchical clustering, it was possible to roughly split the participants into two groups. Mean complexity ratings of these groups did also negatively correlate with each other ($r = -.4$). Furthermore, while a well-known predictor like GIF compression rate (of downsized versions of the images) was a good predictor of the ratings in one group, this was not the case for the other group. From the different relations of predictors and visual inspection of images with high ratings in one and low ratings in the other group, we speculate that the reasons for the systematic differences in complexity ratings could be different accounting for higher spatial frequencies and semantic content by the participants.

Visual Search for Chromatic Composition of Art Paintings by Chimpanzees

Tomoko Imura[1], Shigeki Nakauchi[2], Nobu Shirai[3] and Masaki Tomonaga[4]
[1]Japan Women's University, Tokyo, Japan
[2]Toyohashi University of Technology, Japan
[3]Niigata University, Japan
[4]Primate Research Institute, Kyoto University, Japan

Previous studies showed that when humans were asked to choose the most preferable one among four images of unfamiliar paintings: original (0°) and three hue-rotated images (90°, 180°, and 270°), they preferred to choose the original images regardless of the categories of art paintings (Nascimento et al., 2017; Kondo et al., 2017). Although such preferences seem to be shaped by human-specific cultural and developmental experiences, there may be some biological basis. We examined the ability to discriminate chromatic composition of art paintings for chimpanzees. We measured chimpanzees' sensitivities for colour hues of art paintings using a visual search task. Moreover, six chimpanzees (aged in 18–42 years, one male) were asked to select an original coloured image or 90° hue-rotated image from the six hue-inverted images presented on the display. These images had equal luminance and mean chromaticity. In addition, 24 paintings of three categories (abstract, poster, and flower) were used as visual stimuli. Results showed that the original images were easier to be detected than the hue-rotated images regardless of the category. The advantage for visual processing of the original images may be shared by primate species.

I Like Nature and I Find It Restorative—Are These Two Different Mechanisms? An Experimental Study With Spatially Filtered Images

Claudia Menzel and Michael Schreiner
Social, Environmental and Economic Psychology, Institute of Psychology, University of Koblenz-Landau, Germany

Several theories aim to explain the beneficial effects of viewing nature compared with urban environments. While attention restoration theory proposes that nature's characteristics facilitate the restoration of directed attention, the stress recovery theory postulates that nature evokes positive affect that leads to stress reduction. The perceptual fluency account suggests fluent processing of nature is leading to positive affect and then restoration. All theories have at least some empirical support. Previous findings, including those based on spatially filtered images, indicate that the restorative and affective responses to natural compared with urban environments might originate different mechanisms. We aimed to test whether restorativeness and preference are mediated by different spatial frequencies. Therefore, we presented nature and urban images with all spatial frequencies, only high spatial frequencies, or only low spatial frequencies both for explicit ratings and implicit association tests. Preliminary data of both explicit and implicit measures replicated that generally nature images are liked more and rated as more restorative than urban ones. Importantly, for both measures no interaction of rating term and spatial frequency content was found. This contradicts previous findings which indicated different mechanisms.

Changing Aesthetic Values in Stereo Photography

Oguz Sagdic
TOBB ETU, Ankara, Turkey

The legacy of traditional aesthetic values holds up in the environment of new media; however, we need to extend our visual criteria for beauty to adapt to the fast-changing modern era. There may be a generational difference in people's efficiency in using Virtual Reality space which is a contiguous stream of Stereo Photography. To explore this question, the connection between Stereo Photography and Virtual Reality was examined. By using still stereo photographs (late 19th to early 20th century), we searched for clues for new aesthetic values required by Virtual Reality in frameless space by using A/r/tography as the research method. A study was conducted with a class of Visual Communication Design students through a photo-novel project based on early Stereo Photographs and Chris Marker's La Jetée (1962). In teams of two, we created 5-minute stories told through photography based on simple scripts using conventional photo aesthetics and achieved varied results and findings. We then attempted to recreate the same stories using two smartphones to achieve a stereo video image and compared the results and the implications on changing aesthetic values in photography throughout history.

Subjective Ratings of Affective Pictures Depend on Global Image Properties

Christoph Redies[1], Maria Grebenkina[1], Mahdi Mohseni[1], Ali Kaduhm[1] and Christian Dobel[2]
[1]Experimental Aesthetics Group, Institute of Anatomy, University of Jena School of Medicine, Germany
[2]Department of Otolaryngology and Institute of Phoniatry and Pedaudiology, University of Jena School of Medicine, Germany

It is generally accepted that pictorial content, for example, from affective pictures, plays a decisive role in evoking emotions in human observers. However, previous studies suggest that low-level perceptual properties, such as brightness or color, also have an effect on emotion ratings. Here, we asked whether higher order image properties, which reflect global image structure, mediate emotional processing of affective images as well. We calculated 11 global image properties, which were previously linked to visual preference of visual stimuli, for affective pictures from five datasets (IAPS, GAPED, NAPS, DIRTI, and OASIS). Based on the image properties, an SVM-RBF classifier can predict high and low ratings for valence and arousal, respectively, with 58% to 76% accuracy. By multiple linear regression analysis, we show that image properties can account for between 6% and 20% of the variance in the subjective ratings for valence and arousal. Results vary for the different datasets and the type of ratings. Ratings that correlate positively with each other tend to share similar sets of predictors. In conclusion, using linear and nonlinear analyses, we provide evidence that affective pictures may evoke emotions not only by what they show but also by how they show it.

Psychological Effect of Color and Aroma of Green Tea on Predicted Taste and Deliciousness

Akihisa Takemura[1], Shino Okuda[2], Katsunori Okajima[3] and Yuki Kataoka[2]
[1]Setsunan University, Neyagawa, Japan
[2]Doshisha Womens' College of Liberal Arts, Kyoto, Japan
[3]Yokohama National University, Yokohoma, Japan

To reveal the effect of color and aroma of green tea on a psychological evaluation before drinking, we conducted three experiments where 21 female university students participated. In Experiment 1, they saw six images of tea in a glass at a depression angle of 40° on an LC monitor in a black room whose size is 650W × 900D × 1,480H mm. In Experiment 2, they sniffed six aromas in each bottle, which were flavors of lemon, apple, adzuki bean, orange, peppermint, and vanilla. In Experiment 3, they saw each image while sniffing each aroma multimodally. Participants evaluated predicted sweetness, sourness, and bitterness; predicted deliciousness; and impression with 17 pairs of adjectives. In Experiment 3, the lemon and orange flavor increased sourness more than visual evaluations. The adzuki bean and vanilla aroma decreased sourness more than visual evaluations. Moreover, it was revealed that all aroma decreased bitterness more than visual evaluations. The multimodal evaluation (Z) was assumed to follow a model formulated as $Z = aX + bY$, where a and b were weighting factors, X was the visual evaluation, and Y was the olfactory evaluation. The contribution ratios (b/a) of aroma to color in predicted deliciousness was 3.70.

Q-Methodology and Aesthetic Preferences for IOs: The Role of Alexithymia

Carla Pollicino[1], Jie Gao[2], Daniela Conti[2], Elena Commodari[1] and Alessandro Soranzo[2]
[1]Università di Catania, Italy
[2]Sheffield Hallam University, UK

This study investigated the aesthetic preference for Interactive Objects (IOs) by using an innovative Q-method and tested whether it exists a relationship between preference for IOs and alexithymia, measured by the Toronto Alexithymia Scale (TAS-20). The IOs employed were three-dimensional artefacts differing for size (large vs. small), material (rough vs. smooth), shape (angular vs. rounded), and behavior (vibrating, lighting, sounding, or quiescent). A novel analysis procedure for Q-sorting data was employed to estimate both the importance and the preference for each variable. Results show that behavior was the most important variable, while in terms of preference, participants preferred lighting-up and rounded IOs. Some differences for the preferences emerged between the participants ranking in the two Q-factors emerged from the data. These results are in line with those obtained by Soranzo et al. (2018; *QJEP*) using a Likert-type scale, supporting the robustness of the innovative Q-method. Although no significant relationship emerged between alexithymia and aesthetics preference, it was interesting that participants reporting higher levels of alexithymia were mostly loaded on the same Q-factor.

Data-Driven Mathematical Model of Universality and Cultural Differences in Facial Attractiveness Judgments

Koyo Nakamura[1,2,3], Jan Mikuni[4], Helmut Leder[5] and Katsumi Watanabe[1,6]
[1]Waseda University, Shinjuku, Japan
[2]Japan Society for the Promotion of Science, Tokyo, Japan
[3]Keio Advanced Research Centers, Tokyo, Japan
[4]Keio University, Tokyo, Japan
[5]University of Vienna, Austria
[6]University of New South Wales, Sydney, Australia

Whereas there exists ample evidence for universal standards of facial attractiveness, recent cross-cultural studies have revealed that the criteria for facial attractiveness vary across cultures. One of obstacles in examining universality and cultural differences in facial attractiveness lies in obtaining controlled face stimuli. This study aimed at overcoming this hindrance by using data-driven mathematical modeling. We generated 200 male and 200 female artificial faces from random combinations of 50 shape-parameters and 50 texture-parameters in the FaceGen Modeller. Austrian and Japanese observers rated the attractiveness of the faces on a 9-point Likert-type scale. Then data-driven mathematical calculations were performed to identify quantitative links between attractiveness and facial properties (i.e., shape and texture information), separately for Austrian and Japanese observers. Our attractiveness model revealed that both Austrian and Japanese observers perceived the faces with bigger eyes and smaller noses as attractive, irrespective of sex of the faces. However, there were also specific differences: Austrian observers preferred a fuller lip and darker skin than Japanese observers. These findings suggest that facial attractiveness is judged by both universally shared features, but also culturally attuned preferences. And, our method provides quantitative parameters and predictions by considering both universality and cultural differences in attractiveness judgments.

Gender Categorization and Attractiveness of the Human Body: The Effects of Gender Ambiguity

Slobodan Marković and Tara Bulut
University of Belgrade, Serbia

In this study, we investigated the effects of masculinity (measured by shoulder-to-hip ratio, SHR) and femininity (measured by waist-to-hip ratio, WHR) on gender categorization speed and probability of body categorization as male (M) or female (F). Participants categorized 12 silhouettes of human figures: 4 figures of different levels of masculinity (4 SHR sizes; WHR constant), 4 figures of different levels of femininity (4 sizes of WHR; SHR constant), and 4 ambiguous figures (from the figure with a low SHR and WHR to the figure with a high SHR and WHR). The analyses indicated that the categorization speed increased with the increase of unambiguous masculinity or femininity. The probability of gender categorization of unambiguous figures was almost 100%, but the situation with ambiguous figures was more complex—the figure with the lowest ambiguity is categorized in 50% of cases as a male or female, while the figures with higher masculine and feminine characteristics were dominantly categorized as females: These figures were experienced as females with broad shoulders rather than as males with a narrow waist. This finding suggests that female sexual characteristics (WHR) more strongly determine the estimated gender compared with male characteristics (SHR).

Precision of Isolated Facial-Expression and Body-Posture Representations Determines Integrated Whole-Person Perception of Emotion

Isobel L. Ward[1], Stephan de la Rosa[2,3], Christoph Teufel[1] and Elisabeth von dem Hagen[1]
[1]Cardiff University Brain Research Imaging Centre, Cardiff University School of Psychology, UK
[2]Max Plank Institute for Biological Cybernetics, Tübingen, Germany
[3]FOM University of Applied Sciences, Augsburg, Germany

Previous research on the perception of facial expression has highlighted the importance of context. For instance, affective body posture influences perception of facial expression, such that observers are more likely to perceive a disgusted face as "angry" when presented in the context of an angry body. This integration of face and body emotion cues is highly variable across individuals, offering an opportunity to study the mechanisms underlying integrated whole-person perception. Using standard psychophysical tasks in combination with computational modeling, we indexed the precision of representations of isolated facial expression and body posture cues as well as the influence of each cue on the integrated whole-person percept of emotion. The results indicate that the perceptual integration that leads to a whole-person representation is determined by the precision of the individual cues. These results provide the basis for developing a mechanistic model of how facial expression and body posture cues are combined to create integrated whole-person percepts of emotion and have important implications for our understanding of real-world individual differences in social perception.

Emotional Facial Expressions Modulate Saccadic Response in a Saccadic Choice Task

Léa Entzmann[1], Nathalie Guyader[2], Louise Kauffmann[1,2], Carole Peyrin[1], Juliette Lenouvel[1], Clémence Charles[1] and Martial Mermillod[1]
[1]Université Grenoble Alpes, Université Savoie Mont Blanc, CNRS, LPNC, France
[2]Université Grenoble Alpes, CNRS, Grenoble INP, GIPSA-lab, France

A large number of studies showed that when multiple stimuli compete for eye fixation, emotional stimuli are most likely to attract gaze than neutral stimuli. Happy faces are also easier to detect than other emotional facial expressions. In this study, we used a saccadic choice task to investigate facial expression processing for happy, fearful, and neutral faces. Emotional-neutral pairs of faces were presented on both side of the screen, and participants ($N = 20$) were asked to saccade toward a target (emotional or neutral face). As previously shown, participants were better to saccade toward emotional targets, and especially toward happy faces (i.e., higher accuracy and shorter latency). More interestingly saccade vertical amplitude was also modulated by the target and the emotional facial expression. Precisely, overall saccade ending positions were lower for emotional targets and even more for happy faces. These results (a) confirm an advantage for emotional faces and for happy compared with fearful faces and (b) suggest that participants targeted different features on the face depending on the emotional facial expression. Further investigations, both at the behavioral and computational level, are currently performed in order to disentangle the contributions of perceptual features in this task.

Facial Color Effect on Recognition of Facial Expression: A Comparison Among Japanese and Malaysian Adults and School Children

Satoshi Nakakoga[1], Yuji Nihei[1], Yuya Kinzuka[1], Chang Kah Haw[2], Wan Nazatul Shima Shahidan[2], Haslina Mohd Nor[2], Get Bee Yvonne-Tee[2], Zuraidah Binti Abdullah[2], Tomoko Imura[3], Nobu Shirai[4], Shigeki Nakauchi[1] and Testuto Minami[1,2]
[1]Department of Computer Science and Engineering, Toyohashi University of Technology, Aichi, Japan
[2]School of Health Sciences, Universiti Sains Malaysia, Penang, Malaysia
[3]Department of Psychology, Faculty of Integrated Arts and Social Sciences, Japan Women's University, Tokyo, Japan
[4]Department of Psychology, Faculty of Humanities, Niigata University, Japan
[5]Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology

The change of facial color and expression reflects our mental and physical condition. Therefore, facial color plays a role in the interpretation of an individual's emotions. The previous study indicated the facial color effect on recognition of facial expression; for example, reddish-colored anger faces were perceived angrier than natural-colored anger faces. However, the previous study has only clarified the facial color effect on Japanese adult and requires further investigation. In this study, we conducted a two-alternative forced choice (2AFC) experiment on primary school children and adults in Japan and Malaysia to compare this effect between generations and cultures. For this experiment, anger and fear facial stimuli of Asian and Caucasian were taken from the database and then morphed in five levels. Participants were asked to identify the expression of the morphing face by 2AFC task. As a result, we found a significant interaction between participant groups and facial color condition. For only Japanese and Malaysian adults, the thresholds of anger in reddish-colored faces were significantly lower than those in natural-colored faces. Taken together, we suggested the facial color effect on expression is acquired after childhood and has no culture difference at least in Asia.

Dynamic but Not Static Facial Expressions Are Better Recognized With Low Phase-Signals

Anne-Raphaëlle Richoz, Valentina Ticcinelli, Pauline Schaller, Junpeng Lao and Roberto Caldara
University of Fribourg, Switzerland

Unlike static images routinely used in face processing experiments, natural expressions evolve over time, providing observers with ecologically valid dynamic signals. While recent studies observed that children, elderly people, and patients benefit from the richer dynamic over static information (Richoz et al., 2015, 2018), a consistent body of evidence counterintuitively reported that young adults do not, suggesting the existence of a near optimal expression decoding system in this population. To probe the hypothesis that such evidence is rooted in a ceiling effect, we used the QUEST threshold-seeking algorithm to determine the perceptual thresholds of 70 young adults recognizing static and dynamic facial expressions, parametrically varying for their phase-signals (0–100%) normalized for amplitude and spectra. Overall, we observed that dynamic expressions were all better decoded when presented with low phase-signals (peaking at around 20%). This advantage gradually decreased with

increasing phase-signals, reaching a ceiling effect at 70%. Our data show that facial movements play a critical role in our ability to reliably identify facial expressions given the suboptimal visual signals typical of everyday life interactions. Dynamic signals are more effective and sensitive than static inputs for decoding all facial expressions, for all human observers.

Natural Brief Facial Expression Changes Detection at a Single Glance: Evidence From Fast Periodic Visual Stimulation

Stéphanie Matt[1,2], Milena Dzhelyova[3], Louis Maillard[4], Joëlle Lighezzolo-Alnot[2], Bruno Rossion[3,4] and Stéphanie Caharel[1]
[1]Laboratoire 2LPN (EA7489), Université de Lorraine, Nancy, France
[2]Laboratoire INTERPSY (EA4432), Université de Lorraine, Nancy, France
[3]Institute of Research in Psychological Science, Institute of Neuroscience, University of Louvain, Louvain-la-Neuve, Belgium
[4]CRAN (UM) (UMR 7039 CNRS) – CHU de Nancy – Université de Lorraine (France)

In the human brain, brief facial expression changes are quickly read from faces (Dzhelyova et al., 2017). In this study, faces were embedded in a natural context and varied in viewpoint, identity, gender, age, ethnic origin, and background context. We recorded 128-channel electroencephalography (EEG) in 17 participants while they viewed 50-s sequences with a neutral-expression face at a rate of 5.99 Hz (F) at two faces orientations (upright, inverted). Every five stimuli, the faces changed expression to one of the six basic expression (fear, disgust, happiness, anger, surprised, or sadness; Ekman, 1993), one emotion per sequence. EEG responses at 5.99 Hz reflect general visual processing, while the EEG responses at $F/5 = 1.1998$ Hz and its harmonics (e.g., $2F/5 = 2.3996$, etc.) index detection of a brief change of natural facial expression. At the group-level, the categorization response was measured over occipito-temporal sites and was largely reduced when faces were inverted, indicating that it reflects high-level processes. Our observations with natural expressions highlight a stronger response for sadness, especially over the left hemisphere. Moreover, we observed a right hemisphere dominance for a shift from neutral to fearful faces and a left hemisphere dominance for a shift from neutral to happy faces.

Consistent Behavioral and Electrophysiological Evidence for Rapid Perceptual Discrimination Among Human Basic Facial Expressions

Milena Dzhelyova[1], Qiuling Luo[2] and Bruno Rossion[1,3,4]
[1]UCLouvain, Belgium
[2]Institute of Psychology, School of Teacher Education, Zhejiang Normal University, Jinhua, China
[3]Université de Lorraine, CHRU-Nancy, Service de Neurologie, France
[4]Université de Lorraine, CNRS, CRAN, France

The extent to which the six basic human facial expressions perceptually differ from one another remains controversial. Here we quantified implicit pairwise visual discrimination between facial expressions with a fast periodic visual stimulation approach combined with scalp electroencephalography (FPVS-EEG). We report robust facial expression discrimination responses for each pairwise expression change (i.e., 30 comparisons) bilaterally over the occipito-temporal cortex. While fearful faces presented as common stimuli led to the smallest deviant responses from all other basic expressions, deviant fearful faces were well discriminated overall, and to a larger extent than expressions of sadness and anger. Expressions of happiness did not differ quantitatively as much in the EEG as for slow subjective judgments, suggesting that the clear dissociation between happy and other expressions found behaviorally is not entirely perceptual but reflect higher order processes. However, this expression differed from all others in terms of scalp topography, pointing to a qualitative difference. Despite this difference, overall, we report a tight relationship ($r > .8$) between implicit EEG responses and behavioral explicit measures collected under the same temporal constraints, paving the way for new approaches of understanding facial expression discrimination in developmental, intercultural, and clinical populations.

Contribution of High Spatial Frequencies of Informative Facial Features to Facial Expression Recognition and Discrimination

Nazire Duran and Anthony Atkinson
Durham University, UK

At normal interpersonal distances, all features of a face cannot fall within one's fovea simultaneously. In previous studies, we found that a single fixation of the mouth of disgusted and surprised faces significantly improved recognition of these expressions compared with foveating an eye, and that foveating the central brow of angry faces

reduced the frequency of "neutral" responses to those faces. In this study, we investigated whether these effects are due to foveal processing of high spatial frequencies at the fixated region. Angry, fearful, surprised, disgusted, and neutral faces were presented briefly at a position that guaranteed that the brow, mouth, or midpoint between them fell at the fovea. The fixated feature was fully visible, occluded or low-pass filtered to match the retinal filtering caused by viewing that feature at the brow-to-mouth distance in the periphery. Occlusion of the fixated brow led to poorer anger recognition compared with a fully visible brow. Occlusion of the fixated mouth led to poorer recognition for fear and disgust compared with both the fully visible and filtered mouth. Thus, any advantage of foveal viewing derived not from the additional high-resolution information extracted at fixation, but simply from the processing associated with the fixated locations.

The Happiest Wins With Both Upright and Inverted Faces: Evidence of Part-Based Processing of Facial Expressions Pair

Giulio Baldassi[1], Mauro Murgia[1], Valter Prpic[2], Tiziano Agostini[1] and Carlo Fantoni[1]
[1]Department of Life Sciences, Psychology Unit "Gaetano Kanizsa," University of Trieste, Italy
[2]Faculty of Health and Life Sciences, Institute for Psychological Science, De Montfort University, UK

Experimental evidence suggests that the comparative judgement of facial expressions of emotions is stimulus-driven: when a happy face and an angry face are presented simultaneously, the former is recognized faster than the latter (i.e., happiness advantage). Furthermore, the most intense emotional face within a pair is recognized faster (i.e., Emotional Semantic Congruency effect - ESC). However, no study investigated the nature of the perceptual processing at the basis of these stimulus-driven effects with inverted faces (holistic vs. part-based). In two experiments participants chose the angriest/happiest face, between complete- (i.e., happy/angry, in Experiment 1) and mixed- (neutral/happy-or-angry, in Experiment 2) facial expressions shown side-by-side, both displayed either in upright or in inverted condition. Beyond an overall expected facilitation for upright over inverted faces judgements, results showed that: 1) ESC was robust for faces displayed in both upright and inverted conditions, in favour of a type of processing independence; 2) the happiness advantage was affected by the type of pair being stronger in complete- rather than mixed-facial expressions pair. This difference can rise from the need of extrapolating a reference cut-off for judgements of complete- but not mixed-facial expressions (in which the cut-off is likely to be elicited by the neutral face).

Shadows Between Eyebrows Dissolved the Confusion Between Angry and Disgusted Faces

Chun-Wei Hsu[1], Li-Chuan Hsu[2,3] and Yi-Min Tien[1]
[1]Chung-Shan Medical University, Taichung
[2]School of Medicine, China Medical University, Taichung
[3]Graduate Institute of Biomedical Sciences, China Medical University, Taichung

Prior research reports the confusions between the facial expressions of anger and disgust. Shadows on face are informative to build a three-dimensional mental model regarding its emotional expression. Shadows induced by different light sources overlaid on a Japanese Noh mask alter its perceived facial expression. In this study, we investigate whether the shadows on the whole face is necessary, or shadow on a particular region is sufficient to alter perceived facial expressions. In Experiment 1, we adopt priming paradigm in which one of five emotional faces was presented preceded the target of either disgusted or happy faces. Three kinds of shadows on the prime were manipulated including original, removing shadows between eyebrows, and removing shadows of the whole face. In Experiment 2, the same manipulation of primes was used, but instead, the shadows between eyebrows of the target faces were removed. The results revealed no matter original or removed shadows between eyebrows, both angry and disgusted faces significantly primed the processing of disgusted target. However, the priming effect of the angry face was diminished when the shadows between eyebrows were removed from the disgusted target. We suggest eyebrow's shadow are important to explain the confusion between anger and disgust.

Perceiving Threat: The Role of Body Morphology

Terence McElvaney, Magda Osman and Isabelle Mareschal
Queen Mary University of London, UK

Perception of another's emotional state can be driven by facial or body posture information. Here we examined how body morphology modulates perception of threat. To examine this we conducted an online study ($N = 150$) using computer-generated body stimuli that varied across three morphology levels (musculature, emaciation, and portliness). Stimuli (700×560 pixels) were generated using Daz Studio and presented online with faces blurred. Stimuli were presented randomly, and participants rated perceived threat from 1 to 7. Each stimulus was visible until the participant's response was entered. We used mixed-effects ordered logits to examine the relationship between perceived threat and body morphology. We found a stepwise, linear impact of body morphology,

with each increment in musculature and portliness accompanied by an increase in perceived threat, and each increment in emaciation showing a decrease in threat. All effects remain significant ($p<.001$) when controlling for perceived attractiveness and other demographic factors. For a one unit increase in musculature and portliness, the odds of giving the stimuli a higher threat rating increased by factors of 2.34 and 1.30, respectively. For emaciation, this saw an odds decrease of 0.75. These findings suggest that body morphology plays an important role in perceived threat and may bias real-world judgments.

Trait Anxiety Individuals Have Enhanced Perceptual Sensitivity for Negative Facial Expressions

Hsu Li-Chuan[1,2], Wu Ya-Ting[3], Tien Yi-Min[4] and Lin Chia-Yao[1]
[1]School of Medicine, China Medical University, Taichung
[2]Graduate Institute of Biomedical Sciences, Taichung
[3]College of Public Health, China Medical University, Taichung
[4]Department of Psychology, Chung Shan Medical University, Taichung

Individuals with high trait anxiety often demonstrate attentional bias when they meet threatening stimulus. Furthermore, these people also show higher sensitivity of recognizing fearful faces than low trait anxiety ones show. This study aims to examine whether people with high trait anxiety would express higher sensitivity in perceiving other types of facial expressions, such as angry faces. Trait anxiety was assessed for participants by using the State-Trait Anxiety Inventory—Trait Scale. In Experiment 1, we manipulated emotion intensity of four facial expressions (happiness, fear, sadness, and anger). Participants had to detect any emotionality of the presented faces. In Experiment 2, by blending two facial expressions with reciprocal proportions, three sets of morphed faces were created: The happy face gradually morphs and blends with one of the negative faces (fear, sadness, or anger). For example, a face consists 20% happy and 80% fearful expression. Participants were asked to discriminate the facial expression as positive or negative. The results revealed the group with high trait anxiety expressed significantly higher sensitivity to sad, angry, and fearful faces compared with the group with low trait anxiety. It suggests that an individual with trait anxiety showed negative bias for facial expressions.

The Influence of Ambiguous Stimuli on Interpretation and Perception in Spider Phobia

Anke Haberkamp[1], Winfried Rief[1], Melanie Biafora[2], Thomas Schmidt[2] and Filipp Schmidt[3]
[1]Philipps-University Marburg, Germany
[2]University of Kaiserslautern, Germany
[3]Justus-Liebig-University Giessen, Hesse, Germany

The fast detection of and response to threatening stimuli is an important task of the human visual and motor system, and is especially challenging when stimuli are ambiguous. This study investigates the perception and processing of ambiguous natural spider stimuli in spider-fearful and non-anxious participants. Stimuli were created by gradually morphing natural images of spiders and nonspiders (a crab, a starfish, a bunch of keys, and a flower). In Study 1, participants rated the images on perceptual and emotional dimensions and took part in a response-priming task to measure rapid information processing. In Study 2, results were validated and extended in a go/no-go task. As expected, spider-fearful participants showed an interpretative bias for ambiguous stimuli (i.e., perceived them as more similar to spiders) and rated spider(-like) stimuli as more unpleasant, arousing, and disgusting. Spider stimuli were preferentially processed in spider-fearful participants as observed in faster responses to spider targets; however, responses to ambiguous stimuli were not different to controls (Study 1). We suggest that differences in stimulus duration can explain this finding (Study 2). Our results are in line with predictions of recent electrophysiological studies on rapid information processing of emotional stimuli via the fast, subcortical path to the amygdala.

The Influence of Virtual Reality Public Speaking Training on the Anxiety Level

Stepan Strelnikov and Artem Kovalev
Lomonosov Moscow State University, Russia

Virtual reality (VR) provides a unique opportunity to create new methods of exposure therapy due to the presentation of different kinds of visual stimulation. This study is devoted to investigate the effect of VR training on the level of anxiety during public speaking. We hypothesized that the size of virtual audience may affect the level of anxiety. Six subjects took part in the experiment: four with a moderate level of anxiety and two with a high level of anxiety, which was estimated by the State-Trait Anxiety Inventory. Subjects are invited to prepare a light presentation for public speaking in the VR. The level of anxiety is measured by biofeedback method before and after each presentation. The subject undergoes this

procedure 3 times in different virtual audiences—small, medium, and large. It was found that heart rate and the systolic wave amplitude significantly increased in small audience in comparison to the medium and large audiences. These results may be related to the fact that in small audience listeners were closer to the speaker and their avatars were more detailed, which can affect the presence effect and the anxiety level.
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Does an Escaping Object Look Faster? Animacy-Induced Speed Overestimation in Chasing Events

Giulia Parovel and Stefano Guidi
University of Siena, Tuscany, Italy

In Michotte's paradigm, an object A moves toward and makes contact with another object B, which then moves away. If B's motion is faster than A's, and starts before the arrival of A, B is perceived to intentionally escape from A. Many studies show an association between speed and animacy, in that objects moving faster are judged as more animated. In our study, conversely, we explored how much a square looks faster when intentionally escaping from another square. We used the method of constant stimuli to measure the speed overestimation of the escaping object in comparison to different levels of speed of a single moving object. We also varied the behaviour of the chasing object, allowing it to move either in a linear or in a caterpillar-like way. Paired comparisons data were analysed using generalized linear mixed-effects models to estimate the point-of-subjective-equality in the different conditions. We found a significant overestimation of the escaping object in the fast speed condition, both in the caterpillar-like motion and in the linear motion. These results suggest an interesting connection between specific emotional qualities of motion and its apparent speed, supporting the hypothesis that social causality and animacy are deeply rooted in visual processing.

Dissociable Neural Underpinnings of Consensual and Idiosyncratic Emotional Movie Experiences

Lin Cui, Bingbing Guo, Jiaxin Li, Dan Zhao and Ming Meng
South China Normal University, Guangzhou, People's Republic of China

Individual difference is an important part of human intelligence. It has long been debated among neuroscientists, psychologists, and philosophers that what consensual or idiosyncratic experiences we obtain when we observing same stimuli. However, few studies have separated the consensus and idiosyncrasy from perceptual experience. Here, to address this issue, we examine brain activations by using functional magnetic resonance imaging when participants watched two movies repeatedly (an emotional thriller and a nonemotional scenic movie). Then, changes of functional connectivity based on the "amygdala" response time courses are analyzed to examine how the two types of experience form and reform at network level. Analyses of variance reveal that the three factors (viewing repetition, movie categories, and experience types) significantly interact. For watching the thriller repeatedly, activity in several emotion-related brain areas shows significantly decreased correlations with the averaged amygdala activity across participants. However, when correlating with the residual amygdala activity (activity of each individual participant subtracting the group average), there are no differences. By contrast, repeatedly watching the scenic movie does not change activation correlation to the averaged amygdala activity, whereas correlation to the residual amygdala activity decreases significantly in a large emotion-related brain network. These results suggest a dissociation of the mechanisms underlying the formation of consensual and idiosyncratic emotional movie experiences.

Dynamic Perceptual Strategies Guide Multimodal Emotion Identification

Minke J. de Boer, Deniz Baskent and Frans W. Cornelissen
University Medical Center Groningen, The Netherlands

The majority of emotional expressions used in daily communication are multimodal and dynamic in nature. This study evaluated the perceptual strategies that observers use to extract information and decide on the perceived emotional expressions. We previously found that different, correctly recognized, emotions are associated with distinct fixation patterns. This suggests that specific perceptual strategies, evident from eye-movement behavior, may increase the chances of perceiving specific emotions. For example, fixating mostly on the mouth might increase the

chance of perceiving anger. Here, with this question in mind, we revisit previously obtained eye-tracking data acquired while observers identified the emotions expressed by actors. Our results show that the fixation patterns observed for a correctly perceived emotion versus those observed for same, yet incorrectly, perceived emotion (i.e., different stimuli, but identical responses) are quite distinct too. This suggests that it is unlikely that one can predict the perceived emotion merely on the basis of these fixation patterns. Nevertheless, while the response itself does not appear to be directly associated with specific gaze behavior, the different gaze patterns (a.k.a. perceptual strategies) observed for different emotions suggest that a specific viewing strategy, appropriate for a specific emotion, increases one's chances of recognizing that emotion correctly.

Pupillary Response to Beep Sound Reflects Emotion: Emotion Estimation Method Using Probe Stimulus

Kengo Shimizu[1], Satoshi Nakakoga[1], Junya Muramatsu[2], Takashi Kitagawa[3], Tetsuto Minami[1,4] and Shigeki Nakauchi[1]
[1]Department of Computer Science and Engineering, Toyohashi University of Technology, Aichi, Japan
[2]Department of System & Electronics Engineering, Toyota Central R&D Labs., Inc., Aichi, Japan
[3]R&D Engineering Management Division, Toyota Motor Corporation
[4]Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology, Toyohashi, Japan

Recently, estimation of emotional states using physiological response has become more important. Previous studies reported that pupillary dilatation response (PDR) was induced when viewing emotionally arousing pictures. However, the estimation method by the pupillary response so far is directly linked to the timing of emotion elicitation such as the onset of emotional pictures. Other recent studies have reported that brain activity to deviant sound is enhanced to negative emotions. If the similar phenomenon is found in pupillary responses, estimation of emotional states become possible using pupillary responses to auditory stimuli. In this study, we investigated pupillary responses to auditory oddball tasks in each emotion state elicited by emotional pictures (positive, negative, and neutral). Our results showed that PDR to beep sound in negative and positive emotional states was more dilated compared with neutral, and PDR to beep sound in negative emotional states was induced earlier compared with other emotional states. In addition, the emotion-dependent PDR was not related to the difference between standard and oddball sounds. Taken together, our study suggested that it is possible to estimate the emotional states from the amplitude and the latency of pupil activity by using beep sounds.

Motion-Related Activity in the Human Retina Elicited by Moving Gratings

Jordan Nicolas Alves, James Lubell, Britta Ulrike Westner and Sarang Suresh Dalal
Center of Functionally Integrative Neuroscience, Aarhus, Denmark

A multitude of studies across various species have demonstrated that motion induces synchronous activity in retinal amacrine and ganglion cell populations. However, evidence for retinal motion processing in humans is sparse and not consistent. Here, we investigate whether specific types of motion stimuli elicit motion-related activity in the human retina that can be recorded using electroretinography. The participants passively viewed moving circular gratings with three different speeds, a stimuli category that has been shown to result in massive cell activity synchronization in the mouse retina. Binocular retinal activity was recorded using DTL fiber electrodes and subsequently analyzed in the time and frequency domain. Contrasting the different speed conditions showed clear effects for the fastest moving grating stimulus: This condition elicited evoked potentials with larger amplitudes than slower motions. Time-frequency analysis revealed a power increase in high frequency activity (60–120 Hz) for the high speed condition compared with slower moving gratings. Taken together, this shows retinal activity elicited by moving stimuli, possibly reflecting retinal motion processing.

Structural Connectivity Patterns of Visual-Vestibular Brain Areas PIVC and PIC

Markus Becker[1], Sebastian M. Frank[1,2], Anton L. Beer[1] and Mark W. Greenlee[1]
[1]University of Regensburg, Germany
[2]Brown University, Providence, RI, USA

Visual-vestibular integration is a key feature of human self-motion perception. The parieto-insular vestibular cortex (PIVC) and the posterior insular cortex (PIC) are relevant brain areas of the visual-vestibular network. Here, we examined the white matter connectivity of PIVC and PIC with intrahemispheric cortical areas by probabilistic tractography based on diffusion-weighted magnetic resonance imaging in 20 brains. PIVC and PIC were defined functionally using stimulation with caloric vestibular and visual motion cues in individual subjects during functional MRI. Our results showed high track probabilities for connections with PIVC in the lateral sulcus including the anterior insula, the inferior frontal cortex, the central sulcus, the superior frontal cortex, the cingulum, the intraparietal sulcus, the parieto-occipital sulcus, and parts of the

calcarine. For connections with PIC high track probabilities were found in the supramarginal gyrus, superior temporal sulcus, inferior parts of the central sulcus, the intraparietal sulcus, the parieto-occipital sulcus, and also in parts of the calcarine. These findings replicate and extend previous results from our group showing that PIC and PIVC share connectivity with several cortical areas, whereby PIC exhibits stronger connections to posterior and PIVC to anterior parts of the cortex. Such connectivity could support multisensory integration for self-motion perception.

Decoding the Imprecision of Motion Perception From Activity in Human Visual Cortex

Andrey Chetverikov and Janneke F. M. Jehee
Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen, Netherlands

Visual perception is necessarily uncertain due to noise and ambiguity in sensory signals. Here, we characterize the degree of uncertainty in motion perception on a trial-by-trial basis, using functional magnetic resonance imaging (fMRI) in combination with a novel pattern-based analysis. Participants viewed patterns of dots moving coherently in a random direction. Shortly after viewing the dots, observers reported the perceived motion direction. Using a novel probabilistic approach (cf. van Bergen, Ma, Pratte, & Jehee, 2015, *Nature Neuroscience*), we decoded the posterior probability distribution of motion direction from activity patterns in visual areas V1-V4, and hMT+. We hypothesized that the width of this distribution (i.e., its entropy) might reflect the degree of uncertainty in cortical representations of motion. Accordingly, we compared the width with behavioral variability, reasoning that a more precise representation in visual cortex should be linked to less variable (more precise) behavior. This revealed that uncertainty about motion direction can reliably be extracted from fMRI activity. Specifically, trial-by-trial fluctuations in the width of the distribution reliably predicted variability in the observers' response, both within and across different directions of motion. These results suggest that the precision of motion perception can be reliably estimated from activity in the human visual cortex.

Recalibrating Time Perception to Self-Motion

Luca Lo Verde[1,2], David Alais[2], David Charles Burr[1], Maria Concetta Morrone[3], Hamish MacDougall[2] and Frans A. J. Verstraten[2,4]
[1]Department of Neuroscience, Psychology, Pharmacology, and Child Health, University of Florence, Italy
[2]School of Psychology, The University of Sydney, NSW, Australia
[3]Department of Translational Research on New T
[4]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, The Netherlands

Moving visual stimuli are perceived to last longer than stationary stimuli of the same physical duration. However, it is not clear how stimulus motion and self-motion contribute to this effect, nor is the role of motor action. We used virtual reality to investigate time perception for observers who could actively walk inside a virtual room while performing a temporal reproduction task. Participants were either stationary or walking briskly (at 0.8 m/s), while the environment could either be stationary on the retina, stationary in the real-world or double velocity in the world. For stationary observers, we observed the temporal dilation for moving compared with stationary stimuli, as previously described. However, there was no temporal dilation for walking participants, with either retinal-stationary (moving in the world) or real-world stationary stimuli (moving on the retina). Only for double-speed motion was there a temporal dilation for walking observers. The results suggest that our sensory systems are able to discount self-generated motion in order to perceive veridically genuine external motion, improving the perception of real moving objects while navigating the environment.

Active Control Does Not Eliminate Motion-Induced Position Shifts in a Simulated 3D Environment

Joseph Muscat and Ian M. Thornton
Department of Cognitive Science, University of Malta, Msida, Malta

Motion-induced position shifts (MIPS) refer to situations in which the global, physical position of a target object is misperceived due to its own local motion. In a previous series of studies using two-dimensional (2D) displays, we found that giving participants direct, active control over the global position of a target Gabor patch did not eliminate MIPS. Rather, such errors were amplified compared with those seen in matched, passive judgement conditions. In the current work, we explore the impact of active control in simulated three-dimensional (3D) displays. We created a dynamic tunnel environment through which participants steered a Gabor patch in depth, as in a first-person driving game. In separate conditions, the task was either centre-line following or waypoint collision. We measured the ability to centre the target as a function of local drift behaviour (left drift, right drift, or static). As in our 2D tasks, participants consistently mislocalised the target. When the patch drifted to the left, they positioned it to the right of true-centre, when it drifted right, errors were to the left. Errors with static Gabor patches did not differ from zero. We discuss the implications of these findings for

the design of heads-up-displays and other augmented reality navigation systems.

Effects of Self-Motion on the Spatial Representation Out of the Visual Field

Hiroaki Shigemasu and Yudo Nakano
Kochi University of Technology, Kami, Japan

Even when an object becomes out of the visual field caused by the movement of an observer, a rough position of the object can still be recognized. Although previous studies have investigated updating processes of the representation according to self-motion, the representation of an object out of the visual field is still unclear. In this study, we used a head-mounted display and a pointing task to investigate the effect of self-motion on the updating the representation of the object position out of the visual field. The object became invisible by an actual self-rotation with a rotatory chair or visual rotating information without an actual self-motion. We also examined the effect of object motion during rotation. In this condition, the observer had to discriminate components of self-motion and object motion. The results showed that with a sense of actual self-motion the position of the object was more precisely pointed and suggest the representation out of the visual field was updated more accurately. When the object moved during the rotation, a bias was found irrespective of with or without an actual self-motion. The result suggests the sense of self-motion has no significant effect on the discrimination between self-motion and object motion.

Integrating Visual and Tactile Object-Contact Signals When They Do Not Coincide in Space?

Pierre-Arthur Suray and Simon Watt
School of Psychology, Bangor University, UK

Sensing contact between hand and object is an important control signal in everyday tasks. Artificial devices that provide such feedback are potentially transformative. Here we apply sensory-integration theory to better understand fundamental principles underlying their function. Vision and touch naturally provide redundant signals to object contact. We first asked whether these signals are integrated to improve estimates (as per visual-haptic size estimation). We delivered tactile contact signals to the index finger using a solenoid. Visual contact was a computer-graphics animation, superimposed on the index-finger location via a mirror. We varied the duration of visual and tactile signals independently, to probe whether both contributed to perceived stimulus duration. We found that they did, suggesting integration. We then examined how spatial proximity of the signals affects integration, including during tool use. Separated signals are unlikely to refer to the same event, and so should not normally be integrated. Yet, most devices necessarily introduce spatial offsets (e.g., vision of tool tips, touch at the handles). Preliminary results suggest that visual-tactile integration depends on spatial proximity, but the brain learns when separated signals refer to the same object (in tool use), and integrates them appropriately—a necessary condition for "natural" control of tactile-feedback-endowed devices.

Effects of the Visual Field on Temporal Synchrony Perception Among Visual and Auditory Stimuli

Yasuhiro Takeshima
Doshisha University, Kyoto, Japan

Temporal synchrony perception among visual and auditory stimuli occurs adaptively owing to naturally occurring lags in arrival and processing times. Visual properties associated with temporal characteristics are assumed to modulate temporal synchrony processing among the various senses. This study investigated the effects of the visual field on temporal synchrony among visual and auditory stimuli. Central vision has lower temporal resolution than does peripheral vision. In the experiment, the point of subjective simultaneity (PSS) and temporal binding window (TBW) were compared between central and peripheral vision. The results indicated that a wider TBW was observed for central than for peripheral vision whereas PSS did not differ. Furthermore, this study examined the process of rapid recalibration to audio-visual asynchrony. The correlation score was larger for central than for peripheral vision between the recalibration effect and TBW width. However, the magnitude of the recalibration did not differ between central and peripheral vision. Therefore, temporal synchrony processing among audio-visual stimuli is modulated in the visual field. These modulations would be attributed to the temporal characteristics of visual processing associated with the visual field.

Intelligent Audio Visual Thumble Training

Hafsah Ahmad[1,2], Alessia Tonelli[1], Valentina Salvagno[2], Elisabetta Capris[3], Valentina Facchini[3], Giulio Sandini[1] and Monica Gori[1]
[1]Italian Institute of Technology (IIT), Genoa, Italy
[2]University of Genova (UniGe), Italy
[3]Istituto David Chiossone, Genova, Italy

Scotoma is a blind spot or spots that appear in ones eye due to loss of retinal cells. This blind spot badly effects the fixation stability and naturally forces the patient to develop a secondary fixation point called preferred retinal locus (PRL). Here we present a rehabilitation technique for macular degeneration (MD) patients called Intelligent Audio Visual Thumble Training (IVATT). The idea is to integrate the audio-proprioceptive information to the residual vision of an individual to help them in developing PRL at the healthy part of retina. IVATT consists of a smart watch, used to produce the sound and a LED mounted on a small chip that can be fixed on smart watch screen. With this assembly on wrist, participants had to follow a 70 by 70 cm Archimedean spiral drawn on a hard board placed in front of them. Five MD patients performed this training for 1 month (20 minutes per day). Before and after the training were evaluated the fixation stability maps and audio localization test. Results about these two tests show an improvement in fixation stability and in sound localization.

Mid-Level Sound-Shape Correspondences: Perceptual Grouping in the Bouba/Kiki Effect

Yi-Chuan Chen[1], Pi-Chun Huang[2] and Charles Spence[3]
[1]Mackay Medical College, New Taipei City
[2]National Cheng Kung University, Tainan City
[3]University of Oxford, UK

The Bouba/Kiki effect constitutes a classic sound-shape correspondence, with the meaningless sounds "Bouba" and "Kiki" being mapped onto rounded and angular patterns, respectively. Here we examined whether the local features or the global contour of a visual pattern dominates the Bouba/Kiki effect. We adapted complex radial frequency (RF) patterns which were consensually matched to "Bouba." The grouping process was investigated by segmenting each RF pattern into convexities and concavities and presenting 25%, 50%, 75%, or 100% length of each segment. The convex segments were mainly matched to "Bouba," whereas the concave segments were matched to "Kiki" instead. We then presented convexities or concavities with 50% segment length, and their reversed image, with each segment rotated 180° along the radial axis. The convex segments were reliably matched to "Bouba"; however, their reversed segments were matched to "Kiki." In contrast, concave segments and their reversed segments were consistently matched to "Kiki." Hence, the sound-shape correspondence was not determined simply by the local features of the patterns. Instead, the information used to construct the global contour (i.e., convexities) is essential for a pattern to be matched to "Bouba," thus suggesting that the Bouba/Kiki effect occurs at the mid-level processing of pattern perception.

Colours Associated With Touched Objects and Materials

Christoph Witzel and Knut Drewing
Justus-Liebig-Universität, Hesse, Germany

Cross-modal associations link unisensory experiences to the perceptual function of identifying objects and materials. In three experiments ($n = 50$ participants each), we investigated which colours observers associate with touching real-life surfaces (2×44) and solid, granular, and fluid materials (45 stimuli). For this, observers were asked to adjust the colour they associated with the surface (Experiments 1 and 2) or the material (Experiment 3) they touch, and we tested correlations between colour dimensions and ratings of the haptic stimuli. All three experiments yielded systematic associations between colour and touch. A negative correlation between lightness and roughness, and a positive correlation between colourfulness and softness were in line with previous findings for artificial stimuli. We also observed a relationship between colour and temperature in all experiments; between colour and gloss for the surfaces (Experiments 1 and 2); and relationships between lightness, dominance, and heaviness for the materials (Experiment 3). There were no correlations with preferences, excluding a hedonic origin of colour-touch associations. In a postexperimental questionnaire, most observers reported adjusting the memory colour of the object or material they guessed by touch. These results suggest that colour-touch associations originate from statistical regularities in the natural environment.

Frame of Reference Conflicts in Cross-Modal Simon Effect

Alice Bollini, Claudio Campus and Monica Gori
Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Genoa, Italy

To interact with the environment, we have to combine information coming from different sensory modalities considering the spatial locations of events. The Simon task is a good demonstration of how the spatial representation can

influence behavioral sensory outcome even when the stimulus location is task-irrelevant. Many studies showed that each sensorial modality encodes spatial information according to a specific frame of reference, for example, hearing and vision are based on external coordinates while touch on internal coordinates. To investigate the frame of reference across different sensory modalities, we tested participants with unimodal and cross-modal versions of auditory-tactile Simon task, manipulating the hand's posture. Indeed, crossing the hands over the body midline creates a conflict between external and internal coordinates. Results show that in the unisensory auditory task participants followed the external while in the alternating cross-modal modality task, the Simon effect disappears only in the auditory modality. Moreover, there was a great drop in performance due to sensory-switch costs. These results show how in cross-modal context the weights associated with a spatial frame and a sensory modality change dynamically to adapt to the demands of the task.

A Novel Solution to Investigate Audiospatial Memory Skills in Sighted and Blind Individuals Through Acoustic Virtual Reality

Walter Setti[1,2,3], Luigi Cuturi[2], Isaac Engel[3], Giulio Sandini[4], Lorenzo Picinali[5] and Monica Gori[6]
[1]DIBRIS University of Genoa, Genoa, Italy, U-VIP UNIT, Italian Institute of technology, RBCS Unit, Italian Institute of technology, Genoa, Italy
[2]U-VIP UNIT, Italian Institute of technology, Genoa, Italy
[3]Dyson school of Design engineering, Imperial college of London, London, UK
[4]RBCS Unit, Italian Institute of technology, Genoa, Italy
[5]Dyson school of Design engineering, Imperial college of London, London, UK
[6]U-VIP UNIT, Italian Institute of technology, Genoa, Italy

An open debate in the neuroscientific field is the role of visual experience on cognitive processes (e.g., spatial memory). Research on blind individuals can shed a light on this topic. Here, we present an experimental paradigm based on an acoustic virtual reality environment to study spatial memory and imagery skills through audition in congenitally blind and sighted individuals. Participants were asked to recall sequences of spatialized sounds of increasing length, starting from 2 up to 9 stimuli. To study the influence of active memory processes, items were also recalled in the reversed order presentation. Two experimental conditions based on the nature of sounds were tested: nonsemantic (pink noise) and semantic (meaningful sounds). Our results show that blind individuals performed worse than the sighted group reaching a higher memory span in the forward compared with backward modality. These results suggest that the lack of vision negatively impacts on the ability to manage spatial relations between sounds and on the cognitive load imposed by an active memory process. The system presented in the current work may be the starting point for the development of a clinical evaluation tool to test cognitive abilities in case of blindness.

Does Continuity Matter? Temporal Isolation Effect of Visual Working Memory Modulated by Spatial Continuity of Whole-Body Movement Sequences

Shiau-Chuen Chiou[1,2] and Thomas Schack[1,2]
[1]Neurocognition and Action Group, Center of Excellence Cognitive Interaction Technology, Bielefeld University, Germany
[2]Faculty of Psychology and Sports Science, Bielefeld University, Germany

Remembering a movement sequence by watching is ubiquitous in everyday life. However, how the spatial (dis-)continuity of whole-body movement sequences and the temporal (dis-)continuity of the sequence display influence working memory encoding and retrieval remains unclear. Specifically, temporal distinctiveness models suggest that temporal isolation (i.e., discontinuity) of events will benefit memory performance, while spatial continuity, one of the most important characteristics of human movements, may facilitate perceptual grouping and enhance memory performance on the one hand, but diminish the advantage of "distinctiveness" on the other. By using a change detection task, in which a four-unit movement sequence was followed by a single probe either identical to one of the units or different from all, we found that the temporal isolation effect only occurred on spatially discontinuous sequences when the interstimulus interval (ISI) was at least 1.5 seconds, illustrating a modulation from spatial continuity of movement sequences; moreover, performance on spatially continuous sequences was better than spatially discontinuous ones when ISI was 0 second (i.e., temporally continuous) or shorter than 1.5 seconds, suggesting a perceptual advantage from spatial continuity in visual working memory.

The Role of VWM in Transsaccadic Updating: An fNIRS Study

Caglar Tas, Kaleb Kinder, Bret Eschman, Shannon Ross-Sheehy and Aaron Buss
University of Tennessee, Knoxville, TN, USA

Previous research suggests that transsaccadic object updating may depend on visual working memory (VWM) processes (van der Stigchel & Hollingworth, 2018). In this study, we directly tested this hypothesis by recording

neural data with functional near-infrared spectroscopy (fNIRS) while participants performed a transsaccadic color report task. They were instructed to execute a saccade to a color disk. On half of the trials, target's continuity was disrupted by blanking it for 250 milliseconds after the initiation of the saccade. On some trials, the target's color was also changed during the saccade. Participants were asked to report the color of either the presaccadic or the postsaccadic disk. We hypothesized that blanking the target during the saccade will result in two object representations (presaccadic and postsaccadic). If these representations are stored in VWM, as previously suggested, then we expected to find an increase in activation in posterior parietal cortex (PPC; Todd & Marois, 2004) when object continuity was disrupted (blank), compared with when it was not (no-blank). Our results supported this prediction: We found stronger PPC activation in blank trials compared with in no-blank trials, suggesting that disrupting target's continuity with blanking resulted in two separate object representations which are maintained in VWM.

Internal Noise Explains Visual Working Memory Decay

Crista Kaukinen, Jussi Saarinen and Ilmari Kurki
University of Helsinki, Finland

Many visual working memory models implicitly assume that forgetting is caused by accumulating internal noise (IN) in memory representations. However, only few studies have thoroughly tested this idea using methods allowing IN level estimation. Here we ask how well a straightforward model, where forgetting works solely by increasing IN, explains various measures of memory performance. We used data from our recent psychophysical study with a same-different change detection task. Subjects ($n = 13$) were presented a stimulus consisting of 64 Gabor patches in random orientations followed by 500-, 1,000-, or 5,000-millisecond retention interval. Either low-variance (σ=9°) or high-variance (σ=46°) Gaussian orientation noise was added to the retention stimulus yielding "same" and "different" stimuli. Each stimulus pair was presented twice, and IN levels were estimated from the response consistency over repeated trials. Sensitivity for change (d') decreased strongly (from 2.13 to 1.24) as a function of retention time. A response bias shift toward "different" responses was found in longer retention times. A signal-detection model with constant criterion and variable internal noise could correctly predict the performance, bias shift, and response consistency. The results strongly support the increase in IN as the major mechanism for forgetting in visual working memory.

Is Visual Working Memory Decay Feature-Specific?

Ilmari Kurki, Crista Kaukinen and Jussi Saarinen
University of Helsinki, Finland

Is visual working memory decay a purely random process, or are some features (i.e., fine details) more prone to decay? Here we used a variant of psychophysical classification image method and double pass technique to estimate how feature information is retained in visual memory. A same-different change detection task was used. The memory stimulus was a radial frequency (RF) pattern with 10 RF components at randomized phases. After a retention time (RT) of 500 or 4,000 milliseconds, either low variance "same" (s = 5.7°) or high variance "different" (s = 57°) phase jitter was added to phases of the memory stimulus, generating the retention stimulus. All stimuli were shown twice in randomized order allowing for internal noise estimation. The memory performance was about 45% lower with the long RT. We estimated which radial frequencies in the working memory representations contributed for the decisions, by reverse-correlating the magnitude of the phase jitter of each RF component (on each trial) with the corresponding same-different response. These memory classification images show that decisions are driven by medium to high RF components with similar relative weighting in both RTs. Internal noise increased with RT. These findings suggest that memory decay is not feature-specific.

The Role of Working Memory and Perceptual Similarity in Subsequent Search Misses

Kirill Kozlov and Elena Gorbunova
Higher School of Economics, Moscow, Russia

Subsequent search misses (SSM) is a decrease in accuracy at finding the second target after the successful detection of the first one (Adamo, Cain, & Mitroff, 2013). Target–target perceptual similarity was found to decrease the magnitude of SSM (Gorbunova, 2017), while working memory load (e.g., memory for found targets) increases it (Cain & Mitroff, 2013). We wanted to find out whether both of these factors work together or separately. Thus, we used a combined visual search and working memory task, when the participant had to perform visual search task while holding the stimuli from memory task in working memory. Stimuli for both tasks were rectangles with gaps. Each trial could contain two, one or no targets. In case of two targets, they could have 0, 1, or 2 shared features. Repeated measures analysis of variance was used to analyze accuracy and reaction time. Perceptually similar targets were found more accurate and faster than

perceptually dissimilar ones. There was no effect of working memory load on SSM magnitude. Also there was no significant interaction between WM load and perceptual similarity, $F(3,87) = 0.622$, $p = .566$, $\eta^2 = 0.021$, assuming different mechanisms responsible for perceptual similarity and working memory load factors in SSM errors.

No Difference in Object Memory After Searching Dynamic 3D and VR Environments

Julia Beitner[1], Jason Helbing[1], Dejan Draschkow[2] and Melissa L.-H. Võ[1]
[1]Scene Grammar Lab, Department of Psychology, Goethe University Frankfurt, Germany
[2]Brain & Cognition Laboratory, Department of Psychiatry, University of Oxford, UK

Experiments in the field of scene perception are typically performed on a computer screen. But does such behavior actually resemble real-world behavior? For example, previous research indicates that humans use more memory when being immersed in virtual reality (VR) compared with performing the same task on a screen. This is often explained by the additional, energy-costing head and body movements performed in real environments. Here we investigated whether this memory superiority effect remains when the search task is not performed on static images, but in dynamic three-dimensional (3D) environments, which allow for free navigation within the search environment without physical body movements. Participants searched for multiple objects in immediate succession within multiple scenes in both 3D and VR environments. In the 3D setup, participants could navigate through the rooms presented on a screen by using mouse and keyboard, while in the VR environment, participants moved their heads and bodies. After both search blocks, participants were confronted with a surprise object recognition task, again in both environments. Preliminary Bayesian analyses indicate that memory performance did not differ between the 3D and VR setups. These preliminary results imply that body movement might not be the driving factor in boosting memory performance.

Do Images That Appeal to the Eye Also Stick in Memory?

Lore Goetschalckx, Shyam Sekaran and Johan Wagemans
KU Leuven, Belgium

In this study, we revisited the relation between aesthetics and memorability, for the first time controlling for semantic category. The focus is thereby on the "how" of depicting (i.e., a beautiful image of a subject), rather than on the "what" (i.e., an image of a beautiful subject). We preselected 400 candidate image pairs, matched on semantic category, but expected to differ in aesthetics based on proxies (e.g., stock photo versus snapshot). Each pair was then rated by ~63 participants on a 7-point scale (−3 = *left image is much better than right*, 0 = *equally good/bad*, 3 = *right image is much better than left*) for validation. Pairs with less than 80% of the participants agreeing on the better image were excluded. The 200 remaining pairs with the most extreme mean rating were then presented in a repeat-detection memory task, but never both members to the same participant. A logistic regression revealed that the odds of recognizing (versus missing) a repeat were significantly ($p < .001$) higher for the better image of a pair ($OR = 6.09$) than for its counterpart ($OR = 5.09$). This indicates that, on average, images with higher aesthetic quality are more memorable, when the semantic category is controlled for.

Direct Structural Connection Between Auditory-Temporal and Visual-Occipital Motion Selective Regions

Ane Gurtubay Antolin[1], Ceren Battal[1], Chiara Maffei[2], Mohamed Rezk[1], Stefania Mattioni[1], Jorge Jovicich[3] and Olivier Collignon[1,3]
[1]Institute of Research in Psychology (IPSY) and in Neuroscience (IoNS), University of Louvain, Louvain-la-Neuve, Belgium
[2]Athinoula A. Martinos Center, Massachusetts General Hospital, Charlestown, MA, USA
[3]Center for Mind/Brain Studies, University of Trento, 38123, Trento, Italy

Perceiving and integrating motion signals across sensory systems is a crucial perceptual skill for optimal interaction with a multisensory environment. In primates, including humans, the middle-temporal region (hereafter, hMT+/V5) specializes in processing visual motion signals, while the Planum Temporale (hereafter, PT) specializes for auditory motion processing. It has been hypothesized that these regions can communicate directly to achieve fast and optimal multisensory integration of motion signals. However, the existence of direct anatomical connections between these regions remains unexplored. We therefore evaluated the presence of anatomical connections between the hMT+/V5 and the PT in 15 healthy individuals. Each participant was first involved in an auditory and visual motion localizer in order to define PT and hMT+/V5 functionally. Using diffusion imaging data and conducting probabilistic tractography, we reconstructed white matter tracts between individually defined PT and hMT+/V5. We found reliable connections between hMT+/V5 and PT in both hemispheres in 15 out of 15 individuals,

suggesting the existence of a direct pathway between these visual and auditory selective regions. Our findings have important implications for the understanding of the multisensory nature of motion processing, as this connection might represent the structural scaffolding underlying the auditory and tactile responses observed in hMT+/V5.

Poster Session 5: Wednesday, August 28, 2019

How Do Expectations Modulate Perception?

Kriti Bhatia[1], Ellen Joos[1,2,3,4,5], Anne Giersch[4], Ludger Tebartz van Elst[2,3] and Jürgen Kornmeier[2,3,5]
[1]Faculty of Biology, Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany
[2]Department of Psychiatry and Psychotherapy, Medical Center, Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany
[3]Faculty of Medicine, Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany
[4]INSERM U1114, Cognitive Neuropsychology and Pathophysiology of Schizophrenia, University of Strasbourg, France
[5]Institute for Frontier Areas of Psychology and Mental Health Freiburg, Freiburg im Breisgau, Germany

The information available to our senses is noisy, incomplete and often ambiguous. Our perceptual systems weight this information with perceptual memory concepts to construct stable and reliable percepts and to predict the immediate perceptual future. In this study, we investigated whether predicting the future alters perceptual processing of the present. We presented three repetitions of stimulus pairs consisting of ambiguous stimuli S1 followed by either ambiguous (Condition 1) or disambiguated stimulus variants S2 (Condition 2). Participants indicated their S1 percepts and compared S2- with S1-percepts. For each stimulus pair, the event-related potentials (ERPs) to the ambiguous S1 with an ambiguous future S2 were compared with an ambiguous S1 with a disambiguated future S2. We found larger amplitudes of two ERPs to S1 from the first stimulus pair, compared with the other two pairs. Furthermore, we found a trend for larger S1 ERP amplitudes when S2 was predicted to be unambiguous compared with predictions of an ambiguous S2. This effect was largest for the third stimulus pair. The present results indicate that predicting the future affects perceptual processing of the present. However, some regularity within the immediate perceptual history seems to be a necessary precondition for both efficient perceptual processing and predicting.

Origins of Expectation Signals—A Perfusion MRI Study on Visual Repetition Probability

Hanna Rooslien, Szonya Durant and Jonas Larsson
Royal Holloway University of London, UK

Selectivity in the visual system is commonly investigated using functional magnetic resonance imaging (fMRI) repetition suppression (RS) paradigms as feature-selective blood-oxygen-level-dependent (BOLD) signals are suppressed following feature repetition. However, RS magnitude for face stimuli varies depending on the probability of repetition—a phenomenon known as expectation signals (ES; Summerfield et al., 2008). Unlike RS, however, ES are not apparent in fMRI when attention is diverted (Larsson & Smith, 2012) or in electro-physiological recordings (e.g., Vinken et al., 2018). Critically, hemodynamic events can occur without neural activity (Sirotin & Das, 2009), and thus, ES could have hemodynamic rather than neural origins. Therefore, we replicated the original ES paradigm using arterial spin labeling (ASL) to simultaneously measure cerebral blood flow (CBF) and BOLD. We find (N=15) evidence of ES in CBF and cerebral metabolic rate of oxygen ($CMRO_2$) estimates. These estimates seem to transition from RS in early visual areas (V1/V2) to interaction effects (RS×ES) in higher visual areas (V3 and FFA/OFA). BOLD data show interaction effects in FFA/OFA, replicating previous findings. We demonstrate evidence for expectation dependent differences in neurovascular-coupling, and these effects vary as a function of visual hierarchy. This has important consequences for previous interpretations of ES based on BOLD alone.

Top-Down Control of Gestalt Motion Perception

Alexandre de, Pontes Nobre[1,2], Andrey R. Nikolaev[1], Cees van Leeuwen[1] and Johan Wagemans[1]
[1]KU Leuven, Belgium
[2]Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

We investigated the time course of expectation effects on visual processing of coherent motion. We presented sequences of 10 random-dot-kinematograms (RDKs) with variable levels of coherent motion, while recording participants' electroencephalography. One RDK in the sequence (the target) was followed by an auditory postcue. Participants were requested to rate the coherence level of the cued RDK target. Expectation was manipulated by the position of the postcue in the sequence, so that the probability of the cue following an RDK would increase as the presentation sequence progressed. Behavioral results showed better discrimination of extreme than intermediate degrees of coherent motion. We obtained event-related potentials (ERPs) time-locked to RDK onsets, showing

that with increasing expectation, amplitude of the ERP component N1 increased, but not that of the P1. Crucially, we found no interaction between the effects of expectation and motion coherence for P1, whereas we observed this interaction for N1. In addition, while the P1 amplitude decreased with increasing coherence levels, the N1 amplitude was largest at the intermediary coherence levels. We concluded that expectation does not affect the early processing stage of motion coherence but influences motion perception at the later stages.

Selection History's Effect on Visual Attention Persists After Retraining and Across Multiple Sessions

Dion Henare, Hanna Kadel and Anna Schubö
Philipps-Universität Marburg, Germany

In complex visual scenes, selective attention relies on efficient prioritisation of important objects. Recent work has shown that selection history is a critical component in the determination of processing priorities. In this study, we investigate how changes in selection history across multiple sessions can affect attentional orienting. Thirty-nine participants performed a categorisation task where they learnt to attend to either shapes or colours while electroencephalography was recorded. This was interleaved by an independent search task where all participants identified the orientation of a line embedded within a shape singleton. Results on Day 1 corroborate previous findings that if a coloured distractor is present during the search task, it causes greater interference for individuals who have learnt to categorise colours. On Day 2, half of the participants switched categorisation assignment. By Day 3, participants with experience of shape categorisation showed enhanced selection of the shape target. Participants who switched categorisation assignment showed impaired suppression of the colour distractor, and this is especially true for those who had started with colour categorisation on Day 1. This suggests that the influence of selection history is persistent across multiple days, even in the face of training which directly counteracts its effects.

Real-World Structure Facilitates Object Integration During Multiple Object Processing

Genevieve L. Quek and Marius V. Peelen
Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, The Netherlands

Much of what we know about object recognition arises from the study of isolated objects. In the real world, however, we commonly encounter groups of contextually related objects (e.g., teapot, cup, saucer), often in highly predictable spatial configurations (e.g., teacup above saucer, never the reverse). How does the visual processing of contemporaneous objects differ as a function of their contextual and spatial relatedness? To answer this, we recorded scalp electroencephalography-while participants (N=37) viewed a rapid stream of object pairs presented at a periodic rate of 2.5 Hz. Where most pairs contained contextually associated objects (e.g., table + lamp: Object Match), every fourth pair contained nonassociated objects (e.g., egg + lamp: Object Mismatch). We observed a differential neural response to Mismatch versus Match pairs (reflected at 2.5 Hz/4 = 0.625 Hz) over occipito-temporal electrodes, indicating that observers integrated object information even when performing an unrelated behavioural task (detect handbags/phones). Crucially, this integration index was larger when the image stream consisted of typically configured pairs (e.g., lamp above table) rather than atypically configured pairs (e.g., lamp below table). No such interaction was observed when inverting the display to account for low-level effects. These results indicate that both semantic and spatial relatedness influence visual object processing.

The Generalizability of Visual Statistical Learning: A Case Study in Perceived Real-World Size

Péter Kaposvári and Szabolcs Sáringer
University of Szeged, Hungary

Past research has shown that the visual system automatically learns the transition probabilities between successive stimuli, resulting in more efficient processing of stimuli that can be predicted. To maintain tight experimental control, this work has typically required observers to make extremely simple judgments about the features of abstract stimuli. An important open question is whether visual representations of these temporal regularities are also leveraged toward performing more "real-world" tasks on naturalistic stimuli. Here, as a case study, we ran three experiments investigating the influence of statistical learning on real-world size perception. Observers viewed sequences of object images and made judgments about their real-world sizes (indicating whether the object could or could not fit inside a shoebox). Unbeknownst to observers, the sequences were manipulated such that some items reliably followed others. Although no observer reported noticing these statistical patterns, the temporal structure strongly improved their performance (evidenced by both reaction time and accuracy measures). We conclude that statistical learning forms a core part of how we represent visual objects, with general benefits extending to far more ecologically valid tasks than are usually studied.

The Influence of Context on Behavioural and BOLD Responses to Low-Contrast Information

Gemma Donnelly, Tatjana Lux, Johanna Bergmann, Matthew Bennett and Lars Muckli
University of Glasgow, UK

The brain uses contextual information to form predictions about and make sense of the visual world, especially when input is ambiguous or degraded. We have investigated the influence of context on the processing of low-contrast visual information. We displayed the bottom right corner of a visual scene (our target region) at low contrast (around threshold level) and manipulated the consistency of the remaining part of the image (the surround) with the target region. Psychophysically, we found that consistency between the surround and target influences the ability to identify low-contrast information without affecting detection. Consistent surround and target improves performance whereas inconsistency between these regions hinders performance, indicating that the congruency of top-down predictions influences the processing of bottom-up information on a behavioural level. In a functional magnetic resonance imaging experiment using the same paradigm, we found differences in the blood-oxygen-level-dependent (BOLD) response between consistent and inconsistent conditions within the region of V1 corresponding to the target region. For low-contrast stimulation in the target region the BOLD response was amplified if the high-contrast surround was consistent. This could provide support for theories such as apical amplification and coherent infomax.

The Development the Light Source Bias in Shape-From-Shading

Beverley Ann Pickard-Jones and Ayelet Sapir
Bangor University, UK

Objects that are lighter at the top usually appear convex due to an implicit assumption that light originates from above. This percept is stronger when the light source originates from the above-left, which may suggest a right hemisphere dominance in shape-from-shading. This leftward bias is consistently observed in Western adults who read from left-to-right. In right-to-left reading populations, however, the bias is more variable; at times presenting as a diminished leftward bias, or sometimes as a strong rightward bias. To understand the contribution of cultural factors, such as habitual scanning direction, to the development of the light source assumption, we tested children in Wales and Israel on a visual search task of shaded spheres at different stages in reading acquisition. We expected all preliterate children to exhibit a leftward bias, detecting oddball circles with a shading pattern consistent with light coming from the above left, faster than other orientations. We predicted rightward shifts in Israeli children as reading fluency increased. This might indicate that the leftward bias is a developmental default that can be modified by cultural factors. We will discuss differences between Welsh and Israeli children and implications for the lateralisation hypothesis in shape-from-shading.

An Inversion Effect in Lightness Perception: Light-From-Above Prior Changes Perceived Lightness According to a Pictorial Orientation Cue

Yuki Kobayashi[1,2] and Kazunori Morikawa[1]
[1]School of Human Sciences, Osaka University, Japan
[2]Japan Society for the Promotion of Science, Tokya, Japan

Kobayashi and Morikawa (2018, *ECVP*) demonstrated that upward-facing surfaces are perceived to be darker than downward-facing ones using stereoscopic stimuli. This shows the light-from-above prior's role in lightness perception. Here, we created a nonstereoscopic image which can show surface orientation's effect on lightness. This image depicts a simple gray surface. By inverting the whole image, the depicted surface's orientation can be perceived as upward or downward. Even though the image's two-dimensional and three-dimensional structures are identical, the inversion changes the surface's apparent lightness. This was proved by Experiment 1 in which the participants performed a luminance adjustment task. In Experiment 2, novel participants performed the same adjustment task for the surface images at various angles (12 angle conditions in steps of 30° including directly upward and downward). Perceived luminance levels as a function of the surface's angle formed a U-shape, which was highest for downward-facing surface (angle = 0°) and lowest for upward-facing one (angle = 180°). Those for oblique angle conditions (angle = 30°–150° and 210°–330°) lay between these two data points. The role of high-level processing for lightness perception is discussed.

Incongruent Conceptual Lighting Enhances Uncooperative and Unassertive Conflict-Handling Style

Steffen Ronft[1,2] and Tandra Ghose[1]
[1]Technische Universität Kaiserslautern, Germany
[2]Duale Hochschule Baden-Württemberg Mannheim, Germany

Although it appears that we spend our entire day in white light, yet there are subtle variations in color temperature. More often than not, work environments have fluorescent tube lights with neutral or cold color temperatures (above 3,500 K) while private spaces such as bedrooms/living rooms utilize warm lights with lower color temperature (below 3,000 K). This may lead to a mental representation (concept) of lighting-space congruency. Interpersonal disagreements can happen anywhere. We investigated the influence of match between real and conceptual lighting on conflict-handling styles in different scenarios. Experimental factors in a between-subject design were lighting (warm, 2,500 K; cold, 3,800 K at constant illuminance level of 450 lx) and imagined conflict situations (work-space: conflict with fellow student over unprepared upcoming presentation; private-space: conflict with landlord over apartment-related repairs). Thomas Kilmann Instrument was used to evaluate characteristics of different conflict-handling styles based on their position on the cooperativeness/assertiveness axes, namely, avoiding, competing, compromising, collaborating, or accommodating. Data from 68 participants show that incongruent-conceptual lighting significantly enhances the "avoiding" style ($p < .002$) compared with congruent-conceptual lighting in the experimental space. Thus, the combination of uncooperative and unassertive behavior is more susceptible to lighting-space incongruency compared with styles that are more positive on either or both of the cooperativeness/assertiveness axes.

Specific Visual Features of a Novel Tool Specify Different Physics Priors

Carlo Campagnoli and Jordan Taylor
Princeton University, NJ, USA

When manipulating a new tool, humans show different movement kinematics depending on whether the inner mechanics are visible or not. Although the visual features of the tool clearly must inform the selection of an appropriate model for the novel tool, there has been little investigation into how different visual parameters specify different internal models or, more generally, a physics prior. As a first step toward understanding this phenomenon, we had participants view a collision between a projectile and a target object (e.g., a tool) and then asked to predict the target's future motion trajectory (MT) generated by the collision. When the target was viewed in isolation (no-MT condition), observers relied quite accurately on Newtonian laws of mechanics for point masses. On the contrary, when the target was connected to a physical system (MT condition), participants exhibited a different physics prior. The accuracy of the MT-induced prior mainly decreased with the system's complexity, while its precision varied along several dimensions, including the system's initial state and the scene's spatial and temporal statistics. The results confirm previous evidence that mechanical transparency affects how humans internally represent the functioning of tools, by exposing visual features that favor the selection of specific physics priors.

Food Deprivation Leads to Bias Along the Perceived Size of Food-Related Stimuli

Noa Zitron-Emanuel and Tzvi Ganel
Department of Psychology, Ben-Gurion University of the Negev, Beersheba, Israel

Exposure to food-related stimuli leads to a set of biological, emotional, and cognitive responses. Such responses are even more pronounced following food deprivation. Related research showed that even a short period of food deprivation leads to increased perceptual precision to detect changes in food portion size.It is unclear, however, whether food deprivation leads to systematic bias along the perceived food portion size. Previous research led to inconclusive results, probably due to large variability across the experimental methods and the types of stimuli used. Here, we used a set of basic psychophysical tools, tailored to the field of food perception, to study the effect of food-deprivation on bias in food-size perception. In three experiments, food-deprived and nondeprived participants were asked to compare a series of food and nonfood visual stimuli along their size. We calculated Point-of-Subjective-Equality to measure the potential effect of food-deprivation on the relative perception of size of food and nonfood stimuli. In all experiments and for all stimulus pairs, results showed that food deprivation led to a consistent bias in food-size perception. This bias was expressed by a relative shift along the perceived size of food-related stimuli which were perceived as bigger by food-deprived participants. This highlights the role of motivational factors in size perception of motivationally relevant objects.

The Effect of Aging on the Eccentricity Dependency of Orientation Anisotropy of Perceptual Surround Suppression of Contrast Detection

Menaka S. Malavita, Trichur R. Vidyasagar and Allison M. McKendrick
University of Melbourne, Australia

Orientation anisotropies of perceptual surround suppression of contrast detection (SSCD) are present in young adults. Specifically, at 6° eccentricity, suppression is increased for horizontal stimuli, whereas at 15°, suppression is stronger for radially oriented stimuli. This reflects a link between SSCD and visual field retinotopy. Numerous studies have demonstrated that healthy aging alters features of surround suppression; however, those studies have mostly involved foveal testing. Here we measure perceptual SSCD in the parafoveal region, in addition to the eccentricity dependency of orientation anisotropy. Nineteen younger (mean age: 24.4, 18–32 years) and 19 older (mean age: 66.8, 60–72 years) adults participated. Contrast detection thresholds were estimated for horizontal, vertical, radial, and tangential centre targets with parallel and orthogonal surrounding annuli. Nasal, inferior, and inferotemporal visual field locations at 6° and 15° were tested. We find SSCD is stronger for older adults compared with younger adults at both 6°, $t(35) = -2.243$, $p < .05$, and 15°, $t(35) = -2.062$, $p < .05$. Orientation anisotropy of surround suppression changed from a horizontal bias to a radial bias moving from 6, $F(1, 35) = 5.5$, $p < .05$, to 15°, $F(1, 35) = 15$, $p < .001$, in older groups indicating similar eccentricity dependency of orientation biases of SSCD in both age groups.

Changes in Optic Flow Parsing Across the Adult Life Span

Lucy Evans[1], Rebecca Champion[1], Simon Rushton[2], Daniela Montaldi[1], Laura Parkes[1] and Paul Warren[1]
[1]University of Manchester, UK
[2]Cardiff University, UK

Older observers exhibit both local and global motion processing impairments. Here we investigate changes with age in optic flow parsing (FP)—a neural mechanism that acts to subtract out global motion arising due to self-movement (optic flow) so that scene-relative object movement can be recovered. We assessed different aspects of FP in two tasks ($N = 30$, age range: 20–76 years). Task 1 measured the deflection in perceived trajectory of a probe presented in the opposite hemifield to a two-dimensional expanding radial flow field, providing a direct estimate of the magnitude of subtracted optic flow (FP-gain). Task 2 measured direction discrimination thresholds for a horizontally moving probe in a field of three-dimensional background objects across two conditions: (a) no background movement and (b) background movement consistent with forward observer movement. Smaller differences in thresholds between conditions signify better FP performance (FP-perf). We found strong evidence for a positive correlation between age and FP-gain ($r = .550$, $B10 = 25.636$), suggesting increased optic flow subtraction with age. However, there was evidence for no correlation between age and FP-perf ($r = .136$, $B10 = 0.290$). These data suggest that recovery of scene-relative object movement is functionally critical and the flow parsing mechanism adapts with age to preserve performance.

Age Effects on Visual Search: Contributions of Bottom-Up and Top-Down Processes

Jutta Billino[1], Dion Henare[2] and Anna Schubö[2]
[1]Department of Experimental Psychology, Justus-Liebig-Universität Gießen, Hesse, Germany
[2]Cognitive Neuroscience of Perception & Action, Philipps-Universität Marburg, Germany

Visual search becomes slower and less accurate with increasing age. However, the contribution of bottom-up and top-down processes to these age effects has remained elusive. Declining sensory resources as well as cognitive control capacities could both play a critical role. We used an additional singleton paradigm to investigate age-specific vulnerabilities. A total of 19 younger adults (21–36 years) and 21 older adults (62–74 years) participated in our study. We measured the effect of a color singleton distractor during search for a shape target. Top-down control putatively inhibits stimulus-driven attentional capture. In all participants, we assessed individual sensory and cognitive control resources. Our data corroborated pronounced age effects on visual search performance. Older adults showed higher response times and lower accuracy. In addition, we observed robust distractor effects of the salient additional singleton that were consistent across experimental blocks. Notably, attentional capture was found to be similar in younger and older adults, suggesting retained top-down control in visual search. Individual differences in distractor effects across age groups moreover were predicted by sensory parameters, not by cognitive control measures. Our findings delineate bottom-up age effects on visual search from cognitive processes and qualify the modulation of attentional capture by top-down control.

Age-Related Effects of a Monocular Head-Worn-Display on the Performance in a Lane Change Task

Thorsten Plewan, Magali Kreutzfeldt and Gerhard Rinkenauer
Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany

Monocular head-worn-displays (HWD) are becoming increasingly popular not only in entertainment industry but also in actual workplace scenarios. However, several studies reported negative behavioral effects related to HWD. In this study, we asked younger (19–30) and older (56–69) participants to perform a lane-change task in a driving simulator. Neutral or valid preparation cues were presented via HWD or simulator-screen, while uninformative distractor stimuli were in some trials presented simultaneously on the other device. Results showed that steering movements were initiated faster when task-relevant preparation cues appeared on the HWD and also when no distractor stimuli were presented. While this was true for both age groups, younger participants responded generally faster. With regard to observed error rates (i.e., anticipations and erroneous lane changes), age-related differences were more complex. Overall, younger participants committed only few errors and error rates were not modulated by distractors or devices. Older participants committed more errors and performance was worst when neutral cues were presented via HWD. Taken together, results indicate a straightforward relationship between task-performance and the use of HWD, which is further modulated by age. While response speed using HWD was not affected by age, accuracy decreased with age, especially when uninformative stimuli were presented.

Impact of Observer Age on Color Matching Accuracy and Variability

Jiaye Li, Kevin Smet and Peter Hanselaer
KU Leuven, Belgium

Color matching functions (CMFs) or cone fundamentals are the most fundamental aspects of color science and color perception. Over time, much work has been carried out to ascertain the accuracies of the CIE (International Commission on Illumination) standard CMFs, however without any definitive answer, especially for observers of different ages. Recent work indicates an undeniable discrepancy between visual metamers and those calculated using the standard CMFs or the age-specific CMFs derived using the CIEOP06 model. To further characterize this issue and work toward a better model, color matching experiments will be performed with observers from different age ranges. Matches will be made using primaries with different peak wavelengths to determine the wavelength regions most sensitive to generating matching inaccuracies. Visual matches will be compared with matches calculated using CMFs derived using the individual observer model of Asano (2016), which includes various other parameters affecting CMFs in addition to age. For different age ranges, accuracy and variability will be analyzed as a function of model parameters and primary peak wavelength to derive more appropriate CMFs. This paper reports on the results of a pilot study with two groups of observers with average ages of 25 and 73, respectively.

Age-Related Differences in the Neural Processing of Momentum

Yi-Wen Kao[1], Shuo-Heng Li[2], Joshua Oon Soo Goh[1,2,3], Arthur C. Tsai[4], Li Jingling[5] and Su-Ling Yeh[1,2,3]
[1]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taipei
[2]Department of Psychology, National Taiwan University, Taipei
[3]Center for Artificial Intelligence and Advanced Robotics, National Taiwan University, Taipei
[4]Institute of Statistical Science, Academia Sinica, Taiwan
[5]School of Psychology, University of Birmingham, UK

Greater prior experience increases the contribution of statistical regularity on neurocognitive processes. We evaluated whether older adults, who in principle have more experience and exposure to different types of visual motion, would have stronger representations of momentum than younger adults. In a functional magnetic resonance imaging (fMRI) experiment, 24 younger (mean (*SD*) age = 22.79 (2.48) year-old) and 27 older (mean (*SD*) age = 65.78 (3.07) year-old) adults viewed sequences of sports-related actions consisting of quartets of picture stimuli. Quartets included regular (smooth actions), irregular (scrambled actions), and control (scrambled pictures) conditions for which participants rated the degree of consistency of the actions. Compared with younger adults, older adults rated regular sequences as less consistent, and irregular and control sequences as more consistent. Moreover, older adults obtained higher neural responses in medial frontal areas when they watched regular and irregular sequences in contrast to the control sequences. These findings support more dominant perception of momentum in older than younger adults and implicate medial frontal neural computations in driving this age-related cognitive difference.

Age-Specific Interferences Between Oculomotor and Postural Control

Maximilian Davide Broda, Méline Wölfel and Jutta Billino
Justus Liebig University Giessen, Hesse, Germany

Variation of postural stability increases with age and represents a major risk factor for falls. Although postural control is considered to be primarily an automatic process, stability can be modulated by secondary tasks. In particular, saccadic eye movements have been shown to reduce postural sway, but this beneficial effect critically depends on cognitive task demands. We investigated age effects on interferences between oculomotor and postural control. We measured postural sway under a fixation condition and saccade conditions involving specific cognitive demands, that is, prosaccades and antisaccades. Sway measures were evaluated for two standing positions. A total of 24 younger adults (19–33 years) and 24 older adults (60–78 years) participated in our study. Older adults overall showed more pronounced sway and were more challenged by standing position demands. However, we observed similar beneficial effects of saccades across both age groups. Furthermore, our data supported that postural sway during saccades is increased if cognitive demands are enhanced. Notably, younger adults showed this pattern across both standing conditions, but for older adults it was degraded in the more challenging standing position. Our findings suggest robust stabilization of postural control by saccades. Modulation of sway by cognitive demands of saccades is attenuated with increasing age.

No Country for Old Men? Reducing Ageism Bias Through Virtual Reality Embodiment

Stefania La Rocca, Tosi Giorgia, Brighenti Andrea and Daini Roberta
University of Milano Bicocca, Italy

Ageism is a negative attitude toward aging and elderly people. Many studies have investigated the effects of ageist attitudes and age stereotypes on the behaviour of others toward older persons and the self-related beliefs and behaviour of older adults themselves. By making participants embodying bodies of the same age and older, we aimed to induce the illusion of ownership for the virtual body and tested whether we could reduce negative implicit bias toward elderly people exclusively in the older body condition. We used a within group design including 24 adults participants. They completed four conditions by watching videos in virtual reality. Through a visuotactile synchrony stimulation between real and virtual condition, we elicited an illusion of body ownership. Participants looked at their "virtual" arm while they were touched by the same wooden stick seen in the video, every second for 2 minutes. After each condition we measured the implicit attitudes toward older adults through an implicit association test paradigm. Results suggest a decrease of negative attitudes toward elderly people in adult population after the older body illusion. Future directions aim to replicate the study in an elderly sample in order to investigate how they perceive their own aging process.

Investigating Consequences of Age-Related Hearing Loss on Attention and Executive Control

Claudia Bonmassar[1], Francesco Pavani[1,2,3], Giuseppe Nicolò Frau[4], Domenico Spinella[4] and Wieske van Zoest[1]
[1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy
[2]Department of Psychology and Cognitive Science, University of Trento, Italy
[3]Centre de Recherche en Neuroscience de Lyon (CRNL), France
[4]HNT Department, "Santa Maria del Carmen," Madrid, Spain

Recent proposals suggest that age-related hearing loss (ARHL) may be a possible risk factor for cognitive decline in older adults. The resulting poor speech recognition negatively impacts on cognitive, social, and emotional functioning and relates to Alzheimer's disease. However, little is known about the consequences of presbycusis on other nonlinguistic domains of cognition. The aim of this study was to investigate the role of ARHL on covert orienting of attention, selective attention and executive control. We compared older adults with and without mild hearing loss (26–40 dB) performing a spatial cueing task with uninformative central cues (gaze vs. arrow) as well as a flanker task and a neuropsychological assessment of attention. In both groups, comparable gaze- and arrow-cueing effects were found on reaction time as well as similar flanker interference effects. Notably, hearing impaired individuals showed reduced foreperiod effect on spatial cueing of attention and tended to perform worse in the Montreal Cognitive Assessment (MoCA). This work indicates that attention orienting and response inhibition appear to be preserved following mild hearing loss, even if some specific aspects, associated with higher level voluntary behaviors, seem to be more deteriorated in older adults with mild ARHL.

Seeing a Sound-Producing Event Modulates the Amplitude of the Initial Auditory Evoked Response

Sol Libesman, Damien J. Mannion and Thomas J. Whitford
University of New South Wales, Sydney, Australia

An auditory event is often accompanied by characteristic visual information. For example, the sound level produced by a vigorous handclap may be related to the speed of hands as they move toward collision. Here, we tested the hypothesis that visual information about the intensity of auditory signals are capable of altering the subsequent neurophysiological response to auditory stimulation. To do this, we used electroencephalography to measure the response of the human brain ($n = 28$) to the audiovisual delivery of handclaps. Depictions of a weak handclap were accompanied by auditory handclaps at low (65 dB) and intermediate (72.5 dB) sound levels, whereas depictions of a vigorous handclap were accompanied by auditory handclaps at intermediate (72.5 dB) and high (80 dB) sound levels. The dependent variable was the amplitude of the initial negative component (N1) of the auditory evoked potential. We find that identical clap sounds (intermediate level; 72.5 dB) elicited significantly lower N1 amplitudes when paired with a video of a weak clap, compared with when paired with a video of a vigorous clap. Thus, this study provides evidence that the neural evoked response to an auditory event results from the combination of visual information about sound source intensity with incoming auditory input.

Mutual Complete Transfers Between Visual and Auditory Temporal Interval Learning Support a Central Clock in Subsecond Temporal Processing

Cong Yu[1,2], Shu-Chen Guan[1,2] and Ying-Zi Xiong[1,2]
[1]Department of Psychology, McGovern Brain Institute, Cambridge, MA, USA
[2]Center for Life Sciences, Peking University, Beijing, China

Perceptual learning of subsecond temporal interval discrimination (TID) shows asymmetric partial transfer from more precise auditory to coarser visual modalities, but not vice versa. These findings are interpreted as distributed, rather than central, temporal processing. We studied whether the modality specificity could be eliminated with double training, a technique developed in visual perceptual learning. We first replicated the null transfer from visual to auditory TID learning, and partial transfer from auditory to visual TID learning, with two Gabors or brief tones with a 100-millisecond interstimulus interval. However, visual TID learning, when paired with training of auditory frequency discrimination at the same 100-millisecond interval, transferred to auditory TID, as much as through direct auditory TID training. Similarly, auditory TID learning, when paired with training of visual contrast discrimination at a 100-millisecond interval, improved visual TID, as much as through direct visual TID training. Control experiments revealed no significant impacts of practicing auditory frequency discrimination or visual contrast discrimination alone on TID performance. Additional double training also enabled complete transfer of auditory TID learning from 100 to 200 milliseconds. These results suggest a central clock for subsecond temporal processing, with its actual precision decided by peripheral modalities.

Modulation of Behavioral and Electrophysiological Responses to Visual Targets by the Reward Value of Co-occurring Auditory or Visual Cues

Roman Vakhrushev[1], Felicia Cheng[1], Annekathrin Schacht[2] and Arezoo Pooresmaeili[1]
[1]European Neuroscience Institute, Göttingen, Germany
[2]Leibniz Science Campus Primate Cognition, University of Göttingen, Göttingen, Germany

Previous research has shown that valuable cues from visual (Bayer et al., 2017) as well as from auditory modality (Pooresmaeili et al., 2014) influence visual sensitivity. Here we compare the effects of visual and auditory valuable cues on perception, at the behavioral and electrophysiological levels. The study employed a visual orientation discrimination task (peripheral Gabors, 9°). The Gabor appeared synchronously with either visual or auditory cues that were previously associated with reward value and were irrelevant to the task. By synchronous presentation, we expected that the reward value of the cues permeates the Gabor, thereby facilitating its perception. We found that visual sensitivity (d') and the amplitude of the early N1 component of the event-related potentials (ERPs) were modulated by both high-value auditory and visual cues. However, while auditory cues had positive modulation, high-value visual cues suppressed d' and N1 amplitude. We did not find these differences in early P1 component where both auditory and visual high-value cues increased ERP amplitudes. The results support a distinct mechanism for cross-modal versus within-modal modulation of perception by reward value. Whereas within-modal high-value cues compete for limited processing resources, valuable cross-modal cues can enhance sensory perception in another modality without interference.

Viewing Hand Motion Elicits Tickliness

Godai Saito[1], Reo Takahashi[1] and Jiro Gyoba[2]
[1]Tohoku University, Japan
[2]Shokei Gakuin University, Japan

It is well known that self-produced and externally produced tactile stimuli are perceived differently. Here we examined that viewing hand motion could elicit tickle sensation without touching the participant's knee. In our experiments, the participants were asked the degree of their subject feeling of tickle sensation after they watched self-produced or externally produced hand motion with or without touching their own knee. The results showed that externally produced visual stimuli was perceived as more ticklish than self-produced stimuli, and also visual hand motion presented near to the knee (within approx. 10 cm from the knee) induced tickle sensation. These finding suggest that visual induced tickle sensation is related to externally produced stimuli and occurs in a limited space surrounding body parts.

Olfactory Stimulation Modulates Visual Perception and Brain Activities in the Visual Cortex

Yoshiaki Tsushima, Yurie Nishino and Hiroshi Ando
NICT, Tokyo, Japan

In many moments of our lives, our perceptual system integrates multi-sensory information, in a process called crossmodal perception. Most crossmodal phenomena are interpreted by spatial and temporal correspondences between a pair of unimodal features; however, some of them do not provide clear explanations of crossmodal relevance. One such phenomenon is the "fast lemon" issue: When asked whether a lemon is "fast" or "slow," most people say "fast." Does a lemon really induce "fast" perception? Here, we conducted psychophysical and neuroimaging experiments in order to show the unique aspects of this strange crossmodal perceptual link. In the visual experiments with different olfactory stimulations (lemon, vanilla, or odor-free), in which participants were asked to report the speed of visual motion dots, faster or slower. As a result, we found that participants perceived the slower motion dots with a lemon smell, namely, our visual system counterintuitively made a connection between the lemon and "slow." In addition, brain activities in the visual cortex changed with the olfactory stimulations only when participants had difficulty making a decision. Our results demonstrate a new crossmodal perceptual link between vision and olfaction, and a characteristic feature of crossmodal perception with a pseudo-irrelevant stimulus.

Occipital Cortex Contributions to Color Sensations in Grapheme-Color Synesthesia

Gregor Volberg, Franziska Weiss and Mark W. Greenlee
University of Regensburg, Germany

Grapheme-color synesthetes have color sensations when viewing objectively achromatic letters or numbers. Building on previous results of increased visual cortex excitability in synesthetes, we investigated steady-state electroencephalography responses within the visual cortex during repetitive grapheme presentations. Participants were presented with flickering arrays of color-inducing and noncolor inducing graphemes and the steady-state potential at the driving frequencies was analyzed. Color-inducing compared with noncolor-inducing graphemes produced larger occipital steady-state responses in synesthetes. In addition, significant amplitude differences between grapheme conditions were associated with more vivid visual imagery in synesthetes, as obtained by self report ($r = .58$). No effects were observed in controls who saw matched sets of graphemes. The results suggest enhanced occipital cortex activity is linked to synesthetic misperceptions of color.

Spatiotemporal Integration or Feature Representation? Neuronal Coding of Dynamic Partial Shape Views in Macaque Anterior Body Patch

Anna Bognár and Rufin Vogels
Catholic University of Leuven, Belgium

Humans easily recognize objects even if only a small part of the object is available in every instant at the same retinal position. This requires a strong spatiotemporal integration of the shortly available visual features. Previous functional magnetic resonance imaging (fMRI) studies revealed that the lateral occipital complex plays an essential role in forming a whole shape percept. To investigate the neuronal mechanisms, we measured neuronal activity in the macaque anterior body patch, presenting animal silhouettes moving behind a narrow 0.5° horizontal or vertical slit in both directions. Our goal was to test if the stimulus selectivity of static images is preserved under anorthoscopic presentation and additionally to investigate the strength of feature integration by presenting feature-preserved temporal randomized stimuli as control. Single neurons showed diverse activity. At the population level, stimulus selectivity was preserved for the slit-views. We measured a significantly higher firing activity for the slit-views of original than for their randomized presentations. Using multivariate classification, we observed information

transfer between vertical and horizontal presentations, but weaker than between directions of the same orientation. The generalization matrices had a strong diagonal temporal profile, which suggests that the neurons integrate slit information of their preferred features, but not encode the whole shape.

Object Representations Based Upon Shape Circularity and Local Curvature Identified in Lateral Occipital Cortex

Richard J. W. Vernon[1,2], André D. Gouws[2], Samuel J. D. Lawrence[1], Alex R. Wade[1,2,3] and Antony B. Morland[1,2,3]
[1]Department of Psychology, University of York, UK
[2]York Neuroimaging Centre, Univesity of York, UK
[3]York Biomedical Research Institute, University of York, UK

While curvature-based shape representations have been identified in Macaque V4, the homologue in humans is unclear. To examine human neural responses to curvature, we parametrically varied radial frequency patterns across orthogonal dimensions of amplitude and frequency, presenting them in a rapid event-related functional magnetic resonance imaging (fMRI) design. Responses to these stimuli were explored using multivoxel pattern analysis and representational similarity analysis, conducted in retinotopically defined regions V1-V4, LO-1 and LO-2, plus the functionally defined (objects > scrambled objects) Lateral Occipital Complex, split into LO and pFs. We identified a frequency influence specific to LO1, and an amplitude influence that dominated in all Lateral Occipital regions (LO-1, LO-2, and LO) which was likely capturing shape circularity. Further exploration then revealed an additional influence in these areas, that of local curvature. None of our metrics could reliably explain neural similarity in V4. These results could explain human curvature hyperacuity, and they hint that Lateral Occipital brain regions may be better homologues of Macaque V4, at least in term of curvature processing.

Brain Regions Are Involved in Higher Order Object Perception

Sophia Nestmann[1], Hans-Otto Karnath[1,2] and Johannes Rennig[1,3]
[1]Centre of Neurology, Division of Neuropsychology, Hertie-Institute for Clinical Brain Research, University of Tübingen, Tübingen, Germany
[2]Department of Psychology, University of South Carolina, Columbia, SC, USA
[3]Department of Neurosurgery and Neuroscience, Baylor College of Medicine, Houston, Texas

Lesions to posterior temporoparietal brain regions are associated with deficits in Gestalt perception, but also impairments in the processing of objects presented under demanding viewing conditions. Evidence from neuroimaging studies as well as lesion patterns observed in patients with object orientation agnosia suggest similar brain regions to be involved in Gestalt perception and processing of objects in atypical ("noncanonical") orientation. In an event-related functional magnetic resonance imaging (fMRI) design, we collected data of 20 healthy volunteers to systematically test whether temporoparietal brain areas that are involved in Gestalt perception are also involved in the perception of objects presented in noncanonical orientations (compared with objects in canonical orientation). Using individual temporoparietal regions of interest, we found significantly higher activation during the processing of noncanonical objects compared with objects presented in a canonical orientation. These results suggest that temporoparietal brain areas are not only involved in Gestalt perception but might serve a more general mechanism of complex object perception. Our results challenge a strict attribution of object processing to the ventral visual stream by suggesting dorsal contributions in more demanding viewing conditions.

Looking Through Our Internal Eye: Internally Directed Attention Impedes Object Identification

Charlotte de Blecourt, Eric Maris and Marius Peelen
Radboud University, Nijmegen, The Netherlands

The phenomenon of "seeing less" while attending internal representations is well-known among the general public. However, a direct comparison of internally versus externally directed attention has not yet been performed. In this study, we measured the effect of internal versus external attention on the recognition of objects in natural scenes. Perceptual performance was probed while participants directed attention either internally or externally using a dual-task design. An internal attention state was induced by having participants perform a visual working memory task, while an external attention state was induced by having participants monitor whether briefly presented images exhibited mirror symmetry. Importantly, retinal input was controlled for by using exactly the same stimuli in both tasks. Within each of the two dual tasks, half of the trials ended with the object recognition probe while the other half ended with a probe relevant to the respective task type—either a working memory probe or a question about the number of symmetrical images. Results showed that object recognition (*d*-prime) was worse during the internal compared with the external attention task. This study provides empirical evidence for the distinction

between internal and external attention by showing that directing attention internally hinders naturalistic object recognition.

The Role of Object Frequency in an "Object Decision Task"

Jacopo Turini and Melissa L.-H. Vo
Scene Grammar Lab, Department of Psychology and Sports Sciences, Goethe Universität, Frankfurt am Main, Germany

Objects are found in the environment in a regular way: They appear frequently in some scenes and less frequently, or never, in others. Our cognitive system exploits these regularities to efficiently accomplish visual tasks. Typically, studies compared neural and behavioural response to objects intuitively defined as "consistent" or "inconsistent" within a scene. We tried to assess object frequency in a more systematic way, using Greene's (2013) dataset of images with object labels, and computing the frequency of objects with regard to the whole dataset as well as to specific scene categories. We then tested the role of these measures—comparing them with human observers' ratings and basic image properties—in predicting reaction times (RTs) during an "object decision task" where participants had to categorize objects as either real or fake, after being primed with a scene label. Our results suggest that neither the object frequency computed from the database, nor the rated object-scene consistency, seem to be relevant for the task, while the rated prototypicality as well as the saliency of the object image seem to modify RTs. We conclude that at least for this type of object decision task object frequency information is not behaviourally relevant.

Two Types of "No" Response in Object Detection and Basic-Level Categorization With Fragmented Object Contours

Kosuke Taniguchi[1], Sven Panis[2] and Johan Wagemans[3]
[1]Doshisha University, Kyoto, Japan
[2]University of Kaiserslautern, Germany
[3]University of Leuven, Belgium

In this study, we investigated the different decision processes underlying yes/no responses in object detection and three categorization tasks (i.e., natural/artifactual, superordinate-level, and basic-level category). Images of fragmented object contours with different fragment types (mid-points and salient points) and fragment length (short and long) were briefly presented (150 milliseconds) at the centre of screen. Participants were asked to decide whether or not the depicted object belonged to a particular object category, indicated by specific questions presented before the image (i.e., "Object?" "Natural?" "Bird?" and "Car?"). Gamma finite mixture modelling of the distributions of response times showed that the "no" responses in detection and basic-level categorization were composed of two types of decisions (fast and slow), while the "yes" responses in all tasks and the "no" responses in the natural/artifactual and superordinate-level tasks did not. analyses of variance on response time and accuracy, on the other hand, indicated significant differences between the "no" and "yes" responses at difficult task (i.e., short fragment length). Therefore, "no" responses at detection and basic-level categorization might involve two types of decisions: intuitive (i.e., fast but inaccurate) and accurate decision depending on received information for detection, fast and slow decision by speed of matching processing for basic-level categorization.

Effects of Meridian-Specific Scaling on Shape Discrimination Hyperacuity Across the Visual Field

Anna Beata Zolubak and Luis Garcia-Suarez
University of Plymouth, UK

Preference for contour shape perception was found for the lower visual field (VF) up to 10° when a uniform scaling was applied across the VF. In this study, we investigated contour shape perception across the VF up to 20° using meridian-specific scaling. We measured modulation thresholds ($N = 4$), expressed as the proportion of the radius, with a 2IFC Shape Discrimination Hyperacuity (SDH) task where sinusoidally modulated contours (radial frequency patterns) were discriminated from circles. Stimuli (baseline radius=0.8°) were size scaled according to the cortical magnification factors for the left, right, upper, and lower VF and presented on a calibrated CRT monitor at 5°, 10°, 15°, and 20° across the horizontal and vertical meridians. Performance in SDH task was constant between 5°–15° with higher thresholds at 20° in all parts of the VF, except for the lower VF where it was uniform up to 20°. In the lower VF, thresholds were lower than in other parts; however, these differences were statistically nonsignificant, $F(2.17, 38)=3.1$, $p = .11$. This could be caused by the nonspecific variability in the dataset. Meridian-specific scaling reduces the difference between central and peripheral performance and the magnitude of the lower VF preference for SDH.

Shape Aftereffects Are Retinotopic and Are Explained by the Local Tilt Aftereffect

Edwin Dickinson, Vanessa Bowden, Robert Green and David Badcock
The University of Western Australia, Perth, Australia

In this study, we first confirm earlier findings that shape aftereffects in radial frequency (RF) patterns, patterns deformed from circular by a sinusoidal modulation of radius, can be accounted for by the systematic application of local tilt aftereffects around simple closed figures. Second, by using eye-tracking equipment to constrain the presentation of stimuli to five experimental subjects to periods of time when they were fixated on a stationary dot, we show that the effects of adaptation are only observed when the boundaries defining the shapes of adaptor and test stimuli are presented in retinotopic correspondence. Specifically, we demonstrate, using the method of constant stimuli in a single interval forced-choice task, that circles are perceived as having no RF modulation after adaptation to concentric RF patterns with different radii or similarly sized RF patterns with centre separations that render them discrete in space. Large aftereffects were observed after adaptation to concentric RF patterns with the same radii. We conclude that adaptation to orientation selective filters of the primary visual cortex provides for a general mechanism of exaggerating the perceived difference between successively experienced similar figures when they are retinotopically coincident.

Effects of Microsaccade on Global Processing of Shape

Ken W. S. Tan, Elizabeth M. Haris, Neil W. Roach and Paul V. McGraw
University of Nottingham, UK

Global pooling mechanisms that integrate local form information around an object are thought to underlie the sensitivity of the human visual system to subtle changes in shapes. Tasks demonstrating global integration are typically completed under conditions of steady fixation; however, some research suggests that the percept of global structure can collapse under prolonged fixation. In this study, we investigate whether small ocular movements during steady fixation (microsaccades) influence global processing of shape. Participants were asked to discriminate between two peripherally presented closed-contour radial frequency patterns (created by the addition of sinusoidal modulation to the radius of a circle), while fixational eye movements were recorded binocularly at 500 Hz. Microsaccdes were detected using a velocity-based algorithm allowing trials to be sorted according to the relative timing of stimulus and microsaccade onset. Results indicate a general detrimental effect of microsaccades on task performance consistent with previous demonstrations of saccadic suppression. The presence of global pooling (indicated by a rapid improvement in threshold as additional cycles of modulation were added) appeared to be unaffected, suggesting its relative robustness to small fixational eye movements.

Form Preferences Depending on Symmetry Types and Topological Relations

Līga Zariņa[1], Jurģis Šķilters[1], Nora Bērziņa[1] and Signe Bāliņa[2]
[1]Laboratory for Perceptual and Cognitive Systems, Faculty of Computing, University of Latvia, Riga, Latvia
[2]Faculty of Business, Management and Economics, University of Latvia, Riga, Latvia

Although it is well documented that human perception is sensitive to reflection symmetry, less known are the impacts of other symmetry types and their topological relations. In our study, preferences for different symmetries (e.g., translation, rotation) and basic topological relations (e.g., connectedness, overlap) were tested. Two sets of online experiments were conducted: (a) a preference rating task based on 5-point Likert-type scale ($n = 99$) and (b) a reaction time (RT) forced-choice task with two random options ($n = 91$). The results confirmed preferences for symmetry, however, to different degree in different symmetry types. In RT analysis, the most frequent choices correspond with the results from the rating task. Shapes with dihedral rotation symmetry are most preferred and have the shortest RTs. Less preferred are (a) asymmetric shapes and shapes, (b) belonging to symmetry groups that include only one nontrivial isometric transformation, and (c) with oblique symmetry axis. A significant ($p = .05$) negative association ($r = -.443$) between frequency of choice and RT can be observed. The longest RTs correspond to asymmetric shapes and shapes with glide reflection symmetry. According to our results, also topological relations significantly contribute to form preferences—combinations are rated differently even in the same symmetry group if representing different topological relations.

Does Microgravitation Influence the Optical Apparatus of the Eye?

Svetlana Dmitrieva[1], Maria Gracheva[1,2], Nadezhda Vasilyeva[2], Alexandr Smoleevsky[1], Olga Manko[1] and Yuriy Bubeev[1]

[1]Russian Federation State Research Center Institute of Biomedical Problems, Russian Academy of Sciences, Moscow, Russia
[2]Institute for Information Transmission Problems (Kharkevich Institute), Russian Academy of Sciences, Moscow, Russia

The data available indicate that, after prolonged cosmic flights, some hypermetropic changes could be detected in the eyes of astronauts, perhaps as a result of weightlessness. It was the reason to perform pilot studies using a technique of dry immersion that creates the conditions of microgravitation imitating such effects of weightlessness as redistribution of the liquids in the body and decrease of proprioceptive afferent flows leading to decrease of sympathic tonus of the nervous system. In the framework of the Project "Immersion," we investigated refraction and accommodation in subjects (aged 25–35 years) immersed into special baths for 5 and 21 days (10 and 6 subjects, respectively). The measurements were accomplished by means of auto-refracto-keratometer Righton Speedy-i before the experiment, and 7 days after its end. The aim was to assess the stability of the accommodation regulatory mechanisms using the parameters of accommodation response and high-frequency microfluctuations. After 5 experimental days, a decrease of the accommodation response was found in 11 eyes, and in 7 of them, decrease of high-frequency microfluctuations was found. After 21 experimental days, in three from six subjects, the accommodative responses did not differ significantly from the initial values, indicating high adaptation capability during a given duration of artificial weightlessness.

Visual Acuity Charts: Comparison Study

Maria A. Gracheva[1], Anna A. Kazakova[1,2], Igor B. Medvedev[2], Svetlana I. Rychkova[1] and Dmitry F. Pokrovskiy[2]

[1]Institute for Information Transmission Problems (Kharkevich Institute), Russian Academy of Sciences, Moscow, Russia
[2]Pirogov Russian National Research Medical University, Moscow, Russia

The aim of the study was to compare Lea-screener chart and new visual acuity charts: with wide-space design (IITP) and with proportional design (IITP-V) in view of repeatability. Forty-two subjects (11.1±0.2 years) with ophthalmopathology were divided in two groups: 15: with optic nerve atrophy and retinopathy, 27: with light amblyopia (median visual acuity: 0.1 (1.0 logMAR) and 0.9 (0.05 logMAR), correspondingly). Best corrected visual acuity was assessed twice (test and retest) with three charts in random order, monocularly and binocularly, at the viewing distance of 4 m. We compared test and retest data by Wilcoxon signed-rank test. In Group 1, test and retest was significantly different for Lea chart ($p = .003$), that means poor repeatability; for IITP and IITP-V charts, no significant differences were found ($p = .611$ and $p = .807$). In Group 2, no significant differences were found for all three charts ($p = .727$—Lea, $p = .340$—IITP, 0.974—IITP-V). Thus, according to our data, in group with worse visual acuity (with optic nerve atrophy and retinopathy), Lea-screener chart show worse repeatability than IITP and IITP-V chart. In group with better visual acuity (light amblyopia), all charts provided comparable results.

LogMAR Is Not a Proper Measure for Visual Acuity Assessment

Galina I. Rozhkova

Institute for Information Transmission Problems (Kharkevich Institute), Russian Academy of Sciences, Moscow, Russia

Delusion concerning an advantage of using logMAR (logarithm of the Minimal Angle of Resolution) in visual acuity investigations originated four decades ago when several authoritative scientists claimed that it would be better to express the results in logMAR instead of Snellen ratio, decimal notation, critical spatial frequency, and so on. The initiators mentioned that they could not adduce strong arguments in favor of this idea; their followers also failed to be persuasive. Nevertheless, many optometrists and psychophysicists appeared to be inspired and tried bringing logMAR into use. Indeed, it was realized that logarithmic scales were good for creating visual acuity test charts with a proportional design. However, some essential inconveniences emerged in the logMAR practical usage stimulated us to perform a metrological analysis and to overview clinical reports. The conclusions are as follows: (a) logMAR cannot be considered as a correct measuring unit; (b) usage of logMAR does not provide any advantages in data analysis; (c) in clinical calculations, negative logMAR values often lead to errors. In contrast, Snellen ratio, decimal notation, and critical spatial frequency are well suited to the requirements of metrology and consistent with human intuition. Actually, these three measures are equivalent as they are directly proportional to each other.

Assessing the Status of Visual Cortex in Macular Disease

Holly D. H. Brown[1], Richard P. Gale[2], Richard J. W. Vernon[1], Andre D. Gouws[3], Heidi A. Baseler[1,4,5] and Antony B. Morland[1,3,5]
[1]Department of Psychology, University of York, UK
[2]York Teaching Hospital, UK
[3]York Neuroimaging Centre, University of York, UK
[4]Hull York Medical School, University of York, UK
[5]York Biomedical Research Institute, University of York, UK

The current focus in ophthalmological research concerns physiological changes within the eye, aiming to treat eye disease and prevent further loss of vision. However, comparatively fewer studies assess the consequences of eye disease on visual cortex. Macular degeneration (MD) embodies a collection of disorders causing a progressive loss of central vision. Cross-sectional studies have revealed structural changes in visual cortex in MD, but the rate of change is unknown. We acquired structural magnetic resonance imaging data on 10 patients with different forms of MD and 18 age-matched controls over multiple time points in a ~2-year period, to explore the rate of change in cortical thickness within the occipital pole (OP) and calcarine sulcus (CS). Data were analysed using a linear mixed-effects model. Preliminary data show a significant reduction in grey matter in patients in the OP, and an accelerated rate of decline compared with controls. While patients did have a significantly thinner CS, the rate of change did not differ between groups. Understanding the time course of changes may prove important for visual restoration; if visual cortex is no longer viable, the success of interventions aiming to restore functionally useful vision will be limited.

The Study of the Illusion of Phosphenes in Pupils With Partial Atrophy of the Optic Nerve and With Amblyopia

Svetlana Rychkova[1] and Roman Sandimirov[2]
[1]Institute for Information Transmission Problems, Russian Academy of Sciences, Russia
[2]Pirogov Russian National Research Medical University, Moscow, Russia

The work is devoted to the study the conditions of emergence of the illusion of phosphenes and assessment of its power in children with partial atrophy of the optic nerve (PAON) and children with amblyopia. sixty-nine children of school age were divided into three groups: (a) 22 pupils with PAON, (b) 23 pupils with amblyopia, and (c) 24 pupils of the control group. In this study, we used the test images performed like variants of "scintillating grid" with disks (in the crosshairs of the grid) of different diameters. Test images were displayed on the computer screen. We found significant differences between the manifestations of the illusion of phosphenes in all three groups of subjects. In children with PAON, there was a "shift" of the power of the illusion toward a larger diameter of the disks in comparison with the children of the control group and with the children of the amblyopic group. In amblyopic children, we observed a reduction of the power of the illusion in comparison with the children of the control group. We suppose that these differences may be related to larger receptive fields in children with PAON and to functional inhibition of visual perception in children with amblyopia.

Reduction of Migraine Episodes in Ménière Patients Following Chronic Use of Weak Prismatic Spectacles

Eric Vente[1] and Alexandra Jane Shepherd[2]
[1]Utermöhlen Foundation (Balance & Orientation), Amsterdam the Netherlands
[2]Birkbeck, University of London, UK

One noninvasive treatment of Ménière disease is the chronic use of Weak Asymmetric Base-in Prism spectacles (WABIPS), a method developed by Utermöhlen more than half a century ago. A recent report by Vente et al. evaluated this treatment in a cohort study of 580 unilateral patients. They found 97% subjective satisfaction and reduction of vertigo, and 57% reduced or stopped concomitant medication. This article reports the results of such weak prismatic spectacles on a subset of this group who also experienced migraine. Patients had to fulfill the criteria for unilateral Ménière disease according to the guidelines of the American Academy of Otolaryngology, Committee on Hearing and Equilibrium (a history of cochlear hearing loss, recurrent spontaneous, rotational vertigo attacks longer than 20 minutes) and the International Headache Society criteria for migraine (throbbing, unilateral headaches, photo and phonophobia, nausea, and vomiting), with or without aura. Three hundred twenty-five patients were thereby included in this study. Patients had to use the prism lenses permanently over a 12-month period. After 1 year of WABIPS treatment, 43% of patients with Ménière disease and migraine experienced no migraine episodes (McNemar chisquare = 78, $p < .0001$).

Quantified Motion Illusion Strength Does Not Correlate With Daily Visual Discomfort in People With Migraine

Chongyue He, Bao N. Nguyen, Yu Man Chan and Allison M. McKendrick
The University of Melbourne, Australia

In between migraine events, increased susceptibility to self-reported visual illusions induced by high-contrast striped patterns has been used as an index of greater visual discomfort in people with migraine relative to controls. It is unclear how the mechanisms of visual illusion and visual discomfort are related. We quantified the strength of a contrast induced motion illusion (a variant of the Fraser-Wilcox illusion) with a two-alternative forced-choice task in 36 (16 with aura, 20 without aura) people with migraine and 20 headache-free controls. The illusory motion stimulus was injected with additional physical motion. Participants indicated the perceived direction of stimulus rotation. The physical motion speed that counterbalanced the illusory motion was quantified as the motion illusion strength. Daily visual discomfort was self-reported via questionnaire. Relationships between motion illusion strength, contrast discrimination threshold, and motion sensitivity were also investigated. On average, people with migraine with aura reported greater visual discomfort compared with controls ($p < .05$). Regardless of migraine status, motion illusion strength was negatively correlated with contrast discrimination threshold ($r = -.271$, $p = .04$) but not with any other measurements. Self-reported visual discomfort did not relate to quantified perceptual motion illusion strength.

Simple Reaction Time to Chromatic Stimuli in Patients With Hypothyroidism

Margarita Boyanova Zlatkova[1,2], Kalina Ivanova Racheva[1], Nadejda Bogdanova Bocheva[1], Roger Sproule Anderson[2], Tsvetalin Totev Totev[1] and Emil Slavev Natchev[3]

[1]Institute of Neurobiology, Bulgarian Academy of Sciences, Sofia, Bulgaria
[2]School of Biomedical Sciences, University of Ulster, UK
[3]Department of Endocrinology, Medical University Sofia, Bulgaria

Hypothyroidism causes a slowing of all processes in the body, including the visual system and affects the opsin production and nerve myelination. Patients with hypothyroidism have prolonged reaction time (RT) for achromatic stimuli but RT for chromatic stimuli has not been studied. We measured simple RT for chromatic spots, 4° in diameter, presented at 20° in temporal retina in patients with hypothyroidism and age-matched control groups. We used three contrast levels, multiples of the detection threshold. The chromaticity of the stimuli varied from white to 90°, 270°, 0°, and 180° in the isoluminant plane of DKL space, loosely called blue, yellow, red, and green. The results showed that RT in patients was significantly longer than controls ($p < .001$) under all conditions. The RT increase in the hypothyroid group was most pronounced for yellow stimuli, most notably at lower contrast (536 milliseconds for patients vs. 425 milliseconds for controls, $p < .001$). The RT increase was also contrast-dependent for blue stimuli ($p < .001$). These results indicate that hypothyroidism affects the temporal response for all colours tested, but especially yellow and blue. The contrast dependence of the RT increase in hypothyroid patients requires further consideration.

The Absence of the Visual Looming Illusion in Nonhearing People

Nicola Domenici[1,2], Alessia Tonelli[2] and Monica Gori[2]

[1]DIBRIS, University of Genoa, Italy
[2]Italian Institute of Technology, Genoa, Italy

Time perception is essential to interact with the environment and is strictly connected with attentional resources (e.g., more attention is paid to an event, more it appears to last longer). It has been shown that interval discrimination, in the milliseconds-to-seconds range, is sharpened by hearing, that also calibrates the other senses.Thus, an interesting question is what happens to the temporal perception of briefly displayed visual stimuli when the auditory information is absent as in deaf individuals. To answer this question, we tested a group of deaf and a group of normal hearing participants in a visual oddball-like paradigm. Participants had to discriminate the duration of a target presented as fourth in a sequence of five stimuli. In addition to changing the duration of the target, also the size gradually changed. Our results show that when the oddball encoded only temporal information (being static), deaf participants underestimated its duration. However, the time dilation normally elicited by looming oddballs—encoding both spatial and temporal information—was not experienced by deaf participants. This lack of time dilation suggests that, when hearing is not available, temporal perception is biased, but temporal accuracy can be linked to the properties of the stimuli themselves.

Increased Reliance on Vision During Grasping in Carpal Tunnel Syndrome

Michela Paroli[1], Simon J. Watt[1], Edwin P. Jesudason[2] and Kenneth F. Valyear[1]

[1]Bangor University, UK
[2]Ysbyty Gwyenedd, Bangor, UK

Healthy grasping is characterized by predictive movements, and relies not only on vision but also proprioception and touch. The hand shapes to match object properties "in flight," prior to object contact. Without visual feedback, the hand opens wider and moves slower, yet these compensatory changes are subtle, and skilful anticipatory control is maintained. Here, we investigate the

kinematics of grasping with and without visual feedback in patients with Carpal Tunnel Syndrome (CTS), a peripheral neuropathy caused by chronic compression of the median nerve. Patients with CTS suffer from pain, paraesthesia, diminished touch sensitivity, and impaired fine motor skills. We hypothesized that due to impoverished somatosensory feedback, CTS patients would show exaggerated compensatory changes when grasping without vision. Consistent with this hypothesis, CTS patients slowed their movements more than healthy controls when visual feedback was removed. Hand opening was not disproportionately affected by the removal of visual feedback in CTS, however, and anticipatory grip scaling was maintained. With vision available, CTS patients showed stereotypical grasp kinematics, indistinguishable from controls. Our results highlight the importance of both visual and non-visual signals in the skilful control of grasping and suggest that CTS patients increase reliance on vision to compensate for impaired somatosensory inputs.

Weaker Nonverbal Skills at 5 Years of Age Predict Need for Long-Term Educational Support in Very Preterm Children

Annika Lind[1,2], Anna Nyman[1], Liisa Lehtonen[3] and Leena Haataja[4]
[1]Department of Psychology, University of Turku, Finland
[2]Turku Institute for Advanced Studies, University of Turku, Finland
[3]Department of Pediatrics, Turku University Hospital, University of Turku, Finland
[4]Children's Hospital, Pediatric Research Center, University of Helsinki and Helsinki University Hospital, Finland

Difficulties in skills related to visual perception are common in prematurely born children. We report the predictive value of nonverbal functions at 5 years of age on the need for educational support at 11 years of age in very preterm children (birth weight $\leq$1,500 g and gestational age $<$32 weeks, $n = 141$) without neurodevelopmental impairments. At 5 years of age, neuropsychological functions were assessed with NEPSY II, and at 11 years of age, data on educational support services were collected using a questionnaire. Overall, performance in NEPSY II subtests predicted well a need for later educational support. Poorer scores in those NEPSY II subtests that were related to visual memory, visuomotor, and visual perception at 5 years of age were significantly associated with need for special education and studying on a grade below own age-group at 11 years of age. These results highlight the clinical importance of psychological assessment at 5 years of age in the follow-up of very preterm children and the relevance of visual perceptual skills on other abilities. Early identification of impairments or risk for difficulties enables developmental support in order to strengthen skills and prevent the development of associated or secondary problems.

Unfamiliar Face Processing in Williams Syndrome

Louise Alisar Ewing, Ines Mares, Emily K. Farran and Marie L. Smith
University of East Anglia, Norwich, UK

Researchers have suggested that atypical mechanisms may underpin the often reported strong face processing abilities in Williams syndrome (WS). Yet limited targeted research exists. Here, we investigate unfamiliar upright and inverted face-processing with a version of the "Telling Faces Together" task (Jenkins et al., 2011) that requires participants to differentiate within-person variability (different images of the same person) from between-person variability (different images of different faces). Performance of 16 adults with WS ($M = 28.8$ years) was contrasted with typically developing (TD) adults ($M = 20.4$ years, $N = 23$) and three TD child groups (6–7 years, $N = 32$; 8–9 years, $N = 30$; 10–11 years, $N = 39$). For upright faces, there was no significant difference in WS accuracy relative to the chronological age comparison group ($p = .53$), but a pattern of superior performance to all child groups ($p = .042$; $p = .078$; $p = .079$ respectively). By contrast, they showed a pattern of decreased performance for inverted faces relative to adults ($p = .029$) and two of the children's groups ($p = .09$; $p = .29$; $p = .09$). These results provide further support for strong face identity processing in WS, including direct evidence that this profile encompasses unfamiliar exemplars. Moreover, the dramatic drop in inverted performance suggests utilisation of specialised processing mechanisms tuned to the canonical orientation of faces, perhaps even more than in the typical population.

The Reward Value of Emotional Genuineness in Williams Syndrome

Ines Mares[1], Louise Ewing[2], Amy Dawel[3], Emily Farran[4] and Marie L. Smith[1]
[1]Department of Psychological Sciences, Birkbeck College, University of London, UK
[2]Department of Psychology, University of East Anglia, Norwich, UK
[3]Australian National University, Canberra, Australia
[4]University of Surrey, UK

Typical developing (TD) individuals are sensitive to the authenticity of emotional signals: capable of detecting subtle differences in facial expressions associated with

being "genuine" versus "posed." It is not known whether this sensitivity is present in another group of atypically developing individuals that experience social difficulties, that is, individuals with Williams syndrome (WS). This group is reported to show heightened social drive, speculatively linked to observed atypicalities in face processing. We used an economic key-pressing paradigm to measure the reward values associated with viewing faces expressing genuine or posed emotions (anger, happiness, sadness) in 16 adults with WS, 103 TD adults (similar in chronological age), and 129 TD children (6–13 years, similar range of cognitive ability). Results revealed elevated rewards for happy faces relative to angry and sad faces across all groups. TD children did not differentiate authenticity in their responses, TD adults showed a preference for genuine expressions across emotions, WS participants showed a selective preference for posed happy expressions. Subsequent emotion recognition checks revealed that WS participants experienced difficulties identifying/labelling sadness and anger. Like typical participants, individuals with WS find positive emotions more rewarding, and perhaps surprisingly, where they are sensitive to authenticity, they prefer posed (i.e., social) over genuine smiles.

The Functional State of Magnocellular and Parvocellular Visual Pathways in Depression

Irina Shoshina[1], Elena Isajeva[2], Julianna Mukhitova[2], Ilija Tregubenko[2] and Aleksandr Khanko[3]
[1]Pavlov Institute of Physiology, Saint Petersburg, Russia
[2]Pavlov First Saint Petersburg State Medical University, Russia
[3]St. Petersburg City Psychiatric Hospital No. 1, Russia

The aim of this study was to examine the functional state of magnocellular and parvocellular visual pathways and their interaction in depression. The magnocellular and parvocellular systems are differentially sensitive to spatial frequency. The magnocellular system is most sensitive to low spatial frequencies, the parvocellular system to high spatial frequencies. The study involved healthy participants and patients with depression. We measured visual contrast sensitivity thresholds in detection and comparison tasks (Gabor elements with spatial frequencies of 0.4, 3.6, and 17.8 c/deg were presented). We found that patients with depression are characterized by a decrease in contrast sensitivity in all ranges of spatial frequencies as compared with the mentally healthy. Thus, patients with depression demonstrate a decrease in sensitivity of the magnocellular and parvocellular systems. The problem of sensitivity of the magno- and parvocellular systems is not only theoretical but also of practical importance. The practical significance of this research lies in the development of methods of sensory rehabilitation. We propose to consider the functional state of magno- and parvosystems as a biomarker of psychotic condition.

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Alcohol Usage Predicts Holistic Perception: A Novel Paradigm to Explore Addiction

Thomas Wilcockson[1] and Edwin Burns[2]
[1]Loughborough University, UK
[2]Richmond University, VA, USA

Holistic perception is a special form of automatic and experience dependent processing that prioritises objects of interest through the visual system. We therefore speculated whether higher levels of alcohol consumption are associated with enhanced holistic perception for alcohol cues and reduced holistic processing for nonrewarding items. In our first experiment, we confirmed this hypothesis by showing that increasing regular alcohol usage was associated with greater holistic perception of alcohol but not nonalcohol, cues. We replicated this finding in a second experiment, but confirmed holistic perception was not predicted by experience with a specific drink but rather general alcohol usage. In our final experiment when alcohol images were absent from the task, higher levels of regular alcohol use predicted decreased holistic perception for nonrewarding cues. Increasing alcohol consumption is therefore linked to inverse alterations in holistic perception for alcohol versus nonalcohol cues, with the latter's effects context-dependent. We hypothesise that such inverse relationships may be due to limited cortical resources becoming reutilised for alcohol cues at the expense of other stimuli. Future work is required to determine holistic perception's role in maintaining addiction, its predictive value in successful abstinence, and its relationship with attentional biases.

Poster Session 6

Sensory Eye Dominance Plasticity Is Driven by Attentional Eye Selection

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

Very brief periods of monocular deprivation modify visual processing. For example, patching one eye for a few hours alters the interocular balance on binocular tasks, with the

previously patched eye becoming dominant once the patch is removed. However, it is not clear what drives this shift in eye dominance. Here, we compared changes in sensory eye dominance produced by three types of monocular patching in six adult participants with normal binocular vision. One eye was covered for 150 minutes using either an opaque patch, a translucent (i.e., Ganzfeld) patch, or an inverting prism that rotated the field by 180°. Eye dominance was assessed, immediately after removal, using a binocular rivalry tracking task. Our results showed that all three manipulations shifted dominance duration in favour of the treated eye and this effect decayed exponentially over 30 minutes. These results show that neither changes in luminance nor contrast are strictly necessary to drive shifts in ocular dominance, as both types of input are preserved in the prism condition. Instead, higher level visual processes, such as selective attention, may underpin changes in sensory eye dominance.

Motion Parallax Enhances Depth But Does Not Disambiguate the Hollow Face Illusion

Jayke Parish[1], Harold Hill[1] and Brian Rogers[2]
[1]School of Psychology, University of Wollongong, Australia
[2]Department of Experimental Psychology, University of Oxford, UK

The hollow-face illusion is a well-known example of three-dimensional depth inversion where we see a concave mask as a convex face. The impression of object movement, "following," when the observer moves is particularly striking. We tested whether motion parallax disambiguates depth using continuous ratings of convexity and reported following. For comparison, we also tested the effect of opening/closing one's second eye. For each trial, observers were positioned just past their "flipping" distance, the distance at which their perception changes between convex and concave. Opening a second eye decreased, and closing one eye increased, perceived convexity as expected. However, lateral movement increased convexity ratings of an initially concave percept with "following," consistent with a convex percept, reported after movement in 36/48 cases. Illusory faces were rated less convex but still "followed" in 45/48 cases suggesting they had not been disambiguated. There were no significant differences between observer and object produced parallax. The results show that motion parallax is less effective than binocular disparities in disambiguating the illusion and can make the concave mask more likely to appear convex. This suggests a convexity bias in the interpretation of ambiguous motion parallax information with no disambiguating effect of extra retinal cues.

No Effect of Eye-Dominance in Monocular, Inefficient, Visual Search

Martin Thirkettle and Rhys Finney
Sheffield Hallam University, UK

Better monocular performance with the dominant eye has been reported across a number of tasks including both feature and conjunction search (Shneor & Hochstein, 2006, 2008). However, recent research, using a reading task, found an advantage for binocular viewing, particularly at low contrast, and no advantage for the dominant eye when viewing monocularly (Johansson et al., 2014). Here, we investigated whether this absence of an ocular dominance effect would extend to visual search for nonmirrored letters among mirrored letters, a particularly inefficient search task (Wolfe, 2001). We measured eye dominance using two tests: a sighting eye dominance test and a sensory eye dominance test. Participants then completed the visual search task under binocular and monocular viewing conditions. In target-present and target-absent trials, we report significantly faster correct responses for binocular viewing, and we find no advantage for the dominant eye under monocular viewing. We also found no correlation between the different eye dominance measures, or between the degree of sensory dominance and any monocular performance asymmetry. Our results provide further evidence of the advantage of binocularity but suggest that the previously reported advantage for the dominant eye in visual search may not extend to all search tasks.

Perceptual Dominance in Face Rivalry Is Driven by Low-Level Properties

Lisa Koßmann[1], Claus-Christian Carbon[1,2] and Alexander Pastukhov[1,2]
[1]University of Bamberg, Germany
[2]EPÆG, Bamberg, Germany

Two superimposed semitransparent orthogonally oriented faces produce perceptual rivalry with one face being clearly perceived at a time and perception continuously switching between them. We investigated whether perceptual dominance of an individual face is determined by high-level properties, such as gender, age, or emotion, or low-level properties. To this end, we used 20 female and 20 male faces, aged 20 to 25 years, from the Chicago Face Database. They were randomly paired using a round-robin tournament schedule (eight blocks, 20 trials each). Participants viewed a face pair and continuously indicated which face they currently perceive via key presses. We computed two measures of face dominance, (a) as a proportion of trials in which it was the first face perceived at onset and (b) as a proportion of time it was dominant throughout the trial. An exploratory data analysis using linear mixed models

showed no systematic relationship between either of the two measures and high-level face descriptors, such as gender, age, or emotions (see https://osf.io/q2fjd). We conclude that in face rivalry, perceptual dominance is determined primarily by low-level features such as the size or relative width of the face, or salient local features such as birthmarks.

Bistable Photos Do Not Pop Out But Provoke a Prolonged Inspection

Malin Styrnal[1], Katharina Walther[1], Alexander Pastukhov[1,2] and Claus Christian Carbon[1,2]
[1]University of Bamberg, Germany
[2]EPÆG, Bamberg, Germany

Multistable perception is typically studied using artificial stimuli, such as Necker cube. However, there are many photos posted online that are visually incongruent or produce bistable perception. We compiled a set of 103 unusual looking photos plus a complimentary set of 309 unambiguous but visually similar photos that can be used to study multistability using more naturalistic stimuli (https://osf.io/xezny). During each of the 103 trials, four photos (one target, three controls) were presented in four quadrants in random order, while observers' gaze was monitored via an eye tracker. Observers were (a) asked to locate the target (unusual photo), (b) to categorize the chosen photo as either bistable or visually incongruent, (c) report their confidence, and (d) report whether they had seen that photo before. Only few photos were categorized as purely bistable or visually incongruent. However, participants were very consistent in identifying the part of the image that had the visual conflict. Although odd photos were not visited sooner than control ones, once participants' gaze landed on them, they were looked at for a significantly longer time than control photos. This indicates that visual conflict in naturalistic images is salient enough to retain attention and to command a prolonged inspection.

The Effect of Transcranial Magnetic Stimulation of the Right Inferior Frontal Cortex on Bistable Perception

Merve Fritsch, Veith Weilnhammer and Philipp Sterzer
Charité Universitätsmedizin Berlin, Germany

Conscious visual perception relies on inferring the causes of noisy and ambiguous visual input data. In bi-stable perception, presentation of an ambiguous stimulus leads to spontaneous switches in perception, which are known to correlate with activity in the right inferior frontal cortex (IFC). However, causality remains unclear. Repetitive transcranial magnetic stimulation (rTMS) allows to transiently inhibit a cortical structure to characterize its functional properties. We hypothesized that frequency of perceptual switches would be reduced after rTMS of the right IFC. We performed fMRI-neuro-navigated theta-burst rTMS over the right IFC in 15 healthy adults. Stimulation over the vertex was used as a control condition. Participants viewed ambiguous and nonambiguous versions of a rotating random-dot-kinematogramm before and after rTMS. Participants reported perceptual switches by button presses. Preliminary analyses showed a reduction in perceptual switch frequency after stimulation of the right IFC versus stimulation over the vertex. Our results suggest a causal involvement of the right IFC in bistable perception, thereby highlighting the role of the frontal cortex in conscious visual perception.

A Novel Tool to Study Prediction Error Processing in Bistable Perception

Anna-Lena Eckert[1,2], Veith A. Weilnhammer[1], Katrin Reichenbach[1] and Philipp Sterzer[1,3,4]
[1]Charité—Berlin University Medicine, Germany
[2]Einstein Center for Neurosciences, Berlin, Germany
[3]Berlin School of Mind and Brain, Berlin, Germany
[4]Bernstein Center for Computational Neuroscience, Berlin, Germany

In bistability, an individual's perception shifts between two mutually exclusive percepts. These shifts are not caused by changes in the stimulus and therefore offer a unique window into the nature of conscious perception. We argue that underlying perceptual processes follow the principle of Bayesian inference. Specifically, we assume accumulating prediction error signals that account for shifts in perception. Here, we test this notion in a novel paradigm based on graded ambiguity. $N = 10$ participants indicated the perceived direction of rotation of an ambiguous stimulus. Crucially, varying levels of additional sensory evidence were added to the stimulus array, thereby gradually disambiguating the stimulus' rotational direction. We conducted conventional and model-based analyses to assess the effect of sensory evidence on perceptual decisions. Perceptual decisions were more congruent with the sensory evidence as a consequence of decreased ambiguity. A one-way repeated measures analysis of variance suggested a main effect of sensory evidence on congruent perceptual decisions. The results of an additional random-effects Bayesian Model Comparison favor a model that incorporates a prior on perceptual stability and sensory evidence. Our results indicate that perceptual decisions are effectively modulated by graded ambiguity during bistable perception. This paradigm hence provides a novel tool to study conscious perception.

Modulation of Continuous Flash Suppression Depth by Spatial Attention

Guido Hesselmann[1], Philipp Sterzer[2] and Juliane Handschack[2]
[1]Psychologische Hochschule Berlin, Germany
[2]Charite Universitaetsmedizin Berlin, Germany

The debate about the scope and limits of unconscious visual processing under Continuous Flash Suppression (CFS) has created a heterogeneous landscape of findings that are yet to be reconciled. Attention has been suggested as an important factor in modulating the unconscious processing of visual information under CFS. Our study explored the dependency of conscious and unconscious object recognition, as well as the associated neural processing on visuospatial attention by using functional magnetic resonance imaging measurements ($N = 25$). In addition, we probed the suggested interplay between attention and semantic (numerical) priming effects in a behavioral experiment ($N = 29$). Our results provided no evidence of enhanced unconscious processing in the absence of visuospatial attention. However, we successfully replicated previous work showing that spatial attention enhances the encoding of visible object categories in visual cortex. Behavioral responses suggested a direct manipulation of object processing by visuospatial attention. Our priming experiment revealed a congruency effect for visible stimuli but not for invisible.

Steady-State Visually Evoked Potentials During Continuous Flash Suppression

Christian Valuch and Thorsten Albrecht
University of Goettingen, Germany

Continuous flash suppression (CFS) delays conscious perception of target stimuli presented to one eye by rhythmically presenting Mondrian masks to the other eye. To which extent invisible targets are processed during CFS is hotly debated. We used steady-state visually evoked potentials (SSVEP) in the electroencephalogram (EEG) as an electrophysiological marker of stimulus processing. We presented low- or high-contrast masks at a frequency of 10 Hz to the participants' dominant eye. To the nondominant eye, we presented left- or right-oriented sinusoidal gratings as targets. Targets flickered at 4.55 Hz or 7.14 Hz. Participants reported the target orientation as soon as they could discriminate it. Occipital EEG yielded mask SSVEPs at 10 Hz, which were larger with high-contrast than low-contrast masks, and target SSVEPs at either 4.55 or 7.14 Hz, depending on which target frequency was presented. Interestingly, target SSVEPs were reduced when they were accompanied by high-contrast compared with low-contrast masks. The neural effects were paralleled by differences in behavioral response times, suggesting a close link between early visual processing and conscious perception. Nevertheless, target SSVEPs partly preceded the behavioral response, possibly reflecting residual processing of invisible targets. We also discuss the potential use of our method for studying attentional effects during CFS.

The Extent of Unconscious Semantic Processing Under Continuous Flash Suppression

Wei-Chen Chang[1], Su-Ling Yeh[2,3,4,5] and Shwu-Lih Huang[1,6]
[1]Department of Psychology, National Chengchi University, Taipei
[2]Department of Psychology, National Taiwan University, Taipei
[3]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taipei
[4]Neurobiology and Cognitive Science Center, National Taiwan University, Taipei, Taiwan
[5]Center for Artificial Intelligence and Advanced Robotics, National Taiwan University, Taipei, Taiwan
[6]Research Center for Mind, Brain, and Learning, National Chengchi University, Taipei, Taiwan

Whether semantic information can be processed unconsciously during continuous flash suppression (CFS) remains hotly debated. We investigated whether and to what extent semantic information can be processed under CFS via manipulating the semantic congruency between an invisible prime and a subsequently presented visible target. The meaning of the prime was related to either coldness or warmth and it was presented simultaneously with a high-contrast dynamic mask to one of each eye. In Experiment 1, both the prime and target were words semantically related or unrelated to temperature. Participants had to discriminate whether the target word was warmth or coldness and their reaction times (RTs) were recorded. Results showed slower mean RTs in the congruent than the incongruent condition, suggesting a reversed priming effect. The target was then replaced with illustrations of cold and warm scenes (Experiment 2) or conceptually related words describing personalities (Experiment 3). Results showed no difference in RTs between the incongruent and congruent conditions. These results delineated the boundary conditions of semantic processing under CFS: Word meanings can be registered and accessed if they belong to the same category, but not when the prime and target activate different forms (e.g., word vs. illustration) or different concepts.

CFS's Nonrivalrous Binocular Control Condition Fails to Resemble CFS

Florian Johannes Kobylka, Malte Persike and Günter Meinhardt
Johannes-Gutenberg University, Mainz, Germany

To infer continuous flash suppression (CFS)-specific unconscious processing, it is common to compare effects between CFS and a non-CFS (binocular, monocular or weak dichoptic) control, assuming comparable phenomenal experience in both conditions. The quality of CFS resemblance in the control condition was tested by a two-alternative forced-choice task in which subjects had to identify the presented condition (CFS or control). For both conditions, contrast values corresponding to four levels of localization performance (from 62% to 95%) were determined in a separate task. Generally lower contrast values in the control condition led to shorter presentation durations, which can be used as decision criterion. To rule out this factor, contrast change rate was decreased in half of the control condition trials, resulting in equal presentation durations in both conditions. When controlled for differences in presentation duration and contrast change rate, subjects were able to distinguish CFS from the control condition as soon as localization was possible. These results underpin the speculation that it might not be possible to fully mimic the subjective perception during CFS, rendering dissociation logic inappropriate for drawing conclusions about CFS-specific unconscious processing.

Does the Processing of Preexisting Congruency Associations Need Awareness During CFS?

Weina Zhu[1], Chaoyuan Luo[1], Aoyun Zong[1] and Jan Drewes[2]
[1]School of Information Science, Yunnan University, Kunming, China
[2]Physics of Cognition Group, Chemnitz University of Technology, Germany

It has been shown that some high-level visual processing may occur without conscious awareness. We aimed to investigate whether the preexisting association of semantic congruency between objects and backgrounds in natural scenes can be processed without awareness. By conducting experiments with and without continuous flash suppression (CFS), we examined whether the preexisting association of congruency affects target recognition and response time. In Experiment 1, a background image (natural/manmade environment) as cue was presented before the target image (animal/vehicle). The target was either congruent or incongruent with the background. Participants were not informed about the relationship between cue and target and were asked to decide between animal or vehicle by pressing one of two buttons as quickly as possible. In Experiment 2, we used CFS to suppress awareness of the target, which could be either congruent or incongruent with the background cue presented before the CFS onset. Without CFS, response times (1,370 milliseconds) of target recognition with congruent backgrounds were significantly faster than with incongruent backgrounds (1,419 milliseconds), but there was no significant difference under CFS conditions (2,427 vs. 2,463 milliseconds). The results show that the preexisting association of semantic congruency accelerated target recognition; however, under CFS conditions, this effect was apparently erased.

Comparing Faces and Face Pareidolia Images in Breaking Interocular Suppression

Liu-Fang Zhou, Man Zhang, Chunfu Yang and Ming Meng
South China Normal University, Guangzhou, People's Republic of China

Faces are everywhere and humans excel at face perception. Interestingly, face pareidolia occurs when nonface images trigger illusory face perception. It remains unknown what mechanism may underlie face pareidolia. To address this issue, we examined how fast upright and inverted faces versus face pareidolia images breakthrough continuous flash suppression (CFS). Comparable nonface images that do not trigger pareidolia were also tested for comparisons. In our CFS study, test images were gradually presented to one eye to compete against a high-contrast dynamic Mondrian pattern presented to the other eye. Participants ($n = 29$) were asked to respond as soon as they detected test image. We found that upright faces break CFS faster than inverted faces, replicating previous studies. More interestingly, the inversion effect in breaking CFS is significantly larger for faces than face pareidolia images. The face inversion effect is known to indicate holistic representation of faces. Given that participants were unaware of the test image until it broke CFS, the significant interaction (Inversion $\times$ Image Types) suggests that unlike the holistic representation of true faces, face pareidolia may not automatically occur until the image is represented to the awareness level. Further studies should examine how face pareidolia may occur after awareness representation.

Lateralization of Behavioral Oscillations in Conscious and Unconscious Face Processing

Mengjin Li, Bingbing Guo, Ling He, Shuai Chang and Ming Meng
South China Normal University, Guangzhou, People's Republic of China

Ample evidence supports that the right hemisphere is dominant in processing face and therefore participants often have a left visual field face perception bias. Using visual priming paradigms in combination with a time-resolved behavioral measurement, we investigated the visual field bias in face processing when the prime face was visible (conscious) and invisible (unconscious). In two experiments, a prime face or house in the center of the screen was visible or invisible to participants by using continuous flash suppression, and participants were asked to detect a congruent versus incongruent target that was presented at either right or left visual field. Moreover, we varied the prime-to-target stimulus onset asynchronies from 20 to 800 milliseconds in steps of 20 milliseconds to measure fine-scale temporal dynamics. Behavioral oscillations were found in congruent versus incongruent conditions. More interestingly, we found a left visual field bias at 3 to 4 Hz for visible prime conditions to detect face target and at 6 to 7 Hz for invisible prime conditions. By contrast, no visual field bias was found for detecting house target. These results reveal fine-scale temporal dynamics of left visual field face bias. The behavioral oscillation effects in both visible and invisible prime conditions further suggest intrinsic face processing mechanism lateralized to the right hemisphere.

Does Audiovisual Interaction Boost Subjective Visual Awareness?

Matilda Cederblad, Juho Äijälä, Leah Lousaing, Søren Andersen and Arash Sahraie
University of Aberdeen, UK

The Redundant Target Effect (RTE) refers to the speeding of a response for detection of multiple targets compared with a single target. We have previously shown that visual awareness was a prerequisite for RTE in unimodal presentations in healthy adult participants. Evidence from an audio-visual paradigm (multimodal) has indicated that presentation of an auditory signal can boost an unseen visual stimulus into awareness. We have conducted two experiments to explore these phenomena. In Experiment 1, we measured manual reaction times to a suprathreshold visual targets that was sometimes accompanied by a subthreshold visual target and an auditory beep. Similar to previous studies, we found visual awareness to be necessary for RTE. However, we found only anecdotal evidence for boosting of visual awareness in multimodal compared with unimodal presentations. In Experiment 2, we masked the presentation of a single visual target by using continuous flash suppression such that its presence may or may not be detected on a trial by trial basis. The visual stimuli were also accompanied by an audio beep in half of the presentations. Here, we found stronger evidence for combined multisensory stimulation leading to increased awareness. The findings will be discussed in relation to multisensory gain and subjective bias.

The Dependence of the "Vertical-Horizontal" Illusion on the Orientation of the Illusory Figure

Dejan Todorović
University of Belgrade, Serbia

The arguably simplest strong visual illusion is induced by a figure in the form of an inverted-T: It consists of two equally long straight-line segments, but the vertical/dividing line looks longer than the horizontal/divided line. There are two potential factors of this effect, orientation and division, and one way to disentangle them is to rotate the whole figure, thus varying orientation but keeping division constant. Seven orientations between 0° and 90° were used, in 15° increments. For each orientation, a row of nine stimulus figures was presented in which the divided line was constant but the dividing line increased or decreased in 5% increments. Subjects had to choose the figure in which the two lines looked equally long. For every orientation, the dividing line in the average chosen figure was physically shorter than the divided line. However, the strength of the illusion depended on angle, decreasing steadily from 16.8% at 0° (when the dividing line was vertical) to 6.6% at 90° (when the dividing line was horizontal). The illusory effect at 45°, equal to 11.0%, may be exclusively attributed to division, because at this angle, both segments were oriented diagonally, midway between horizontal and vertical.

Does Tool-Use Modulate the Perceived Size of an Afterimage During the Taylor Illusion?

Charlotte Grove[1], Lucilla Cardinali[2] and Irene Sperandio[1]
[1]University of East Anglia, Norwich, UK
[2]C'MoN Cognition, Motion and Neuroscience Unit, Istituto Italiano di Tecnologia, Center for Human Technologies, Genoa, Italy

The Taylor illusion is a multimodal phenomenon in darkness, whereby an afterimage of the hand induced by a brief flash of light appears larger when the hand is moved away from the participant's eyes and smaller when it is moved closer. Previous research has demonstrated that proprioceptive cues from the arm contribute to this effect. Here, we aimed to demonstrate whether the somatosensory representation of the arm can also act as an extra-retinal cue and affect the Taylor Illusion. This somatosensory representation can be temporarily modified by tool-use. The perceived size of afterimages during the Taylor illusion was measured before and after participants were trained with a long tool, in order to induce morphological changes in the mental representation of arm length. Our results suggest an effect of tool-use on the strength of the Taylor illusion, whereby changes in perceived afterimage size were greater when participants experienced an increase in length of their arm as a consequence of tool-use. These findings provide novel evidence that size perception can be modulated by multisensory information that originates from the body schema.

Learning to See the Titchener Illusion in the Periphery: Evidence for Calibration of Size Perception Under Fixed Sensory Input

Cécile Eymond[1], Tal Seidel Malkinson[1] and Lionel Naccache[1,2,3]
[1]Inserm U 1127, CNRS UMR 7225, Brain & Spine Institute (ICM), Sorbonne Université, Paris, France
[2]Department of Neurology, AP-HP, Pitié-Salpêtrière—Charles Foix Hospital, Paris, France
[3]Institute of Translational Neuroscience, IHU-A-ICM, Paris, France

In general, objects appear slightly smaller in the periphery compared with the fovea (Newsome, 1972). Is this perceptual ratio stabilized to ensure coherent size perception across the visual field? In separate sessions, participants first evaluated the peripheral and foveal apparent sizes of a disk altered by the Titchener illusion. With surrounding larger disks, the classic reduction effect was observed only in the fovea. Surprisingly, in the periphery, the disk was perceived as large as in the fovea, deviating from the expected periphery/fovea perceived size ratio. We then tested whether the peripheral apparent size of the Titchener stimulus could be calibrated. We adapted a procedure in which changing an object's physical size when viewed foveally calibrates accordingly its peripheral perceived size (Valsecchi & Gegenfurtner, 2016). In each trial, with the stimulus' size maintained fixed, participants first evaluated the stimulus' peripheral apparent size, then made a saccade toward it. Across trials, participants' peripheral perceived size decreased, now corresponding to the classic illusory effect. In a control condition without saccades, the peripheral appearance remained unchanged. The emergence of the Titchener illusion in the periphery suggests that top-down signals may adjust peripheral size perception to match the expected periphery/fovea ratio, thus supporting perceptual stability.

No Correlation Between the Muller-Lyer Illusion and the Size-Distance Illusion: The Limited Applicability of the Misapplied Size-Constancy Scaling on Geometrical Optical Illusions

Shuichiro Taya
Keio University, Tokyo, Japan

The concept of "misapplied size-constancy scaling" is well known and frequently introduced in textbooks, but there is much controversy about which geometrical illusion can be explained with this concept. In this study, I measured the effect of apparent distance on perceived size (i.e., the magnitude of the corridor illusion) as a "benchmark" for individual differences in the strength of size-constancy scaling and examined to what extent the constancy scaling contributes to geometrical illusions by calculating the correlation between the "benchmark" and the magnitude of each illusion. In the experiment, the strengths of the Muller-Lyer illusion (MLI), the Ponzo illusion (PNZ), the Poggendorff illusion (PGD), the Kanizsa shrinkage illusion (KZS) and the corridor illusion (CDI) were measured with the method of adjustment. The results from 64 participants showed that the magnitude of CDI was significantly correlated with those of PNZ and PGD ($r = .53$, and $r = .45$, respectively) but was not correlated with MLI or KZS. The result of a principal component analysis suggests that the CDI, PNZ, and PGD share a common factor. The current findings indicate that, contrary to popular belief, different mechanisms are mainly responsible for MLI and PNZ.

Early Predictors of Psychosis Risk Relative to Multisensory Disruption in the Flash Tap Illusion: An Electroencephalography Investigation

Francesca Fotia[1], Francesca Ferri[2], Vincenzo Romei[3] and Jason Cook[1]
[1]University of Essex, UK
[2]University of Chieti, Italy
[3]University of Bologna, Italy

Successful integration of multisensory stimuli depends on the temporal coincidence of different stimuli occuring within a set time frame, known as the temporal binding window (TBW). Previous research showed somatosensory timing deficits and enlarged TBW in schizophrenia. Here, we used the tactile-induced Double-Flash-Illusion phenomenon (tDFI, the perception of a second illusory flash) to investigate the somatosensory-visual TBW in relation to schizotypy, a personality trait linked to characteristics observed in schizophrenia. Participants were always presented with one visual flash and two tactile taps to the index finger at various delays from the flash. They reported whether one or two flashes were perceived. The intertap delay at which the percept switches from two to one flash is indicative of the TBW. Moreover, we measured EEG oscillations within the beta band, shown to correlate with the tDFI. We found individuals with higher schizotypal traits to have wider TBWs and slower beta waves accounting for the TBW within which they perceive the illusion. These results indicate a potential link between reduced temporal sensitivity and slow oscillatory beta activity. Furthermore, it suggests that the TBW might constitute a reliable early marker for psychosis risk and this might represent a further step toward early prognostic approach.

The Tail of the Barn Swallow: Does White Spot Stretching Affect Its Perceived Length in Humans?

Daniele Zavagno[1], Damiano Avanzi[1] and Nicola Saino[2]
[1]University of Milano-Bicocca, Milan, Italy
[2]University of Milano, Milan, Italy

Several studies showed that male barn swallows (Hirundo rustica, BS) with particularly long tails enjoy many advantages in sexual selection. BS tails present white spots that vary in length, and variation is directly proportional to tail's length. Spots may be a cue for females when choosing their partner. Do they affect the perception of tail length? Given the difficulty in testing the hypothesis on the female of the species, and given the evidence that some nonhumans species (like pigeons) can perceive optical illusions, the aim of the study was to test on humans the effect of white spots on the perception of BS tail length. By digitally modifying the image of a half BS tail, we created four different stimuli: original tail with original spots, original tail with stretched spots (30% longer), shortened tail (2% shorter) with original spots, and shortened tail with stretched spots. Thirty people participated to a paired comparison forced-choice task experiment in which they were asked to indicate which of two tails was longer. Participants were exposed to 12 pairs presented 10 times in random order. Results show that the extension of the white spots has no effect on tail length perception in humans.

Cognitive and Temperamental Determinants of Susceptibility to the Ponzo Illusion

Magdalena Przedniczek and Hanna Bednarek
SWPS University of Social Sciences and Humanities, Warsaw, Poland

The purpose of the study was to define structures of connections between the cognitive and temperamental factors as predictors of susceptibility to the Ponzo illusion. While the cognitive predictors of visual illusions have been widely researched, the temperamental ones have not been studied so far. Among the cognitive predictors, we analyzed cognitive style FDI (EFT, Witkin), attention networks: alerting, orienting and executive control (ANT, Posner), and mechanism of inhibition and updating of information processes in WM (n-back, stop signal paradigm). The temperamental determinants of the Ponzo illusion were tested for/FCB-TI/(Strelau). In sum, 170 participants (93 women) aged 20 to 33 years ($M = 24.75$; $SD = 3.29$) participated in the study. The results showed that susceptibility to the Ponzo illusion is associated with FD cognitive style. The relationship between the efficiency of cognitive control and attention networks, and susceptibility to the Ponzo illusion is moderated by temperament traits: briskness and activity. The results confirm the role of individual differences in susceptibility to the Ponzo illusion.

Completeness of a Circle Promotes Flash-Induced Shape Distortion Illusion

Kenzo Sakurai
Tohoku Gakuin University, Sendai, Japan

A visual shape distortion illusion that circles turn into polygons (e.g., hexagons) can be induced in a short period by alternating circles and their blurred patterns (Sakurai, 2014, 2016; Sakurai & Beaudot, 2015). One possible account for this illusion is that less curved outputs of adapted curvature detectors produce apparent polygons (Sakurai, 2018). To extend these studies, we investigated

whether completeness of a circle would be required of this shape distortion illusion. The latencies of the distortion illusion for incomplete circles (e.g., a semicircle) were measured. Stimuli consisted of black line-drawings of a complete circle (360°) and incomplete circles (300°, 240°, 180°, 120°) 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 latencies of shape distortion illusion for incomplete circles were longer than that for a complete circle. This suggests that completeness of a circle promotes the shape distortion illusion.

Dazzle Camouflage Can Cause a Misperception of Ship Direction That Could Cause Torpedoes to Miss Their Targets

P. George Lovell[1], Rebecca J. Sharman[1], Andrew Brown[1] and Tim S. Meese[2]
[1]Abertay University, Dundee, UK
[2]Aston University, Birmingham, UK

During World War 1, ships were painted in contrasting "dazzle" patterns designed to mislead submariners about their speed and heading. In the early part of the war, the biologist Graham Kerr lobbied the head of the admiralty (Winston Churchill) to adopt a parti-coloured scheme inspired by animal colouration. This was tested and subsequently abandoned. Later, Norman Wilkinson suggested that ships should be painted with highly contrasting geometric patterns, inspired by cubist painters. Following the war, a court hearing found that Wilkinson should receive credit for developing ship camouflage. Admiralty research found little evidence of increased survival for either sort of colouration, though ship-camouflage was good for morale. In this study, we reconstruct both types of camouflage and assess participants' judgements of ship direction (bearing) under varied pattern-contrast and viewing distances. For the first time, we find strong effects of dazzle camouflage upon judgements of bearing, average errors were 10° at a 1 km viewing distance for dazzle camouflage resembling that deployed on the Mauretania. This could have resulted in a 15% reduction of torpedo hits. Errors were smaller for particoloured ships (based upon the HMS Argonaut) and in the opposite direction (−4°). Thus, dazzle camouflage can cause torpedoes to miss their targets.

Tucking in Your Shirt Makes Your Body Look Slimmer and Your Legs Look Longer: Psychophysical Measurements of Illusions Caused by Clothing

Akitoshi Tomita, Kyoka Saito and Kazunori Morikawa
Osaka University, Suita, Japan

Clothing takes advantage of visual illusions to make the wearer look slimmer or better-proportioned (Morikawa, 2017). However, there have been very few scientific studies that measured such illusions. We investigated visual effects of tucking in shirts psychophysically, using the staircase method. The standard stimuli were realistic computer graphics human models wearing a shirt and a skirt (either black or white), with the shirt either tucked in or untucked. The comparison stimuli were the same person wearing gray full-body tights. In Experiment 1, the bust, waist, and hip measurements of the comparison stimuli were varied in steps of 2 cm. Participants' task was to estimate the unclothed torso shape and choose the stimulus that appeared slimmer than the other. The result showed that the "tucked-in" stimuli appeared significantly slimmer than "untucked." Also, black clothing looked significantly slimmer than white clothing. In Experiment 2, the leg length of the comparison stimuli were varied in steps of 1 cm, and participants' task was to choose the stimulus that appeared to have longer legs than the other. The result demonstrated that the legs of the "tucked-in" stimuli looked 7 cm longer than "untucked." The mechanism and implications of these illusions are discussed.

Assessment of Lenses Designed for Mesopic Vision

Pablo Concepcion, Marta Alvarez, Melisa Subero, Eva Chamorro, Jose Miguel Cleva and Jose Alonso
IOT, Madrid, Spain

The optical industry has recently brought to the market lenses designed to optimize night driving vision, that is to say, under mesopic lighting conditions. These lenses are characterized by a progression profile with a slight underpowered region above the fitting cross. In this study, we analyse the performance of these lenses in patients in which a negative defocus in distance vision produces an improvement/decrease of mesopic visual acuity (VAm). For that, the study comprises two parts. First, VAm with ±0.25D defocus is evaluated in 52 subjects after 15-minute darkness adaptation. Results showed that 17% of patients improved and 19% decreased their VAm. In a second step, participants were asked to use standard lenses and lenses optimized for night vision for 7 days each and rate their satisfaction (scale 1-5). Users under

45 years of age tested single-vision lenses and those over 45 tested progressive addition lenses. Results showed that lenses specifically designed to optimize night vision provided significantly better satisfaction than standard lenses ($p = .001$), mainly due to those patients in which VAm improved with an induced negative defocus ($p = .002$) and patients whose VAm did not change under ± 0.25D defocus ($p = .002$).

Parafoveal Contrast Sensitivity for a Continuous and Discontinuous Radial Stimulus Under Mesopic Conditions

João Lourenço, Jeannette Ngadjeu, Stephanie Mroczkowska and Luis Garcia-Suarez
University of Plymouth, UK

Age-related macular degeneration (AMD) shows signs of parafoveal rod dysfunction and a decrease in contrast sensitivity, which is heightened when assessed under dim light levels. This study assesses parafoveal mesopic contrast sensitivity and, indirectly, rod summation in healthy young subjects under three light levels (10, 1, and 0.1 cd/m^2). A "C" shape stimulus of 7.5° radius and 2° width was centrally presented on a calibrated CRT monitor. A continuous "C" and two discontinuous "C" with discontinuities of 0.3° and 0.5° were used. The discontinuity sizes were chosen to be below and above the rod areal summation value (0.4°), respectively. Contrast detection thresholds were measured for four healthy participants. They had to indicate, using a 4AFC task, where the stimulus main gap was displayed (top, bottom, left, or right position). Thresholds were estimated with a QUEST adaptive staircase method and averaged from three repeats. Although the continuous stimulus provided the best performance at every light level, findings showed similar performance at 10 and 1 cd/m^2 for both discontinuous "C" stimuli, but at 0.1 cd/m^2, thresholds were lower for the 0.5° discontinuous stimulus. This suggests an increase of rod output and might be used in AMD subjects to confirm possible rod dysfunction.

Metacontrast Masking in the Hierarchy of Visual Processing: Effects of Light Adaptation Level and Assessment Through Contrast Response Functions

Tomke Trussner and Thorsten Albrecht
Department of Experimental Psychology, University of Göttingen, Germany

In metacontrast masking, the visibility of a briefly presented target stimulus is reduced by a subsequent masking stimulus, which is presented in close spatiotemporal proximity. Although this phenomenon is known for more than a century, the functional localization within the hierarchy of visual processing is still debated. In our study, we investigated the influence of very early visual processing on masked target discrimination performance. To this end, we assessed contrast response functions (CRF) for metacontrast masked stimuli under different stimulus onset asynchronies (SOA) and different light adaptation levels of the visual system. Results show stronger masking effects under dark adaptation than under light adaptation for low to intermediate target luminance but a slightly reversed effect at the highest target luminance. Regarding the CRFs, we found clearly nonlinear CRFs under dark adaptation compared with a relatively more linear CRFs under light adaption. Regardless of the level of light-adaptation, CRFs became more and more nonlinear with increasing SOA. Overall these findings suggest a crucial role of magnocellular pathways in metacontrast masking. In addition, masking effects may arise on different levels of the visual hierarchy for different SOAs. Implications of our findings for theories of visual masking are discussed.

Biases in Brightness Assessment Procedures

Laurens Van de Perre[1], Marc Dujardin[2], Peter Hanselaer[1], Kevin Smet[1] and Wouter Ryckaert[1]
[1]Light & Lighting Laboratory, ESAT, KU Leuven, Ghent, Belgium
[2]Faculty of Architecture, KU Leuven, Ghent, Belgium

Determining the relationship between the luminance of a stimulus and its perceived brightness is crucial in several domains such as road signage, colour-appearance-modelling, lighting design and visual perception in general. Several psychophysical procedures exist to capture such relationship. One of the oldest, although nowadays rarely used, procedure is partition scaling. The observer is presented with two stimuli having luminance values equal to the minimum and maximum of the investigated luminance range. The observer adjusts the brightness of a third stimulus such that two perceptually equally brightness intervals are created, which can be further partitioned into smaller intervals. Finally, an interval scale is constructed directly from the observer judgments. One of the most commonly used procedures for brightness evaluation is magnitude estimation. The observer is presented with a reference and test stimulus and gives a numeric response matching the ratio of the perceived brightness of the test and reference stimuli. Despite being a simple procedure, it requires prior knowledge of the magnitude function in choosing the test stimuli luminance values. Literature indicates that psychophysical procedures can suffer from several biases such as range-, order- and centring

bias. In this work, both methods are compared on robustness and susceptibility to possible biases.

Does Our Pupil Size Influence Subjective Brightness Perception?

Intan Kusuma Wardhani[1,2,3], Sebastiaan Mathôt[3] and Nico Böhler[1]
[1]Ghent University, Belgium
[2]University of Oslo, Norway
[3]University of Groningen, the Netherlands

Our pupil responds to light influx from our surrounding by changing its size. Changes in our pupil size, however, do not make us perceive the world as brighter or darker. There are many indirect cues in our environment (e.g., light intensity, same brightness of other objects or the background) that support brightness constancy. The question of our study was whether changes in pupil size influenced our subjective brightness in the absence of such indirect cues. Two experiments were performed to test how participants judged the brightness of a tester stimulus relative to a referent stimulus following a manipulation for their pupil size. In Experiment 1, we manipulated pupil size by inducing a secondary task with different memory loads (i.e., larger pupils in higher load). In Experiment 2, we presented a red or a blue stimulus (i.e., red light induced larger pupils than equiluminant blue light). In both experiments, we found that the tester stimulus was perceived as darker when pupils were large. We surmised that this was due to a strong association between large pupils and darkness. However, more studies with different methods are needed to confirm our findings.

Reading Deficits in Posterior Stroke: Associated Deficits and Cerebral Basis

Sheila Kerry[1], Grace Rice[2], Ro Robotham[3], Matt Lambon-Ralph[2], Alex Leff[1] and Randi Starrfelt[3]
[1]University College London, UK
[2]University of Cambridge, UK
[3]University of Copenhagen, Denmark

Pure alexia (PA) is a disorder of reading in the context of preserved language capabilities. The hallmark symptom of PA is a word length effect (WLE), an abnormal increase in reading RT with increased word length (number of letters). While PA is typically associated with damage to the left fusiform, the neural correlates are still debated. Furthermore, questions remain about how "pure" PA is, that is, whether it is a selective reading deficit, or if it is associated with milder deficits in recognition of faces or objects. We present data on 65 participants with lesions affecting the posterior cerebral artery territory. All participants completed a battery of reading and writing test, including single word reading with varying word lengths, text reading, irregular and regular word reading, and single word writing. In addition, tests of face and object processing were completed, and lesions were characterised using structural MRI. Preliminary analysis indicates that 27 participants demonstrate a significantly elevated WLE and impaired word reading compared with controls. These participant's performance on writing and face recognition test will be investigated. Associations between performance on the reading battery and the brain lesions of these participants will also be explored.

Similar Incidences of Face and Word Recognition Deficits in Patients With Left and Right Posterior Stroke

Ro J. Robotham[1], Sheila Kerry[2], Grace Rice[3], Alex Leff[2], Matthew Lambon Ralph[3] and Randi Starrfelt[1]
[1]University of Copenhagen, Denmark
[2]Institute of Cognitive Neuroscience, University College London, UK
[3]MRC Cognition and Brain Sciences Unit, Cambridge University, UK

Face and word processing have traditionally been thought to rely on highly lateralized cognitive processes, with face processing relying more heavily on the right and and word processing more on the left hemisphere. This builds on evidence from neuropsychological case studies of patients with pure alexia and pure prosopagnosia, as well as functional imaging data. The aim of this study was to investigate the lateralisation of face and word processing in patients with posterior cerebral artery stroke selected purely on the basis of lesion localisation. In sum, 58 patients and 31 controls were tested with the WOF test, a novel paradigm assessing face, word and object recognition, as well as with the Cambridge Face Memory Test and a reading-out-loud task. For most conditions of the WOF test and for the CFMT, there was no significant difference between the left and right hemisphere patient groups. Also, the proportion of patients in each group with face recognition deficits and visual word processing deficits, respectively, did not differ significantly. In the reading-out-loud task, however, the left hemisphere group performed significantly worse than the right hemisphere group. This suggests that face and word processing may be supported by processes that are more bilaterally distributed than previously thought.

Face Processing Abilities in High School Students With Severe Developmental Dyslexia

Christina Kühn[1], Kristian Bjerre Andersen[1], Christian Gerlach[1] and Randi Starrfelt[2]
[1]Department of Psychology, University of Southern Denmark, Odense, Denmark
[2]Department of Psychology, University of Copenhagen, Denmark

Recent studies indicate that adults with developmental dyslexia also show deficits in face processing. These deficits may be subtle, and the majority of participants in previous studies have been university students. We report a study of face processing in a group of young dyslexics ($N = 25$, age 18–23 years) enrolled in a high school education specifically designed for people with severe dyslexia and 25 matched controls. We test whether face processing deficits are also evident in this group of young participants with severe dyslexia. We report here data from the Cambridge Face Memory Test (CFMT) and a lexical decision task. Comparing dyslexics to controls, we find: (a) participants with dyslexia are impaired in lexical decision (as expected on a reading test) and (b) on the CFMT, some dyslexics perform poorer than controls, while others perform well within the normal range. Thus, while we find a greater variability of face recognition performance in the dyslexics compared with controls, the performance of individual participants suggests a dissociation between impaired reading and preserved face recognition.

Featural and Configural Processing of Faces and Houses in Matched Dyslexic and Typical Readers

Bahareh Jozranjbar[1], Árni Kristjánsson[1,2] and Heida Maria Sigurdardottir[1]
[1]Department of Psychology, University of Iceland, Reykjavík, Iceland
[2]Faculty of Psychology, Higher School of Economics, National Research University, Moscow, Russia

Previous research shows that regions of the left ventral stream are hypoactive in dyslexic readers. Accordingly, recent evidence suggests that dyslexic readers are poorer than typical readers at recognizing faces and other complex objects. This is surprising as dyslexia is rarely considered to be a disorder of visual cognition. Word and face recognition, in particular, are often considered to be supported by distinct processes, but there is some evidence that faces and words are processed in overlapping brain regions. Word recognition nonetheless relies heavily on featural processing, in which the left hemisphere might excel, while the right hemisphere is more involved in configural processing, often important for face recognition. Both processes might nonetheless be of some use for all objects. This study investigated whether dyslexic readers are at a disadvantage when it comes to featural vs. configural processing and whether this is specific to certain object classes. Dyslexic readers found it harder to recognize houses both featurally and configurally relative to matched controls, but featural and configural processing of faces appeared intact. Our results seem inconsistent with an impairment in featural processing but consistent with the proposal that people with dyslexia also suffer from specific object recognition problems.

EEG-Neurofeedback Effects in Children With Developmental Dyslexia

Ivan Milenov Hristov, Tsvetalin Tovev, Stefan Alipiev Tsokov and Juliana Alexandrova Dushanova
Institute of Neurobiology, BAS, Sofia, Bulgaria

The electrophysiological neurofeedback (EEG-NF) could be used for treating brain and behavioural disturbances. The dyslexics can be examined through their task-related EEG-frequency anomalies revealed through alpha/theta oscillations during visual attention. The alpha/theta amplitude-ratio can be used as an attentional deficit indicator. Our aim was to evaluate the EEG-NF effects on frontal, temporal, parietal, and occipital alpha/theta amplitude-ratio in dyslexic children before and after training and compared with control groups. The children with and without developmental dyslexia had to discriminate the contrast differences between sinusoidal-gratings perturbed by white noise in two tasks: one with a spatial frequency 2 c/deg, the other with the doubled frequency illusion. When participants showed brain activity pattern with alpha/theta ratio>1 during the stimulus onset the NF-signal was presented as a green cross after stimulus offset and turned red if the ratio was <1. NF-altered alpha/theta ratio in dyslexics after training became more pronounced in the left hemisphere, similar to controls. In both groups, the inferior and middle temporal areas showed more often maximal alpha/theta ratio. The training increases the frontal alpha/theta activity in the dyslexics. The NF could be applied as a part of a multimodal approach with effects on neuroplasticity of dyslexics.

Motion Detection for Isoluminant Gratings Presented in the Left and Right Visual Fields

Riku Asaoka[1], Tatsuya Yoshizawa[2] and Haruyuki Kojima[1]
[1]Kanazawa University, Japan
[2]Kanagawa University, Yokohama, Japan

Visual field asymmetries have been reported in various visual tasks. It remains unclear that color-motion processing has such an asymmetry. In this study, we examined visual filed differences in motion detection for the isoluminant stimuli presented in the left and right visual fields (LVF and RVF). The isoluminant color stimuli were preliminarily determined using minimum motion method for each participant and visual field. The two isoluminant red-green sine wave gratings were presented for 160 milliseconds, 5 arc deg away from the center of the display. One of the gratings was stable, while the other one drifted either to the left or right. The participants' task was to report whether they perceived motion of either grating. We calculated the percentage of motion reports as a function of red–green contrast for each participant and visual field and found that the motion was more easily perceived in the LVF than in the RVF. The result suggests that motion perception with color system has a dominance in the left visual field.

Revisiting the Peripheral Bias for Optic Flow

Hiroshi Ashida[1], Xirui Yang[1] and Chien-Chung Chen[2]
[1]Kyoto University, Japan
[2]National Taiwan University, Taipei

It is suggested that biases in processing expanding and contracting optic flow reflect more exposure to the former as a result of forward locomotion. Such biases might already exist at the stages of local motion processing, especially in the peripheral visual fields where the difference by the flow type is more pronounced. However, inconsistent findings have been reported regarding whether the bias in peripheral motion perception is centrifugal (i.e., flow with forward motion) or centripetal (i.e., flow with backward motion). We reexamined the centrifugal bias in counterphase flickering sinusoidal grating (Georgeson & Harris, 1978; Zhang et al, 2013) and centripetal bias in random-dot coherence (Edward & Badcock, 1993) under directly comparable conditions. Each type of motion display was presented 20° or 40° to the left of fixation, and the participant reported the perceived motion direction. The results generally replicated with each of the previous studies, that is, centrifugal bias for counterphase gratings and centripetal bias for random dots, suggesting that the inconsistent results were primarily due to different stimulus and experimental conditions. We also found substantial individual differences as some participants showed clear centripetal bias for the counterphase gratings.

Interference Across Space and Time for Apparent Position in the Peripheral Vision

Masahiko Terao and Fuminori Ono
Yamaguchi University, Japan

Recently, we reported a spatial distortion effect in the peripheral vision. When two disks were presented in the center region of the visual field, the perceived position of each disk was not so different from its actual location. However, when two disks were presented further from the center region, the perceived position of the disk at the center side was shifted toward the disk at the peripheral side. This suggests that the visual system estimates the disk separation, which is a global relationship by, integrating local position signals and that output of this estimation process varies across visual field. Here we report that similar distortion occurred even when two disks were presented at different timing. We tested various SOA and found that the spatial distortion survive even when the onsets of two disks were separated as long as 300 milliseconds. Interestingly, the second disk presented at the peripheral vision backwardly biased the apparent position of the first disk which was presented 300 milliseconds earlier. Our findings suggest that the estimation process for global relationship integrates local position information over a large time window and that the apparent object position is not yet established even 300 milliseconds after the input.

Salience-Driven and Goal-Driven Effects on Visual Selection as a Function of Eccentricity

Elle van Heusden, Mieke Donk and Christian N. L. Olivers
Vrije Universiteit Amsterdam, the Netherlands

Eye movements can be driven by salience or goals. Previous work has shown that salience-driven selection prevails immediately after the presentation of a visual scene, while afterward goal-driven biases toward task-relevant stimuli take over. Here, we investigated how the time courses of salience-driven and goal-driven selection change as a function of eccentricity. To do so, we asked

people to make a speeded eye-movement toward a predefined target. This target could either be salient or non-salient and was presented at one of three different eccentricities. We show, in line with previous results, that salience only affects short-latency saccades, while task-relevance affects saccades later in time. Importantly, the time frame within which saccades are dominated by salience increases with eccentricity whereas goal-driven selection is stable across eccentricities. These findings indicate that the time courses of salience-driven and goal-driven selection are differentially affected by eccentricity.

Testing a Prediction of the Central-Peripheral Dichotomy in Visual Inference: Visual Backward Masking Is Weaker in the Peripheral Visual Field

Yushi Liu and Li Zhaoping
Max Planck Institute for Biological Cybernetics, University of Tuebingen, Germany

Visual backward masking occurs when perception of a briefly presented target is impaired by a mask presented 30 to 100 milliseconds after the target. One account of this masking argues that top-down feedback from higher to lower visual brain areas along the visual pathway is involved. Top-down processing helps visual recognition in challenging situations, such as a very short viewing duration of the target, as follows. First, the bottom-up sensory inputs arising from the target generate an initial hypothesis about the target's character; second, the brain's internal model of the visual world generates a synthesized visual input consistent with this hypothesis; third, top-down feedback compares this synthesized input with the actual bottom-up visual input; fourth, the initial hypothesis is strengthed or weakened when synthesized and actual inputs have a good or poor match, respectively. Accordingly, a mask can interrupt this process when the bottom-up input from the subsequently presented mask rather than the target is compared with the top-down synthesized input. Zhaoping (2017) recently proposed that top-down processing for object recognition is weaker in the peripheral visual field. This predicts that visual backward masking is weaker peripherally. We report psychophysical experiments to test this prediction, using various target-mask presentation intervals and visual viewing eccentricities.

The Effects of Stimulus Eccentricity and Size on the Consciousness-Related EEG Signatures

Niina Salminen-Vaparanta[1], Mika Koivisto[1], Giulia Segurini[1], Antti Revonsuo[1,2] and Simone Grassini[1,3]
[1]University of Turku, Finland
[2]University of Skövde, Sweden
[3]Norwegian University of Science and Technology, Trondheim, Norway

Numbers of studies have investigated when conscious visual perception is reflected in event-related potentials (ERPs). Typically, consciously seen stimuli induce more negative deflection in N200 time window (visual awareness negativity, VAN) and more positive deflection in P3 time window than the stimuli that remain unconscious. However, there are also studies where VAN is not observed for consciously seen stimuli when ERPs to seen and unseen stimuli are compared. It is unclear what factors could explain these contradictory findings. Typically in these studies where VAN is not observed, the stimuli are relatively small, presented to the peripheral visual field and mask is used. We studied the effects of the location of the stimulus in the visual field and the stimulus size on ERPs by replicating an experiment where VAN has not been observed. We found that VAN was not elicited in the experimental conditions where bigger visual stimulus was used than in the original set up or when the stimuli were presented closer to the fixation than in the original set up suggesting that the distance of the stimulus from the fixation or the size of the stimulus do not explain the lack of VAN in these types of studies.

Who's Got the Global Advantage? Visual Field Differences in Navon's Paradigm

Christian Gerlach[1] and Nicolas Poirel[2,3]
[1]University of Southern Denmark, Odense, Denmark
[2]Université Paris Descartes, France
[3]Institut Universitaire de France, Paris, France

In 1979, Martin reported a right visual field (VF) advantage for local-level responses and a left VF advantage for global-level responses in Navon's classical paradigm with compound letters. These findings have since been confirmed in split-brain patients, in patients with unilateral brain damage, and in functional imaging with normal subjects. Despite this apparent convergence, VF differences in normal subjects seem flimsy and are reported in some studies but not others. This inconsistency may reflect small effects combined with small samples. Here, we test VF differences for global precedence (local RT–Global RT consistent trials) and global-to-local interference effects (local RT inconsistent trials–local RT consistent trials) in

a large sample ($n = 337$). We find that global-to-local interference effects are larger for compound letters presented in the left than in the right VF ($dz = .27$, $p < .0001$) but find no evidence for VF differences in global precedence effects ($dz = .06$, $p = .26$). These findings suggest that (a) the hemispheres do not differ in global/local processing per se for consistent stimuli, but (b) global shape dominates more in the right than in the left hemisphere when conflicting information at different spatial scales must be resolved.

Individual Differences in Biases in the Perception of the Ambiguous Motion Quartet Across Spatial Scale

Charlotte Boeykens, Johan Wagemans and Pieter Moors
KU Leuven, Belgium

Perception of the ambiguous motion quartet is predominantly characterized by apparent motion in one of two directions: vertical (up-down) and horizontal (left-right). Previous studies documented a vertical bias, indicating vertical apparent motion when the aspect ratio is 1. Wexler (2018) studied biases in motion quartet perception across different orientations and observed high individual variability. In this study, we asked whether similar biases can be observed between and within individuals for stimuli across different spatial distances. In Experiment 1, observers reported percepts of motion quartets with a stimulus onset asynchronies of 320 milliseconds, displaying dots (radius 0.36°) positioned in combinations of 17 horizontal and vertical distances ranging 0.6° to 5.4°. Our results show vertical biases in most observers, with considerable interindividual variability where a minority showed veridical perception or horizontal biases. Transitions between percepts seem to scale with larger spatial distances, indicating that biases are not invariant across scale. In Experiment 2, observers reported percepts of motion quartets with an aspect ratio of 1 presented across different locations in the visual field. Our results show no systematic differences in bias across the visual field. Interestingly, recurrence plots of the time series of percepts show considerable individual differences in perceptual dynamics.

Examining the Effect of Ketamine on Gestalt Perception

Pablo Rodrigo Grassi[1,2,3], Lena Danyelli[4,5,6], Zümrüt Duygu Şen[4,7], Martin Walter[4,5,7] and Andreas Bartels[1,2,3]
[1]Department of Psychology, University of Tuebingen, Germany
[2]Centre for Integrative Neuroscience, Tuebingen, Germany
[3]University Clinic Magdeburg, Clinical Affective Neuroimaging Laboratory, Magdeburg, Germany
[4]Clinical Affective Neuroimaging Laboratory, University Clinic Magdeburg, Germany
[5]Leibniz Institute for Neurobiology, Magdeburg, Germany
[6]IMPRS, Max-Planck-Institute for Biological Cybernetics, Tuebingen, Germany
[7]Max-Planck-Institute for Biological Cybernetics, Tuebingen, Germany

Predictive coding postulates that the organisation of the visual scene not only relies on the incoming information but also on prior knowledge about the world. As such, perception reflects the combination of bottom-up sensory information with top-down prior beliefs (predictions) about the source of the sensory input. These top-down prior beliefs are thought to be fed back from higher hierarchical levels to sensory cortices via glutamatergic N-methyl-D-aspartate receptor (NMDA-R) signalling to be compared with the sensory input. In accordance with this, there is evidence that the NMDA-R antagonist ketamine weakens the role of priors in perception. Moreover, there are mixed reports that schizophrenic patients, who have a hypofunction of cortical NMDA-Rs, show greater resistance to visual illusions. Here, we investigated in a placebo-controlled blinded study the effect of ketamine on the perception of an asymmetric bi-stable motion illusion. The stimulus consisted of four pairs of dots that could either be perceived as unbound dots moving locally (low-level default perception) or as two squares sliding over each other in transparent motion (prior-belief-dependent high-level perception). Following predictive coding, we hypothesise to observe a relative decrease of the prior-belief-dependent perception after ketamine infusion. However, preliminary results reveal no treatment-dependent effects.

Thresholds for Detecting a Signal in an Ambiguous Figure

Valeriia Karpinskaia[1], Irina Shoshina[2] and Yuri Shilov[3]
[1]Saint-Petersburg State University, Saint-Petersburg, Russia
[2]Pavlov Institute of Physiology, Russian Academy of Science, Moscow, Russia
[3]Samara University, Russia

Observers viewed a Necker cube consisting of broad black lines on a white background. They were required to detect a white dot on one of the lines of the cube which could be located either on the front or back face depending on the

observer's interpretation of the cube. A "yes-no" method was used to measure the separate thresholds for the two different interpretations. There were also control trials without the Necker cube. There were no differences in observers' criteria for detection in the two conditions but sensitivity (d') was lower for the back face compared with the front face interpretations ($p < .01$). For the control stimulus, there were no differences in criterion or sensitivity. The experiments show that thresholds can be affected by the interpretation of the size and distance of the figure. We suggest that observers treat the two physically equal stimuli in two different ways—either as close and large or far and small—and this would account for the different results.

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The Two Types of Observers in Multialternative Perceptual Choices

Shi Liang[1,2], Muzhi Wang[3], Long Ni[3] and Hang Zhang[2,3,4]
[1]Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, China
[2]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China
[3]School of Psychological and Cognitive Sciences and Beijing Key Laboratory of Behavior, China
[4]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, China

Although perceptual decision-making has been extensively studied, little is known about multialternative choices with more than two alternatives, the study of which may reveal computational heuristics that are inaccessible through two-alternative choices. We investigated multialternative choices in a color-matching task, where alternatives were colored disks located on a virtual circle and subjects must identify by saccade the disk whose color matched that of the fixation disk. The number of alternatives could be 2, 3, 4, 6, 8, or 12. We also manipulated the task difficulty by varying color dissimilarity (Experiment 1) or noise level (Experiment 2). Forty-eight human subjects participated, whose response time (RT) and accuracy were recorded. In both experiments, subjects' overall accuracy had a bimodal distribution, through which we isolated two types of subjects. The high-accuracy subjects' RT increased with increasing number of alternatives and task difficulty, while the low-accuracy subjects' RT remained largely unchanged across the conditions. Correct responses were faster for the former, while wrong responses were faster for the latter. Subjects who were tested in both experiments showed highly consistent patterns. Simulation with leaky competing accumulator models suggests that varying the strength of lateral inhibition can lead to the observed two behavioral patterns.

Among the Two Kinds of Metacognitive Self-Evaluation, One Is Predictive of Illusory Object Perception, the Other Is Not

Diana Lints, Sandra Vetik, Kadi Tulver and Talis Bachmann
University of Tartu, Estonia

The relationship between expectation-induced hallucination proneness and self-confidence in performance was studied in a visual perception task. The task was either to recognize briefly shown faces as male or female or to rate the subjective clarity of a square surrounding the face. Importantly, in a few critical trials, the square was not shown. Upon completion, participants rated their performance in the face recognition task on a scale of 0% to 100%; they were also asked whether they were sure that their estimation was correct. Out of 25 participants, 23 "hallucinated" on at least one trial, rating the square as visible when it was actually absent. A significant negative correlation between hallucination proneness and self-confidence in performance (as measured by the self-rating) was found: the more hallucinations a subject experienced, the less confident he or she was in his or her performance in the face recognition task. Most subjects underestimated their performance, meaning that higher ratings were also more accurate. Thus, higher hallucination proneness was related to more inaccurate ratings of one's own conscious perception. Confidence in self-ratings as measured by the second follow-up question was unrelated to both hallucination proneness and self-confidence in performance, suggesting that there is no unitary mechanism of metacognitive evaluations.

Uncertainty Due to Speed Variability Causes Decisional But Not Sensorial Biases in a Go/No-Go Task

Cristina de la Malla and Joan López-Moliner
Vision and Control of Action Group, Department of Cognition, Development and Psychology of Education, Institut de Neurociències, Universitat de Barcelona, Spain

To cross a busy street we need to make sure that cars are far enough and move at a speed that makes the crossing decision safe. Using this analogy and a go/no-go paradigm, we designed a task where participants decided whether to make a square cross a large screen from the bottom to the top by pressing one of two keys of an input device. Two groups of three targets approached the screen midline from the sides, and participants had to make their go/no-go decision avoiding the square being hit by the targets. The variability between the targets' speed differed in each trial, modulating the environment's uncertainty. Such

uncertainty determined the number of times participants decided to go but not the probability of successful crossing. To disentangle whether the difference in the amount of go responses was due to a decision or a sensory bias, we run a second experiment where participants had to decide whether the horizontally moving targets would collide before or after a sound they heard. Results indicate that only 30% of the change in go responses was due to sensory biases. Thus, the environment's uncertainty had a larger effect on decision rather than on sensory mechanisms.

Motion Extrapolation and Decisions Under Risk in the Gain and Loss Domains

Paul A. Warren, Rebecca Champion and Sonia Mansouri
University of Manchester, UK

Warren et al. (Proc. R. Soc., B., 2012) suggests that humans can estimate variability in the trajectory of a dot on a random walk and exploit this to make near-optimal decisions about future position. Participants observed the dot until it disappeared behind an annular occluder before setting the angular position and size of a "catcher" to predict its point of reemergence. Points (P) were scored for catches, decreasing linearly with catcher size (C), with no penalty for misses. Performance was close to expected value maximising. Cognitive decision-making is known to differ in loss versus gain domains and so here we looked for a similar difference in the motion extrapolation task, manipulating the reward structure in gain (Catch: $P = 150 - C$; Miss: $P = 0$) and loss ($P = 50 - C$; Miss: $P = -100$) conditions. Crucially, at each trajectory noise level tested, the optimal catcher size was the same for loss and gain domains. Consistent with our previous study, participants reduced C appropriately as trajectory noise increased. However, C was approximately 5° smaller (i.e., riskier) in the loss domain. These data suggest decision-making in this context is good but is sensitive to outcome valence.

Visual Confidence in Younger and Older Adults: What Drives Individual Differences in Metaperception?

Lena Klever[1], Pascal Mamassian[2,3] and Jutta Billino[1]
[1]Justus-Liebig-University Giessen, Germany
[2]École Normale Supérieure, Paris, France
[3]Centre National de la Recherche Scientifique, Paris, France

Visual perception is not only shaped by sensitivity but also crucially by confidence, that is, the ability to estimate the accuracy of a visual decision. There is robust evidence that younger observers have access to a reliable measure of their own uncertainty when making visual decisions. This metacognitive ability might be challenged during aging as noise in the sensory systems increases and cognitive control resources decrease. We explored age effects on visual confidence investigating contrast discrimination in a confidence forced-choice task. We determined discrimination thresholds for trials in which perceptual judgments were indicated as confident and for those in which they were declined as confident. Younger adults (21–38 years) showed significantly higher discrimination thresholds than older adults (60–78 years). In both age groups, perceptual performance was linked to confidence judgements, but overall results suggest reduced confidence efficiency in older adults. However, we observed substantial variability of confidence effects within the group of older adults. This variability was closely linked to individual differences in executive functions. Our findings suggest that age effects on metaperception might be primarily mediated by cognitive control resources.

A Reverse Hierarchy for Perceptual Confidence?

Tarryn Balsdon[1,2], Valentin Wyart[1] and Pascal Mamassian[2]
[1]Laboratoire de Neurosciences Cognitives et Computationnelles (Inserm U960), Département d'études Cognitives, École Normale Supérieure, PSL University, Paris, France
[2]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Paris, France

The reverse hierarchy theory (Hochstein & Ahissar, 2002) proposes that conscious, deliberate perception proceeds from top-down, accessing higher levels of visual processing, and only tuning down to low-level representations as required. A natural prediction from the reverse hierarchy theory is therefore that metacognitive monitoring will have greater access to high-level compared with low-level visual information. We tested this prediction using two perceptual discrimination tasks on the same visual stimuli: grayscale faces in which the eye direction and contrast of the irises was manipulated. In the low-level task,

observers discriminated whether the left or right eye was higher contrast, a decision relying on information processed in early visual cortex. In the high-level task, they discriminated whether the gaze direction was looking to the left or the right of them, a decision that arguably relies on information processed in the Superior Temporal Sulcus (Perrett et al., 1992), high in the visual processing hierarchy. Metacognitive performance was measured in a confidence forced-choice task (Mamassian, 2016): every two trials observers chose which trial they were more likely to be correct. There was weak evidence for better metacognitive efficiency for the high-level compared with the low-level task.

Meta-Meta-Meta Perception

Samuel Recht, Ljubica Jovanovic, Tarryn Balsdon and Pascal Mamassian
Laboratoire des Systèmes Perceptifs, CNRS, Ecole Normale Supérieure, Université PSL, Paris, France

It is often stated that every decision comes with a feeling of confidence. Thus, confidence decisions should themselves come with a feeling of confidence. To test this prediction, participants performed four consecutive tasks on each trial. First, they performed a two-alternative forced-choice spatial frequency discrimination task and rated confidence in their performance (low/high). After two consecutive trials, they evaluated which of the two confidence ratings better reflected their performance (confidence forced-choice judgement). This is a "meta-confidence" judgement rather than another confidence judgment on the initial task. Finally, participants rated their performance (low/high) in their confidence forced-choice judgment ("confidence in meta-confidence"). We compared performance in the spatial discrimination task for the three levels of meta-perceptive judgments (eight categories). Spatial frequency discrimination performance was different between trials rated low versus high at the first level. This difference was greater for trials chosen as having more accurate confidence ratings (second level), and even greater for chosen trials with a high-confidence rating (third level). Therefore, participants performed each meta-judgement with above chance accuracy. Comparison with an ideal observer showed no evidence for a systematic decrease in sensitivity of confidence judgments across the levels. In conclusion, every judgement comes with a reliable feeling of confidence.

Thursday, August 29, 2019

Poster Session 7

The Geometry of High-Level Colour Space

Mubaraka Muchhala, Nick Scott-Samuel and Roland Baddeley
University of Bristol, UK

The optimal representation of a signal is determined by the task and the dominant noise. In colour, most work has concentrated on low-level tasks, where the predominant noise is photoreceptor based (Vorobyev & Osorio, 1998). For high-level representations, what matters is not the colour, but what that colour informs the user about the world, and the dominant noise is due to failure of colour memory (Baddeley & Attewell, 2009). Here, we estimated the properties of this high-level representation by testing colour memory across hue and saturation. We identify "basins of attraction" in this space, corresponding to Berlin & Kay's basic colour terms (Berlin & Kay, 1969). We propose these biases are due to a nonuniform prior over colours. We compare the predictions of two such priors: an empirical prior, based on the observed distribution of colours in the world, and an optimal prior due to distortions to the geometry induced by the task. To identify the form of this prior, we are training a deep network to identify objects purely based on colour and measured how changes in colour were reflected by changes in object classification. Comparisons between the empirical data and these two models will be presented.

The Role of Visual Coding for Discrimination of Difficult-to-Name Colors

Ivana Jakovljev[1] and Sunčica Zdravković[1,2]
[1]Faculty of Philosophy, University of Novi Sad, Serbia
[2]Laboratory of Experimental Psychology, University of Belgrade, Serbia

Our previous work showed that participants dominantly use visual coding when discriminating simultaneously presented blue and green stimuli but not when these stimuli are presented successively. We reasoned this strategy difference comes from color names usage in the latter, memory task, and tested it using shades that are difficult to name. We isolated 16 such shades, that participants (18) could name 38.2% of the time (contrary to 87.13% for blue–green) and used them to investigate visual coding in simultaneous (15 participants) and successive (14 participants) discrimination tasks. Visual interference was added, creating

four experimental conditions: neutral (all stimuli colors in the same shape), control (all in different shapes), congruent (target and test: same color, same shape), incongruent (target and test: same color, different shapes). Visual interference was significant in simultaneous, $F(3, 42) = 20.02$; $p < .001$, and successive task, $F(3, 39) = 9.96$; $p < .001$, while incongruent condition increased participants' RTs. When perceived colors are difficult to name, unlike for blue–green discrimination, memory task is also compromised by visual inference. This suggests that strategy is altered and now visual coding dominates in both tasks.

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Grain Size of Colour

Jan Koenderink[1,2] and Andrea van Doorn[2]
[1]KU Leuven (University of Leuven), Belgium
[2]Utrecht University, the Netherlands

Generic human observers discriminate 10 million colours, can reproduce about a thousand, use about a hundred in art work, and can name about 10. These numbers range over six orders of magnitude. The 10 million and the 10 we take from the literature. We used a colour picker task to establish the 1,000 and obtained 100 from hearsay (due to our artist friends). Here, we report on the grain size as due to ecological factors. We investigated hunter-gatherer ecology in steppe or savannah environments, the ecology under which human colour vision evolved during recent evolutionary periods. We establish that the grain size due to object reflectance and (daylight) illuminant metamerism accounts very well for the colour picker results (about a thousand object colours). However, we have not been able to account for the pattern found in the perception on the basis of statistics obtained from available data bases of varieties of daylight and object (mostly botanical, some minerals) reflectances. The empirical pattern can hardly be due to human anatomy/physiology as this implies a much higher resolution. It is likely to be due to ecological priors for the hunter-gatherer existence.

Affective Reactions to Coloured Patterns

Andrea van Doorn[1], Doris Braun[2] and Jan Koenderink[1,3]
[1]Utrecht University, the Netherlands
[2]Justus-Liebig University Giessen, Germany
[3]KU Leuven (University of Leuven), Belgium

There exists a huge literature on colour harmony, of which a tiny part might be described as properly belonging to the sciences. We attempt to answer the question of whether there exists a fairly generic affective reaction to colour combinations at all. Various problems to overcome include the frequent confusion with aesthetic judgment, the nature of the spatial structure of the stimuli, and more. We used two types of patterns, one textural (self-similar random Gaussian noise, no edges), the other a discrete random mosaic (Voronoi cells, many edges). Colours in each pattern included a wide gamut of mixtures of black, white and one up to three chromatic hues. These stimuli thus reflect typical artistic use. Patterns were refreshed every second. A questionnaire consisted of seven 5-point Likert-type scales of the affective dimensions soothing-irritating, weak-strong, dull-vivid, subdued-intrusive, calm-lively, blunt-piercing and gloomy-cheerful. Over 30 participants included a wide range of ages and both genders. We find good concordance in their responses. The results perfectly reflect the conventional dichotomy between warm and cool colour families. The spatial structure of the patterns plays a role, thus one cannot merely relate "colour harmony" to a small set of colours, as is common practice.

Visual Inference for Warm/Cold Perception of Surfaces

Hsin-Ni Ho[1], Hiroki Terashima[1], Kohta Wakamatsu[2], Jinhwan Kwon[3,4], Maki Sakamoto[3], Shigeki Nakauchi[2] and Shin'ya Nishida[1]
[1]NTT Communication Science Labs, NTT Corporation, Tokyo, Japan
[2]Toyohashi University of Technology, Japan
[3]The University of Electro-Communications, Chofu, Japan
[4]Kyoto University of Education, Japan

Humans can make warm/cold judgments based on the sight of a surface only. This process presumably involves inference of thermal experience from visual information. As there is a long-held belief that reddish colors induce warm feelings, while bluish colors induce cold feelings, we aim to examine whether and how color information relates to warm/cold perception of surfaces. Here, we asked participants to give warm/cold ratings to 1,934 color photographs of surfaces from various material categories and analyzed color histograms of these images in L*a*b* color space. We used L-1 regularized regression and multiple-domain adaptation techniques with predefined image statistics and regions in color histogram as predictors to examine the contribution from color features. We found that color features can explain about 30% to 40% of the variance in warm/cold ratings. The most influential ones are mean values in a* channel (red–green) and b* channel (yellow–blue) and colors with hue angles between 45° and 90° (orange–yellow). Inclusion of the knowledge of material-temperature association (e.g., metal is cold) could increase the explanation power to 55% to 60%. These findings indicate that the visual inference process for warm/cold perception of surfaces

depends on low-level color statistics and cognitive factors such as the knowledge of color-temperature/material-temperature correspondences.

Color Affects Recognition of Expression in Emoticons: A Cross-Cultural Study

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

We investigated the effect of color on the emotion read from emoticons and explored cross-cultural differences. The study was conducted in Japan ($N = 22$), the United Kingdom ($N = 64$), and the United States ($N = 31$). Angry, Sad, Neutral, Surprised, and Happy emoticons were presented in Red, Orange, Yellow, Green, Cyan, Blue, Purple, and Light Gray. Participants assessed each emoticon on visual scales with anchors corresponding to each emotion (e.g., "Not Happy–Happy"). We found that color affected emotion recognition in Japanese and, to a lesser degree, U.K. viewers: The expressiveness of Sad emoticons was enhanced by cool colors but diminished by warm colors; for Angry emoticons, the warm–cool effect was reversed. Surprisingly, cross-cultural consensus between the two Anglo populations was lacking: color hardly affected the emotion read for the U.S. viewers. Our results suggest that congruency of the affective meaning of the emoticon and its color may facilitate recognition of the conveyed emotional message. This phenomenon depends, however, on culture-specific communication rules (cf. Hall, 1981): It is marked in high-context culture (Japan), with implied nuances; less manifest in medium-context culture (United Kingdom); and barely discernible in low-context culture (United States), with information vested in explicit codes. The findings can be useful for developing effective intercultural communication.

Different Effects of Color/Color Inversion on Fear and Disgust

Hiromi Sato[1], Shiori Muranaka[2], Wakana Hata[2] and Isamu Motoyoshi[1]
[1]Department of Life Sciences, The University of Tokyo, Japan
[2]Department of Integrated Sciences, The University of Tokyo, Japan

Rapid recognition of threats and dangers are necessary for humans to survive. Negative emotions such as fear and disgust are known to initiate immediate avoidance from threats and dangers in the environment. Emotions are often thought to be brought about by higher order complex information such as context, but some negative emotions might be directly summoned by simple image features rapidly encoded in the visual cortex, independently of the recognition of objects and scenes. In this study, we examined how simple image features such as color and luminance affect the emotional valence of natural scenes. The observers rated the fears and disgusts of 200 natural scenes, their achromatic versions, and the RGB inverse version. Results showed that the removal of color information strongly reduced disgust, but did not reduce fear, and the RGB inversion reduced disgust while increasing fear. That is, color and luminance had an asymmetric effect on fear and disgust. These results demonstrate the influence of simple image features on emotion, and suggest that different visual pathways (e.g., Magno/Parvo streams) are involved in neural processing of fear and disgust.

Facial Colour Can Be Observed Even in a Scrambled Image

Katsuaki Sakata[1] and Hitomi Shimakura[2]
[1]Joshibi University of Art and Design, Tokyo, Japan
[2]Shiseido Global Innovation Center, Yokohama, Japan

Assessment of the saturation effect of facial skin colour on brightness perception revealed the Helmholtz-Kohlrausch (H-K) effect with uniformly coloured patches. However, the facial images showed an inverted H-K effect and appeared brighter with decreasing saturation. We assessed the effect of stimulus size, shape, and colour recognisability of human faces from uniform patches including a 2° disk image, a hand-shaped image, an isometric patch of the facial image, and a uniform colour patch with eyes and lips. Furthermore, we assessed the effect of recognisability of human faces and its contrast on the stimulus derived from facial images comprising a four-step resolved-scrambled image, a nonscrambled, and a scrambled image without high-contrast areas in three-step saturation, and five hues under constant luminance. Twenty participants selected the brighter image among the two stimulus images comprising faces or uniform colour patches. The brightness perceived in facial images corresponding to a skin tone showed an inverted H-K effect, whereas that from the uniformly coloured patches and facial images not corresponding to a skin tone displayed normal H-K effect, irrespective of size or shape. Thus, facial colour is perceivable without facial recognition.

Red Biases Sex Categorization of Bodies

Na Chen, Koyo Nakamura and Katsumi Watanabe
Waseda University, Tokyo, Japan

Red has been shown to influence emotions, cognition, and behavior. It was suggested that people tend to respond "male" when in doubt of a person's sex both by faces and bodies (Johnson, Iida, & Tassinary, 2012; Watson, Otsuka, & Clifford, 2016). However, little has been known about the red effect on sex categorization. In this study, we examined whether red background color could influence the gender recognition of faces and bodies, compared with green and gray colors. Visual stimuli were made from seven levels of morphing faces (along sexual dimorphism dimension; Experiment 1) and bodies (along WHR; Experiment 2), combined with three background colors (i.e., red, green, and gray). Participants ($N = 42$, 20 female, $M_{age} = 21.1$, $SD = 1.9$) were asked to judge the gender of the stimulus by pressing two labeled keys. Results showed that red background has little effect on the gender categorization for faces, but it could bias the sex categorization of bodies, that red background could enhance the "male" gender perception. Those results indicated that red color could bias the body gender recognition, with a reinforcement of "male" gender judgment, which might be mediated through the dominance and aggression dimensions.

Intergenerational Differences in Colour Preference

Galina V. Paramei, Annie Veenman and Letizia Palumbo
Liverpool Hope University, UK

We explored colour preference of "young" (18- to 30-year-old) and "mature" (60- to 70-year-old) participants. According to ecological valence theory, colour liking reflects preference for objects associated with that colour (Palmer & Schloss, 2010); we therefore anticipated differences between the two age groups due to their exposure to disparate object assortments. Participants indicated their colour preference on a bipolar visual scale (*not at all* [−100] to *like very much* [+100]). Six colours—red, orange, yellow, green, blue, and purple, each rendered as light, dark, and saturated—were presented randomly as singletons (Experiment 1) or with superimposed congruent or incongruent object names, adopted from Taylor and Franklin's (2012) study (Experiment 2). For both age groups, we found highest preference for blue and lowest for green and purple. The young preferred red and orange more than the mature, who disliked these colours. Furthermore, the colour–word congruency had greater effect for the mature participants: congruent object names amplified their colour preference, whereas incongruent ones partly reversed it. The intergenerational differences in colour preference conceivably result from variation in valence of colour–associated objects. Furthermore, stronger congruency effect in the older group suggests more solidified system of colour–object associations.

Determination of Optimal Colour and Maximum Colour Deviation of Food Products

Jan Audenaert and Frédéric Bernard Leloup
Light & Lighting Laboratory, KU Leuven, Ghent, Belgium

Photooxidation is one of the major causes of food deterioration of a variety of products, such as dairy products and meats. In result, light absorbers or blocking materials are being embedded into food packaging. Yet, to avoid "overpackaging" and thus unnecessary packaging costs in relation to the defined shelf life, knowledge is needed on the maximum allowed product discoloration. This study reports on two psychophysical experiments in which the optimal colour and allowed deviation has been determined for two food products, that is, ham sausage and gouda cheese. An experimental setup was built with which the products' colour can be changed against an invariant background by use of a projector. Based on the measured spectral reflectance of both products and on the projector calibration, 144 different hues were defined for both products. The optimal product colours were determined from the psychophysical test in which 15 observers indicated their likeliness of buying the presented product on a 0 to 10 scale. In a second stage, 15 further observers were asked to indicate the maximum allowed colour deviation. Both tests were repeated at different light levels. The results offer valuable insights for defining new illumination and packaging conditions in retail applications.

The Role of Colour on Apparent Technology

Rossana Actis-Grosso
University of Milano-Bicocca, Milan, Italy

In a previous study, we found a gender stereotype for technological products, according to which more technological products are associated to male gender, whereas less technological products are associated to female gender. Here, we studied the possibility that this bias is not related to technology per se, but to Apparent Technology (AT) instead, similarly to Apparent Usability, that is, the tendency of users to evaluate products' usability at a first sight. Accordingly, we hypothesize that judgements on AT should be based on colours, which are

known to be stereotypically associated to gender. Pictures of six items with different degrees of inherent technology (i.e., low, medium, and high) have been presented to 21 participants, asking to rate them for (a) Degree of technology, (b) Pleasantness, (c) Intention to purchase, and (d) Usability. Each item could have one of eight possible colours (e.g., red or black). Results showed an effect of colour on the perceived technology only for items with a high degree of technology, with items coloured in black, white, or steel judged as more technological than the same items coloured in colours such as red or yellow. Thus, AT seems to be based on visual features stereotypically associated to male gender.

Phase and Position Cues in Motion

Alexandra Hibble, Hannah E. Smithson and Paul Azzopardi
University of Oxford, UK

First-order motion refers to a change in phase of the Fourier components of an image, whereas third-order motion refers to a change in position of a feature. Combining sinusoid gratings with circular windows, we can produce two-frame kinematograms in which changes in the phase of the grating and the position of the window are manipulated separately. At the fovea, participants are more sensitive to changes in position than phase and respond to conflicting cues using change in position. However, there is a greater relative weighting of phase information at low spatial frequencies, consistent with the first-order motion system being more sensitive to low spatial frequencies. In the periphery, sensitivity to both phase and position decreases, with sensitivity to position decreasing more rapidly. We suggest that the decline in sensitivity to position is consistent with a cortical scaling for third-order motion, and the shallower decline of phase sensitivity is suggestive of a subcortical neural substrate for first-order motion. Previous studies suggest a greater reliance on phase cues in periphery; the change in relative weighting between phase and position information with periphery will be discussed with reference to potential neural substrates.

A Magnetoencephalographic Study of Apparent Motion Illusion in Relation to the Two-Dimensional and Three-Dimensional Stimulations

Akira Imai[1], Hiroki Takase[1], Keita Tanaka[2], Hidehiko Okamoto[3] and Yoshinori Uchikawa[2]
[1]Shinshu University, Matsumoto, Japan
[2]Tokyo Denki University, Japan
[3]International University of Health and Welfare, Otawara, Japan

We examined an apparent motion illusion of beta movement in relation to two-dimensional (2D) and three-dimensional (3D) stimulations by measuring event-related fields of magnetoencephalography (MEG). Participants observed the 2D and 3D stimulations under two conditions of optimal-beta-movement and no-movement. Data from 204 channels of MEG recording were summed up to predefined 19 areas for two hemispheres totally 38 areas and were applied to the method of Minimum-Norm-Estimates for calculating activity of signal source at each area. Superior occipital area showed significantly larger activity for movement condition than that for no-movement, thereby suggesting that the motion could be perceived at this area. Significant differences between movement and no-movement conditions were also shown at middle temporal and superior frontal areas. The difference between 2D and 3D stimulations might be indicated at superior frontal area that the activity for 2D stimulation was marginally larger than that for 3D stimulation. These results suggest that the motion perception would originate from the primary visual cortex (V1). Then, the signals of motion and others at the V1 should be transmitted for sites such as parietal and frontal areas, and these brain activities could be transformed into a kind of causal signal for stereoscopic vision.

The Psychophysiological Mechanisms of Vection Illusion Perception

Oxana Klimova, Artem Kovalev and Anton Gasimov
Lomonosov Moscow State University, Russia

Vection describes the sensation of ego-motion induced by moving visual stimuli that cover a large part of the visual field. This research was aimed to study whether perception of visually induced circular vection is changed if rotational velocities of 30, 45, or 60 °/s of stimuli were used, and what were the psychophysiological mechanisms of vection. The eye tracking was used to examine parameters of optokinetic nystagmus to identify vection periods which were provoked by the rotating optokinetic drum with black and white stripes in CAVE virtual reality system. Seventeen volunteers passively observed rotating stimulation: 18 trials (3 Velocities $\times$ 2 Directions $\times$ 3 Repetitions) were presented in pseudorandom order each for 2 minutes. It was found that for all stimuli rotation, slow phases velocities of nystagmus were significantly longer compared with nonvection periods ($F = 44{,}5$, $p < .01$). Also, during vection perception periods, we found the decrease in alfa-band activity in parietal and central areas of left hemisphere. It is suggested that the increase in slow phases of nystagmus and decrease in alfa band occur because of an increase in the sensory conflict between visual and vestibular sensory channels.

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The Role of Vestibular System in the Cutaneous or Visually Induced Self-Motion Perception

Kayoko Murata[1], Hidemi Komatsu[2] and Makoto Ichikawa[1]
[1]Chiba University, Japan
[2]Keio University, Tokyo, Japan

Visually induced self-motion perception (vection) has been studied as a visual sensation. However, multiple sensory modalities, other than vision, may contribute to the perception of self-motion (Gibson, 1966). Murata et al. (2014, Psychology) recently found a new type of self-motion perception elicited by cutaneous sensation, which accompanies with vestibular system inputs. This finding proves that the self-motion perception is a multiple sensory phenomenon, which involves vision, vestibular sensation, cutaneous sensation, and so on. The purpose of this study is to understand how vestibular stimulation affect perception of self-motion by each of visually induced self-motion and cutaneously induced self-motion perception. In our experiments, we presented air flow as cutaneous stimulus, and optical flow as visual stimulus, with or without vibration (0.75 Hz) of a platform which hold participant's body as stimulus for vestibular system. We measured the strength, latency and duration in self-motion perception for the vision condition, cutaneous condition and with or without stimulus for vestibular system condition. We found that stimulus for vestibular system quickened to perceive self-motion in cutaneous sensation while it had no effect on visually induced self-motion perception (vection).

Motor Congruency and Multisensory Integration Jointly Facilitate Visual Information Processing Before Movement Execution

J. A. Elshout[1], N. van der Stoep[1], T. C. W. Nijboer[1,2] and S. van der Stigchel[1]
[1]Department of Experimental Psychology, Utrecht University, the Netherlands
[2]Center of Excellence for Rehabilitation Medicine, Brain Center Rudolf Magnus, University Medical Center Utrecht, Utrecht University and De Hoogstraat Rehabilitation, the Netherlands

Attention allows us to select important sensory information and enhances sensory information processing. Spatial attention and our motor system are tightly coupled: Attention is shifted to the target location before a goal-directed eye- or hand movement is executed. Studies have shown that congruent eye–hand movements can boost this premovement shift of attention. Moreover, visual information processing can be enhanced by multisensory integration (MSI). In this study, we investigate whether the combination of MSI and motor congruency can further enhance visual information processing. Fifteen participants performed congruent eye- and hand movements during a 2-AFC visual discrimination task. The discrimination target was presented in the planning phase of the movements at the movement target location or a movement irrelevant location. Three conditions were compared in which we presented a target (a) without sound, (b) with sound spatially and temporally aligned (MSI), and (c) with sound temporally misaligned (no MSI). The results show that performance was enhanced at the movement relevant location when congruent motor actions and MSI coincide compared with the other conditions. These findings reveal that congruence in the motor system and MSI together lead to enhanced sensory information processing before a movement is executed.

Sound Freezes Transient Visual Presentations as Revealed by Microsaccade Inhibition

Hsin-I. Liao[1] and Lihan Chen[2,3,4]
[1]NTT Communication Science Laboratories, NTT Corporation, Tokyo, Japan
[2]School of Psychological and Cognitive Sciences, Peking University, Beijing, China
[3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China
[4]Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, China

Crossmodal integration has strong impact on our perception. In crossmodal freezing effect (Vroomen & de Gelder, 2000), concurrent sounds facilitate the detection of visual targets, as the sounds "freeze" the visual display for better performance. Evidence has shown superior colliculus is a hub that receives multisensory inputs and projects the neural signals (related to attention and eye movement) throughout the brain network. We hypothesize that the characteristic parameters of eye movement could reveal the microgenesis of perceiving visual apparent motion (within 1 second) during audiovisual integration. Participants viewed the Ternus display in which the bistable motion states were modulated by the time interval between the two visual Ternus frames: Short interstimulus interval ($\sim$80 milliseconds) leads to element motion and long interstimulus interval ($\sim$230 milliseconds) group motion. Behavioral results showed that synchronous beeps enhanced the dominant percept of group motion. Eye movement results showed that microsaccade (MS) occurrence was inhibited as a function of the interstimulus interval in both sound and baseline (no-sound) conditions. Moreover, the

latency of MS occurrence was delayed in the sound condition, suggesting a cost of crossmodal binding of audiovisual events. In sum, the current results provide neuropsychological evidence for the crossmodal freezing phenomenon.

Visual-Spatial Perception Is Not Affected by Exact Position of Tactile Sensation But Lateralized Somatosensory Attention

Sachiyo Ueda, Kazuya Nagamachi and Michiteru Kitazaki
Toyohashi University of Technology, Japan

Illusory body ownership to the virtual body is induced by synchronous movement of a real body and a virtual body. This illusion can also occur in third person perspective (3PP) to some extent as well as in first person perspective (1PP). This study examined whether spatial perception was affected by the embodied-virtual-body-centered coordinate using "illusory line motion" that was yielded by a tactile cue on the left or right hand. In Experiment 1, we captured participant body movements and presented a moving virtual body synchronously or asynchronously via a head-mounted display. Three viewpoint conditions (1PP, 3PP-behind, and 3PP diagonally behind) were set. In the 3PP diagonally behind condition, the motion direction of the illusion was expected to reverse if the spatial perception was affected by the virtual-body-centered coordinate. We found that the virtual-body-centered illusory line motion was induced in all viewpoint conditions, regardless of the body ownership. In addition, the illusion occurred even when the virtual body was removed. These results suggest that in cases where the real body is not visible, visual spatial attention is linked with lateralized somatosensory attention rather than the exact position being given tactile stimuli.

Crossmodal Correspondence Between Sensory Mode and Hue: Comparing Explicit and Implicit Measures

Sandra Utz[1,2], Julia Hartmann[1] and Claus-Christian Carbon[1,2]
[1]University of Bamberg, Germany
[2]Forschungsgruppe Ergonomie, Psychologische Æsthetik, Gestaltung, Bamberg, Germany

Strong evidence exists for crossmodal correspondences between sensory mode and hue in nonsynesthetes occurring in explicit matching tasks (e.g., Palmer et al., 2013). Aim of this study was to further investigate this phenomenon by using more strongly controlled stimuli and by extending the paradigm with implicit besides explicit measures. In the explicit task, 31 students had to match eight different colours with chords, harmonized scales, and excerpts from Bach's Well-Tempered Clavier in all major and minor keys. Major mode was associated with yellow and orange and minor mode with blue and purple—largely corresponding to previous findings (e.g., Palmer et al., 2013). In the implicit task (a speeded classification task), colours were presented simultaneously with a major or minor chord and participants had to classify the presented colours on the basis of their shapes (circle or square). No crossmodal congruence effect (i.e., faster responses or higher accuracy) for specific mode-colour combinations was found. The nonoccurrence in the implicit contrary to the explicit paradigm points to the possibility that crossmodal correspondences are mainly shaped by culturally and quite explicitly set norms which might not be in action when fast and rather unaware processes have to be executed.

Visual and Kinesthetic Alleys Formed With Sticks

Atsuki Higashiyama
Ritsumeikan University, Kyoto, Japan

This study concerns with geometry of visual and kinesthetic spaces. One way to determine geometry of visual space was to construct parallel and equidistant alleys in depth. From evidence that parallel alleys lay inside equidistant alleys (Blumenfeld, 1913), Luneburg (1947) and others have suggested that visual space is hyperbolic. Another way is to test the size–distance invariance hypothesis (SDIH) that a ratio of perceived size to perceived distance equals tangent of the visual angle. We examined these hypotheses with alley experiments. Twenty observers visually and kinesthetically adjusted orientation of two 2.1-meter-long sticks laid in depth so that they appeared (a) to neither diverge nor converge, (b) to be separated by the same lateral distance all along their length, or (c) to be perpendicular to the frontal plane. The visual settings of sticks differed from the kinesthetic settings, which were largely influenced by orientation of the lower arms. Despite changes of instructions, the settings of sticks did not change for either sense modality, suggesting that both spaces are Euclidean. But, the size–distance relation that was derived from the settings indicated that the visual settings fitted the SDIH but the kinesthetic settings did not, suggesting that kinesthetic space is non-Euclidean.

"See What You Feel" Method: The Effect of Distance on Crossmodal Size Estimation

Olga Daneyko[1], Angelo Maravita[2] and Daniele Zavagno[2]
[1]Sheffield Hallam University, UK
[2]University of Milano-Bicocca, Milan, Italy

During ECVP 2014, we reported a study on the Uznadze haptic size aftereffect in which a crossmodal method was employed (haptic sensation and visual estimation) to measure the illusion's magnitude. Participants would undergo haptic adaptation and then find on a visual scale made of solid spheres the ones that corresponded in size to the spheres they were holding out of sight. In such experiments, we positioned the visual scale at two different distances, finding a small effect of scale distance on size estimation. This year we present the results of a study in which we investigated the effect of scale distance in out-of-sight haptic size estimation. Forty-five participants were randomly assigned to one of three groups, distinguished by visual scale distance (30, 160, and 290 cm). By finding the match on the visual scale, participants evaluated the size of four spheres (diameters 30, 38, 46, and 50 mm), one hand at a time for 3 times. Results show a general underestimation of sphere size for both hands at all three distances; however, underestimation was smaller at 30 and 290 cm and noticeably bigger at 160 cm. Such findings demand for more experiments as they suggest a nonlinear scaling process related to visual distance.

Reliance on Vergence and Size Cues in Action-Based Distance Estimates

Anne-Emmanuelle Priot[1,2], Charles-Antoine Salasc[1], Pascaline Neveu[1] and Cyril Vienne[1]
[1]Institut de Recherche Biomédicale des Armées, Brétigny-sur-Orge, France
[2]INSERM U1028, CNRS UMR5292, Lyon Neuroscience Research Center, Bron, France

Randomly varying target size has been proposed to mitigate size cue for distance in paradigms investigating the role of vergence in distance perception (Howard, Perceiving in Depth, 2012). To test this hypothesis, participants had to manually adjust the position of a cursor at the perceived distance of a cross target whose diameter was varying randomly across distances. Participants performed the task in two conditions: with vergence unaltered and through the view of a telestereoscope modifying vergence. The estimated distance of the cross target was negatively correlated to the size of the target, suggesting that overall, participants used size cue for distance. In the telestereoscope condition, the strength of the correlation was even increased. Variable errors of distance estimates also increased in the second condition, suggesting that the weight of the conflicting vergence cue likely decreased in favor of size cue for distance. Multiple regression analyses performed on individual data suggest some variations in individual reliance on size cue for distance. When the visual information is reduced, object size still plays a major role in distance perception, even if target size is randomly changing across distances. Its contribution to distance perception appears increased when vergence is altered.

Can Lilliputians Reach Gulliver—Is Hand Length Our Distance Measure

Tijana Todić Jakšić[1] and Oliver Tošković[2]
[1]Faculty of Philosophy, University of Priština, Kosovska Mitrovica, Serbia
[2]Laboratory for Experimental Psychology, Faculty of Philosophy, University of Belgrade, Serbia

Previous researches have shown that vertical distances are perceived as larger from physically equal horizontal distances due to integration of visual, proprioceptive, and vestibular information. It might be that people use arm length as a subjective measure unit in depth perception. The aim of this research was to examine differences in perceived arm length on horizontal and vertical axis. Research involved 13 students, whose task was to navigate the experimenter to put stimuli at certain, vertical or horizontal distance in such a way that examinee would have been able to reach it with the tips of his or her fingers. Half of the experimental situations involved disorientation of examinees in order to investigate the impact of vestibular information on perception of one's arm length. Analysis show that the same arm is perceived as shorter on vertical axis. We assume that arm length is used as subjective measure of perceived distance, and therefore physically same distance on vertical axis will seems larger because it contains more units. It is interesting that the difference in perceived arm length is reduced with disorientation of the examinees, which leads to conclusion that vestibular information are important for space and distance perception.

Grasping Spheres With a Twist: Mapping Out End-State Comfort

Lina Katharina Klein, Guido Maiello, Marcel Schepko, Vivian Charlotte Paulun and Roland William Fleming
Justus-Liebig University Giessen, Germany

The visually perceived location, orientation, and material properties of objects affect how we pick them up. In addition, if planning a specific action (e.g., rotating the object a certain amount), we may select grasps that consider the end-state comfort of the movement. Here, we investigated multidigit grasp pose when humans picked up spheres to place them at prespecified locations and orientations. Participants ($n = 10$) wore a data glove while performing reach-to-grasp movements to a 7 cm diameter metal (625 g) or Styrofoam sphere (6 g). We recorded the palm orientation while participants lifted the spheres with the right hand and placed them down at either the same orientation or with a 90° counterclockwise rotation around the vertical axis. The orientation of the participant's palm at the beginning of the grasp changed, around the vertical axis, as a function of both the required movement trajectory ($p < .0001$) and of the required rotation ($p < .01$). We employ these data to construct a descriptive model of human hand pose selection that takes into account perceived position, orientation, task, and material properties.

Embodied Advertising: Hand Holding Interferes the Preference of a Handbag

Jung-An Chin[1], Li-Chuan Hsu[2,3] and Yi-Min Tien[1]
[1]Chung-Shan Medical University, Taichung
[2]School of Medicine, China Medical University, Taichung
[3]Graduate Institute of Biomedical Sciences, China Medical University, Taichung

Grounded cognition emphasizes that our cognitive activity is raised and interacted with our bodily states, actions, and even mental simulations (Barsalou, 2008). Furthermore, previous studies show the orientation of a product toward a participant's dominant hand could facilitate his or her mental simulation of motor responses. This research addresses the question that whether such mental simulation will further contribute to the preference of products. We use pictures of handbags and nonhandbag products as materials so that we can selectively induce the mental simulation of handhold with pictures of handbags. We also manipulated motor response (holding a mouse or not). Participants were asked to conduct a categorization task (Experiment 1) or a preference evaluation task (Experiment 2). Results revealed that compared with handbag conditions, participants categorized faster to nonhandbag product while they were holding mouse. Participants' preference evaluation for handbag was higher in the pictures with hand than that with no hand. However, the preference was interfered when participants were holding a mouse than when their hands were free. These results showed the occupied perceptual resources which were required for embodied mental simulation impaired the categorization and preference of the visual product. It implied facilitation of embodied mental simulation decreases purchase intentions.

Differences in the Spatial Attention of Fencers and Nonathletes

Masaki Takayose[1], Yusuke Sato[2], Masashi Fukami[2], Hideaki Sato[3], Takako Hiraki[4], Ryo Koshizawa[4] and Shuhei Shiroma[5]
[1]Nihon University College of Industrial Technology, Chiba, Japan
[2]Nihon University College of Commerce, Chiba, Japan
[3]Nihon University College of Law, Chiba, Japan
[4]Nihon University College of Economics, Chiba, Japan
[5]Nihon University College of Humanities and Sciences, Chiba, Japan

Fencers need to process visual information from a wide field in order to perform well. By assessing visual strategies and cerebral activities of fencers and nonathletes, we examined how visual information is extracted from a space and attentional resources are allocated. Participants were female fencers and female nonathletes. They performed in a modified spatial cueing paradigm. The angles from the fixation point to the target were 5° and 15°. The cue stimulus consisted of three conditions (valid, invalid, and neutral). In these paradigms, the participants were required to press a key when a target was presented. Eye tracking and electroencephalography (EEG) were used to record eye movements and cerebral activity. Event-related potential (ERP) was obtained from the recorded EEG. The reaction time of fencers was faster than that of nonathletes in all conditions. Gaze velocity revealed that while some nonathletes were quick, they attempted to detect the target in their central vision only. Under the neutral 15° condition, the N1 ERP component amplitude increased in fencers but decreased in nonathletes. From these results, we concluded that while fencers could allocate attentional resources to a wide spatial field, nonathletes could not, possibly due to a lack of such resources.

Anticipation Skills of Badminton Players Regarding Overhead Strokes Revealed by Using a Temporal Occlusion Method

Yasuhiro Seya and Hiroko Nakamura
Aichi Shukutoku University, Nagakute, Japan

It is well known that sport-specific perceptual and cognitive abilities as well as physical abilities contribute to athletes' successful performance in sport. In this study, we

investigated the abilities of experienced badminton players and novices to anticipate the type of overhead strokes (i.e., high clear, drop, and smash) by using a temporal occlusion method. In an experiment, experienced badminton players and novices viewed video clips of opponents' strokes which were occluded at one of the five temporal points from −400 milliseconds to 100 milliseconds based on the shuttlecock-racket impact. The participants were asked to accurately predict the type of strokes. Results showed significantly higher proportions correct in the experienced players than in the novices. The experienced players yielded significantly better performance than chance level even at the occlusion condition of −400 milliseconds. The analyses for each type of strokes showed significantly better performance to the drop shot than to the smash shot in the experienced players, while they revealed significantly better performance to the high clear shot than to the other stroke shots in the novices. These results are discussed in relation to literature on expertise and deception in sports.

Estimated Size of a Basketball Hoop Predicts Success in Shooting Baskets

Carl Granrud, Gabriel BelzileRolland, Chuk Davis Ezeli, Hunter Katona, Margaret Maday, Erica McDonald and Alana Reed
University of Northern Colorado, Greeley, CO, USA

Our research explores the relationship between actions toward objects and judgments of the objects' sizes. A previous study found that participants judged a basketball hoop as larger if they were successful at making baskets and smaller if they were less successful. However, this effect occurred only for size estimates made from memory. If the hoop was in sight as participants judged its size, shooting success was uncorrelated with estimated size. This study followed up on these findings, asking whether estimated size correlated with shooting success when participants made size estimates before shooting. Participants viewed a basketball hoop and then estimated its size from memory. They then attempted 15 basketball shots. Estimated size correlated significantly with shooting success; participants who judged the hoop as larger generally made more baskets and those who judged it as smaller generally made fewer baskets. Previous results showed that shooting success predicts estimated size; the new results show that estimated size predicts shooting success. This suggests that shooting success does not cause variations in estimated size. Instead, it is likely that an unidentified third variable causes the correlation between shooting success and estimated size. We are currently working to identify this variable.

Snakes and Cakes—Perceived Distance of Appetitive and Aversive Stimuli

Oliver Toskovic
Laboratory for Experimental Psychology, Faculty of Philosophy, University of Belgrade, Serbia

Vertical distances are perceived as longer than horizontal ones. This perceived distance anisotropy can be attributed to differences in effort required for reaching objects in front or above us. Accordingly, we might argue that such tendency might differ for appetitive (provoking reaching) and aversive objects (provoking avoidance). We performed two experiments with 18 participants in each, whose task was to match distances of two stimuli on horizontal and vertical direction, in virtual reality display. Stimuli were virtual objects representing appetitive (cakes) or aversive (snakes) stimuli, positioned in front or above subjects in VR. In the first experiment, participants were matching distances of identical stimuli (cakes to cakes and snakes to snakes), while in the second one, they were matching distances of opposite stimuli types (cakes to snakes and vice versa). Results showed significant effects of direction (vertical distances were perceived as longer) which is in line with all previous findings. But we did not find any effects of stimuli type, meaning that perceived distance anisotropy remained unchanged for appetitive and aversive stimuli. We might argue that perceived distance anisotropy is not related to reaching effort, or that these stimuli types did not provoke reaching or avoiding actions.

Amount of a Donation Is Influenced by Imaginary Temporal Distance

Kyoko Hine[1], Sho Kasaka[2] and Yoshiaki Tsushima[3]
[1]Toyohashi University of Technology, Japan
[2]Tokyo Denki University, Japan
[3]National Institute of Information and Communications Technology, Tokyo, Japan

Amount of a donation is a major preoccupation for a charitable organization. Usually, people hesitate to contribute to an unfamiliar community/organization. Do we have any good way to get people to pay larger amount of contributions to unfamiliar people? Previous studies suggest that imagining the near future evokes a feeling of caring about close people whereas imagining the far future evokes a feeling of caring about unfamiliar people. Does such imaginary temporal distance affect charitable behavior? In this study, participants were randomly assigned the near future condition ($N = 12$) or the far future condition ($N = 12$). Participants in the near future condition were asked to imagine what they would do the next day. On the other hand, participants in the far future condition imagined what they would do 10 years after. After the imagination, participants were asked to report how much they would

donate money to their own country and a foreign country. The amount of donation to a foreign country in the far future condition was significantly higher than that in the near future condition. This study clearly showed that imaginary temporal distance affects amount of a donation.

Does Visual Space Correspond to Imagined Space?

Nicole Ruta, Alistair Burleigh and Robert Pepperell
Cardiff Metropolitan University, UK

Visual space has a nonlinear structure that is reflected in artistic depictions of observed and imaginary space (Pepperell & Haertel, 2014; Mather, 2015). Recent studies showed that the same neuronal pathways are activated during mental imagery and perceptual tasks (Kosslyn et al., 2001; Palmiero et al., 2019). We therefore hypothesised that imagined visual space corresponds to the nonlinear structure of observed visual space. To test this, we integrated drawing tasks with psychophysical measures. We asked participants to imagine looking at a series of identical objects arranged in a line, to pay attention to one in particular, and then to draw how all the objects appeared in their imagination. We found that participants drew the attended object significantly bigger than the peripheral objects, which corresponds to the way people report perceiving visual space (Baldwin et al., 2016). A further set of online studies was conducted to quantify perceptual qualities of participants' mental images, first stimulated by semantic descriptions and then by visual stimuli of both human figures and abstract discs. Our findings confirmed the critical role of enlarged object size in imagined visual space and its intrinsic link with the phenomenology of visual perception.

Area Perception in Interior Space

Christoph von Castell, Heiko Hecht and Daniel Oberfeld
Johannes Gutenberg-Universität Mainz, Germany

Perceived floor surface area is an important aspect of interior-space perception. However, little is known in regard to the relevant visual cues that inform floor-area perception, and how these cues are weighted in the judgment process. We stereoscopically presented rectangular interior spaces on a head-mounted display (HTC Vive) and varied room width (3–7 m), room depth (5–9 m), and ceiling height (2–5 m) independently of each other in a factorial design. Observers remained stationary in the virtual rooms and could dynamically explore their layout by means of head movements. Observers estimated the floor area of the presented rooms in units of square meters. Our results show that the judgments of floor area mainly relied on an additive rather than multiplicative combination of the width and depth dimensions. This is inconsistent with the geometric principles, but it is consistent with performance in area estimation of small rectangular two-dimensional objects. The estimated floor area was largely unaffected by the manipulation of ceiling height. This is at odds with architectural guidelines, which hold that an increase in ceiling height should reduce perceived floor area. Potential mechanisms underlying the additive combination of width and depth are discussed.

Characterization of Visual Detectors Using Stimuli Carrying Controlled Versus Natural Statistics

Lorenzo Landolfi[1] and Peter Neri[2]
[1]Scuola Superiore Sant'Anna, Pisa, Italy
[2]Ecole Normale Supérieure, Paris, France

A central question in contemporary vision science is whether and how visual detectors adapt their response characteristics to natural signals. We break this complex problem into two interrelated issues: (a) how the visual detector may adapt to signals that fall directly within its response field and (b) how it may adapt to signals that fall outside its response field but may modulate its response to what is presented within the response field (contextual effects). We measure perceptual tuning of human visual detectors when stimulation is applied either directly or indirectly to the response field, for stimulation that is either artificially uncorrelated or conforms to natural statistics, and while performing tasks that either enforce or do not enforce explicit processing of contextual information. We demonstrate how to avoid artefacts that are potentially introduced by the correlated nature of natural statistics and that may impact our tuning estimates. When these confounding factors are controlled for, it becomes possible to compare and model the operation of visual detectors in response to different input statistics. We discuss the specific adaptive properties that become measurable in response to natural statistics, both with relation to local stimulation and to contextual modulation from the surrounding scene.

Is the Representation of Size Variance Scale Invariant?

Midori Tokita[1], Yi Yang[2] and Akira Ishiguchi[2]
[1]Mejiro University, Tokyo, Japan
[2]Ochanomizu University, Tokyo, Japan

It has been suggested that the representation of orientation variance is independent of mean orientation. Unlike orientation, which is measured on the interval scale, size, speed,

and brightness and so on are measured on the ratio scale. Thus, the variance value changes with the mean value to achieve the same relative variability. Herein, we examined whether the representation of variance in the latter cases is independent of the mean value, the same way as that of the orientation variance. To test this, we performed an experiment using the size of a disk. The set of stimuli comprised 16 disks each with a different variance. We then tested how the mean size of the disk set affected the precision and accuracy of the variance discrimination task, introducing six levels of mean size. For each mean size, we obtained the Weber fractions (WF) and points of subjective equality using the method of constant stimuli, in which the observers decided which size variance was larger in each trial. Our results showed that the WF was constant within a certain range of mean size. Furthermore, the WF increased when the difference in mean size was large. Scale invariance of size variance discrimination is discussed.

Predicting Perceptual Ocean Surface Wind From Images

Ying Gao, Xiaofeng Chang, Junyu Dong, Jiqiang Feng and Lin Qi
Ocean University of China, Qingdao, People's Republic of China

Control of Sailing boats on the sea is a complex process as natural conditions such as winds have strong influence on it. The wind changes fast and it is difficult to predict. Experienced sailors are able to estimate the ocean surface wind according to the visual perceptual information of the sea surface. To approximate human perception of ocean surface wind for sailing control, a deep learning-based model is designed to effectively predict whether the current ocean surface wind exists in images captured through monitoring equipment on sailing boats. The prediction process is automatic by considering the different states of the ocean surface environment under different wind conditions and can be used for route planning and dynamic anticollision for sailors or unmanned sailing boats. The proposed method is a combination of VGG19-Net and SVM. The VGG19-Net is used to extract the visual perceptual features of the ocean surface images and SVM is used to predict whether the perceptual feature is windy or calm. The fivefold cross validation for hyperparameters selection is tested in the classification experiments. The average accuracy over five validation sets is 93.5%.

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Perceptual Load and Inattentional Deafness During Natural Scene Perception

Luca Chech and Nilli Lavie
Institute of Cognitive Neuroscience, University College London, UK

High perceptual load in a task has been shown to result in inattentional blindness and deafness. Previous research has typically established these effects by varying the set size or perceptual demands of the task, using rather simple stimuli (e.g., crosses, letters). Here, we aimed to establish the impact of perceptual load on awareness during natural scene perception. Observers classified natural scene images according to their perceived level of visual complexity. Images whose complexity ratings were below the 25th percentile (low load) or above the 75th percentile (high load) were then presented to new observers in a novel postcue search task. Observers attended to a series of images and made object category presence/absence responses (e.g., "was there a chair in the last image") to an occasional probe and detected a tone, randomly presented on 10% of the images. Results showed longer search RTs and lower accuracy for high (vs. low) complexity images, thus confirming that complexity ratings corresponded to visual search load. Importantly, tone detection sensitivity was significantly reduced for tones presented during high (vs. low) complexity images. The results establish the effects of visual complexity on perceptual processing and demonstrate that search of more complex scenes results in inattentional deafness.

Far-Peripheral Neural Correlates of Scene Processing

Anna C. Geuzebroek[1], Alida J. Q. Chen[1], Albert V. van den Berg[2] and Koen V. Haak[1]
[1]Department of Cognitive Neuroscience, Donders Institute, Radboud University, Nijmegen, the Netherlands
[2]Department of Cognitive Neuroscience, Radboud University Medical Centre, Nijmegen, the Netherlands

In everyday life, we are completely embedded in the visual scene surrounding us. Nevertheless, our understanding of the neural mechanism of scene perception is dominated by studies bounded by a monitor. This limits the stimuli to the most central part of our visual field, and it is "assumed" that the same principles can directly be applied to peripheral vision. However, it is well known that visual information is processed in a significantly different eccentricity-dependent manner, meaning that our grasp of the scene processing networks is biased toward more central contributions. More recently, Elshout et al. (2018) and Mikellidou et al. (2017); however, delineate the V2A and Prostriate as great examples of areas devoted to monitor

far-peripheral vision, although maybe unconsciously. Here, we present a novel method to present wide-field scenes that fill the binocular visual field almost completely, to discover how far-peripheral scene information is processed uncovering functionality of area V2a.

EEG Event-Related Potentials to Recognizing Natural or Urban Scenes Presented Upright or Upside-Down

Priscilla Heard[1], Yu Lim[1], Alice Stephenson[1] and Ute Leonards[2]
[1]University of the West of England, Bristol, UK
[2]University of Bristol, UK

Kaplan (1995) suggested that natural environments are particularly rich in characteristics necessary for the restorative experiences of fatigue (Attention Restoration Theory). Joyce, Redmill, and Leonards (2017) reported that gait was slower to urban rather than natural scenes, possibly due to the visual discomfort induced by the urban scenes and the higher cognitive load. We follow this up with an EEG study where 50 urban scenes and 50 natural scenes were presented to 20 participants, in random order, once in their normal orientation and once inverted to control for the effect of low-level stimulus characteristics (stimulus presentation = 1,000 milliseconds; ISI = 1,000–1,500 milliseconds). Some scenes were presented repeatedly with the same orientation, and the participants were asked to respond to any such repeated scene. The Event-Related Potentials were averaged for each experimental condition: (a) urban upright, (b) urban inverted, (c) natural upright, and (d) natural inverted. The amplitude of the P100 measured over the Oz electrode was significantly smaller for urban as compared with nature scenes, irrespective of orientation. More interestingly, the P300 for the urban upright was significantly larger than for the other three conditions, suggesting greatest attention and automatic additional recruitment of higher cognitive processes in urban image processing.

Dynamical Coding of Natural Textures in the Human Visual Cortex: an EEG Study

Isamu Motoyoshi, Taiki Orima and Suguru Wakita
The University of Tokyo, Japan

To understand the temporal dynamics of neural information processing of visual textures, this study analyzed relationships between visual evoked potentials (VEPs) and simple image statistics and some deeper representations in natural textures. We recorded EEG signals from 14 observers viewing 166 natural texture images presented foveally in random order for 500 milliseconds with a 750 milliseconds blank. We computed the correlation coefficients between occipital VEP amplitudes (O1+O2) and image statistics believed to be encoded in V1 and V2, and the responses of multiple layers in a DNN model (VGG19). The analysis revealed that correlations with moment statistics (*SD* and kurtosis) rose up at different latencies across spatial frequencies, and those with cross-band energy correlations at later latencies. Correlations with the maximum response of each DNN layer also varied at different latencies across layers. Similar data were obtained for PS-synthesized images, but there were significant differences at latencies of 200 to 300 milliseconds. These results indicate that early visual cortex encodes with systematically different temporal dynamics for different classes and spatial scales of image statistics and for different levels of a DNN representations.

Effect of Lighting Conditions on Visual Texture of Cloths

Shino Okuda and Aiko Deguchi
Doshisha Women's College of Liberal Arts, Kyoto, Japan

The purpose of this study is the effect of diffusional or directional properties of lighting on the visual texture of cloths. We conducted a psychological experiment on the visual texture of some cloths. First, we set five kinds of lighting conditions, which were different in the ratio of directional lighting using LED lamps as directional light source and with fluorescent lamp as diffusional light source. Also, we prepared eight kinds of black cloths and each cloth was put on the waved plastic panel. Participants observed each cloth and evaluated visual texture with 11 adjective-pairs, glossy-mat, rough-fine, hard-soft, thin-thick, cold-warm, light-heavy, dry-wet, stable-dynamic, blurred-distinct, planar-stereoscopic, artificial-natural. Also, they answered "valuableness," "beautifulness," and "preference." Seventeen participants are all female in their 20. According to the results, amunzen (polyester 100%) and linen (jute 100%) were glossier, as the ratio of directed light was higher. However, velour (polyester 100%) and spark-satin (nylon 100%) were not affected by the lighting conditions. In conclusion, the visual appearance is affected by the diffused/directed properties of the lighting conditions.

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Relations Between Material Classes, Material Attributes, and Image Statistics

Mitchell van Zuijlen, Sylvia Pont and Maarten Wijntjes
Delft University of Technology, the Netherlands

Humans can visually differentiate between and within material classes, such as metal, skin, and so on. This affords successful interaction with the environment facilitating judgment if a red glow is originating from dangerously hot metal or from the reflectance of red plastic. This ability to visually differentiate seems to be driven by our ability to perceptually judge attributes, such as glossiness, hardness, and so on, which is suggested to be (partly) mediated by image statistics, such as the peak, width, and shape of colour or luminance distributions. We collected 30 exemplars for 15 material classes. For each stimulus, 10 participants made perceptual judgments for 10 attributes. In addition, we measured four image statistics. Inter- and intraobserver correlations showed that participants were consistent and that there was agreement between participants, but the measure of agreement depended on the attribute. The distributions of attributes were distinct between some classes, such as glass and stone, but showed similarities for others, such as skin and paper. While attributes and image statistics displayed weak correlations when generalized over all classes, they increased in strength for individual classes. This suggests that some relationships between image statistics and attributes are material class specific, in addition to the generic ones.

Predicting Material Softness Dimension in Active Touch

Dicle Dovencioglu[1], Katja Doerschner[1,2] and Knut Drewing[2]
[1]National MRI Center, Bilkent University, Ankara, Turkey
[2]Department of Psychology, Justus-Liebig University, Giessen, Germany

People attribute softness to describe a wide variety of materials that differ substantially in their physical properties such as silk or cream. In a perceptual study, we showed that perceived softness dimensions are beyond compliance, we identify four new dimensions: deformability, viscosity, surface softness, and granularity. In a video analysis on a large data set (20 Materials $\times$ 10 Subjects), we extract spatial and temporal patterns of hand motions during free and haptic explorations of soft (e.g., velvet, slime) and hard materials (e.g., chick peas, glass balls). We show that softness dimensions are evident in this recently identified set of eight exploratory procedures: pressure, rub, stroke, rotate, stir, pull, run through. Then, we train a support vector machine with this large data set of exploration patterns. After cross-validation, we can predict the softness dimensions of new exploratory hand motions at above chance accuracy levels, as high as 97% for granular materials. We conclude that (a) the materials' softness dimensions systematically influence how participants optimally explore materials, (b) different softness dimensions manifest themselves both in perceptual judgements and in hand motion patterns, and finally, (c) these patterns have predictive power to decode the nature of materials from hand motions.

Progressive Power Lenses With Plano Peripheral Mean Power: Influence of the Prescription and Assessment of Visual Fields

Amelia González, Marta Álvarez, Melisa Subero, Eva Chamorro, José Miguel Cleva and José Alonso
IOT, Madrid, Spain

Recent studies have demonstrated that peripheral mean power (PMP) of a progressive addition lens (PPL) influences visual perception of the users. Because of that, lenses with a distribution of PMP close to zero have been recently proposed. However, the influence of the refractive error of the user in visual performance provided by these lenses has not been analyzed. In this study, the undistorted viewing field (CVA) of lenses with plano PMP is compared against lenses with the standard distribution of positive PMP in a group of 9 myopes and 14 hyperopes. CVA was evaluated using a rotational platform that makes the participants look through the lateral areas of the PPL lens. While being positioned at a predefined set of angular positions on the platform, the participants were asked to identify 0.1 logMAR low-contrast letters. Results showed that myopes achieved a 24% wider CVA with plano PMP lenses in comparison with standard lenses ($p = .047$). For hyperopes, the difference in CVA was not significant ($p = .249$). These results suggest that CVA depends on the value of the PMP linked with the refractive error being myopic or hyperopic.

Understanding Peripheral Looking Strategies Related to Simulated Preferred Retinal Loci

Marcello Maniglia[1], Kristina Visscher[2] and Aaron Seitz[1]
[1]University of California, Riverside, CA, USA
[2]University of Alabama, Birmingham, AL, USA

Here, we present a systematic approach to characterize eye movement strategies in cases of central vision loss that

distinguishes different oculomotor components, namely, Saccadic Rereferencing, Saccadic Precision, Fixation Stability, and Latency of Target Acquisition. We tested this approach in a group of healthy individuals in which peripheral looking strategies were induced through the use of a gaze contingent display obstructing the central 10° of the visual field. The use of simulated scotoma helps overcome a series of challenges that research in clinical populations face, from recruitment and compliance to the diverse etiologies of disease and the extent and nature of the visual loss, offering the possibility of testing the development of compensatory oculomotor strategies and possible intervention approaches. Results show substantial differences in characteristics of peripheral looking strategies, both within and across individuals. This more complete characterization of peripheral looking strategies will help us understand individual differences in rehabilitation after central vision loss.

Visual Acuity and Visual Performance in Children With Ophthalmopathology

Anna A. Kazakova[1,2], Hristo P. Tahchidi[1], Svetlana I. Rychkova[2], Maria A. Gracheva[2], Igor V. Senko[1] and Alla V. Strizhebok[1]
[1]Pirogov Russian National Research Medical University, Moscow, Russia
[2]Institute for Information Transmission Problems (Kharkevich Institute), Russian Academy of Sciences, Moscow, Russia

The aim of the work was to assess dependance of visual performance on visual acuity in children with ophtalmopathology. Subjects were 62 children with ophtalmopathology (7–14 years, 10.8±2.0), visual acuity 0.08–1.25 dec. units. Visual performance was assessed by means of two computer programs elaborated for Bourdon test with Landolt rings (Test 1) and detection of the gap in the nonthreshold Landolt ring (Test 2); viewing distance −50 cm. Partial correlation between visual acuity and visual performance (excluding age factor) appeared to be $rs=.472$, $p<.01$ by Test 1; $rs=.607$, $p<.01$ by Test 2. Taking into account this significant correlation, the subjects were divided into two groups: (a) with mild ophthalmopathology ($N=36$, ametropes with and without amblyopia, visual acuity—0.5–1.25 (0.92±0.16)), (b) with severe ophtalmopathology ($N=26$, optic nerve atrophy and retinopathy, visual acuity—0.08–-0.63 (0.2±0.17)). The visual performance in group with mild pathology was significantly better than in the other group (Mann–Whitney test, $p<.01$). Visual performance is correlated with visual acuity and is significantly lower in children with severe organic ophthalmopathology, that should be taken into account in the inclusive education.

Neuropsychological Assessment of Visual Information Processing in Childhood—Study Aims

Eline Kreuze and Christiaan Geldof
Royal Dutch Visio, Centre of Expertise for Blind and Partially Sighted People, Amsterdam, the Netherlands

Neuropsychological assessment of visual information processing in childhood includes assessment of visual attention and visual perceptive functioning, a complex and time-consuming process. Many commercial instruments are based on outdated theories. Well-defined tests from research labs are unavailable for clinical practice. Clinicians therefore rely on outdated tests, nonvalidated, and nonstandardized tests and additional subtests that were not designed to assess visual information processing. The resultant variability in diagnostic instruments and procedures undermines clinical decision-making. This study aims to construct a comprehensive neuropsychological assessment battery to map visual information processing functioning in children and adolescents. A systematic literature review will be conducted to identify neuropsychological tests measuring visual information processing function(s). Subsequently, a first selection of tests is made using a Delphi study to define their construct validity and to construct new test(s) if the available instruments appear insufficient. Constructing a clinically relevant assessment instrument requires an integrative theoretical framework describing the visual information processing functions and their relevance for functioning in daily life. The instrument may serve future diagnostic specificity, further understanding of disorders causing deficits and indicating interventions in rehabilitation. Close collaborations between clinicians and vision scientists might be essential to arrive at such results.

Effect of Visual Impairments on the Auditory–Visual Fusion in Speech Perception: A Pilot Study

Lucia Schiatti and Monica Gori
Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Genoa, Italy

In people with typical vision, speech is a bimodal percept resulting from the cross-modal integration of visual and auditory information at the level of the central nervous system. Visual impairments may have a critical impact on the mechanisms of audiovisual associations underlying such bimodal perception. Our hypothesis is that a congenital or acquired prolonged deprivation of the visual component of speech perception may influence the mechanism of auditory-visual fusion, possibly giving less weight than usual to the visual remaining modality. We tested this hypothesis by performing a McGurk test in low vision adults with more than 2 years of

visual impairment and in a control group of sighted people (presenting blurred and unblurred visual conditions). In accordance with previous work, the latter showed a reduced McGurk effect of visual-audio fusion for the blurred condition. In contrast, low vision individuals show higher dominance of the auditory modality. These preliminary results confirm our hypothesis that visual impairment alters the mechanism of auditory-visual fusion for processing verbal information.

Allocentric Representation in the Tactile and Visual Domains: A Comparison of Sighted, Low Vision, and Blind Children

Chiara Martolini[1,2], Giulia Cappagli[2,3], Sabrina Signorini[3], Antonella Luparia[3] and Monica Gori[2]
[1]DIBRIS, University of Genoa, Italy
[2]Italian Institute of Technology, Genoa, Italy
[3]IRCSS Fondazione Istituto Neurologico Casimiro Mondino, Pavia, Italy

The ability to switch from an egocentric to an allocentric frame of reference is fundamental to build a veridical spatial representation of the environment. However, no study to date has compared allocentric representations of space in the tactile and visual domains by comparing the performance of children with and without visual experience. Our study assessed the ability of 5- to 12-year-old visually impaired and blindfolded sighted children to switch from egocentric to allocentric coordinates in a tactile and a visual mental rotation task, in which they were asked to change their body perspective while localizing objects in space. Results indicate that while low vision children manifest the ability to switch from egocentric to allocentric coordinates earlier in the tactile domain compared with the visual domain, sighted children manifest the ability to switch from egocentric to allocentric coordinates earlier in the visual compared with the tactile domain. Moreover, results indicate that blind children show a delay in the acquisition of allocentric spatial representation compared with low vision children. These findings suggest that vision might be necessary to calibrate touch during the development for spatial updating, that is fundamental to switch from egocentric to allocentric coordinates.

Vr Reveals Link Between Reduced Head–Trunk Coordination and Congenital Glindness

Davide Esposito[1,2], Alice Bollini[2] and Monica Gori[2]
[1]DIBRIS, Università di Genova, Italy
[2]Istituto Italiano di Tecnologia, Genoa, Italy

The development of the spatial cognition takes place by gathering motor and sensorial experience. In this context, the motor control of the head plays an important role, as it is the anatomical site of vision, hearing, and vestibular information. Hence, learning the causal link between head movement and change of the perceptual scene is crucial. It is well known that, in infants, the head is controlled and moved together with the trunk. Here, we hypothesize that the decoupling happens gradually as the sensorimotor system builds an internal model of the head dynamics, with the visual input playing a crucial role in this operation. If so, then head and trunk should be more bound in blind people than in sighted individuals. To test our hypothesis, we developed an ad-hoc made acoustic virtual reality game that required blind and sighted individuals to rotate head and trunk, coordinated or free. Results showed that, compared with healthy controls, when free to move, head and trunk of blind individuals were more bound, supporting our hypothesis. Future efforts will address the development of a training aimed at decoupling head and trunk, with the goal of improving spatial orientation skills in blind people.

Blindness Onset Impacts the Anatomo-Functional Organization of the "Visual" Cortex

Jyothirmayi Vadlamudi[1,2] and Olivier Collignon[1,3]
[1]Institute for Research in Psychological Sciences, Université Catholique de Louvain-la-neuve, Belgium
[2]Institute of Neuroscience, Université Catholique de Louvain-la-neuve, Belgium
[3]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

The study of blind individuals represents a unique model to understand how change in sensory experience shapes brain development. However, the impact of blindness onset on the brain functional and structural architecture remains poorly understood. In our study, we used magnetic resonance imaging to characterize the amount of functional (sound-induced activity) as well as structural (cortical thickness, surface area, and volume) reorganization in the occipital cortex of people with early and late acquired blindness. Preliminary results show increased cross-modal response to sounds in occipital regions of both blind groups, but to a larger extent in case of early visual deprivation in cuneus, pericalcarine and lingual gyrus. These

same regions show a trend for increased cortical thickness but reduced surface area in the early blind, whereas those regions show a global reduction in cortical thickness, surface area, and gray matter volume in late blind people. Altogether, these results show that the occipital cortex remains highly susceptible for structural and functional reorganizations even in late acquired-blindness, but that such changes are distinct from those observed in case of early blind people.

Time-Resolved Discrimination of Audiovisual Emotion Expressions

Federica Falagiarda and Olivier Collignon
Université catholique de Louvain, Belgium

Humans seamlessly extract and integrate the emotional content delivered through faces and voices of others. However, it is poorly understood how perceptual decisions unfold in time when people discriminate emotions' expressions conveyed through dynamic facial and vocal signals, as in natural social contexts. In this study, we relied on a gating paradigm to track how the recognition of expressions of emotions across the senses unfolds over exposure time. We first demonstrate that across all emotions tested, a discriminatory decision is reached earlier when seeing faces than hearing voices. Importantly, multisensory stimulation consistently reduced the required accumulation of perceptual evidences needed to reach correct discrimination (isolation point). We also observed that expressions with different emotional content provide cumulative evidence at different speeds, with Fear being the expression with the fastest isolation point across the senses. Finally, the lack of correlation between the confusion patterns in response to facial and vocal signals across time suggests distinct relations between discriminative features extracted from the two signals. Altogether, these results provide a comprehensive view on how auditory, visual, and audiovisual information related to different emotional expressions accumulates in time, highlighting how a multisensory context can fasten the discrimination process when minimal information is available.

Poster Session 8

New Stereotest—Sensitivity and Specificity

Zsófia Csizek[1], David P. Piñero[2], Eszter Mikó-Baráth[1], Anna Budai[1], Pedro Ruiz Fortes[2], Carlos Javier Hernández Rodríguez[2], Roberto Soto Negro[2] and Gábor Jandó[1]
[1]University of Pécs Medical School, Hungary
[2]Department of Pharmacology and Anatomy, University of Alicante, Spain

Even though amblyopia has a high prevalence in the population (3%–6%), screening for the disease is not properly implemented. In this study, we evaluated the sensitivity and specificity of a new Android-based stereotest (dynamic random-dot stereogram E—DRDSE) for the detection of amblyopia. We used different densities of random dots to set several levels of difficulty: very low density (VLD 0.7%) and low density (LD 1%). In comparison: Lang II, TNO, Stereofly and Frisby stereotests were also performed. We examined 376 children in Alicante, Spain (aged 4–15 years, mean age 7.2 years). Ophthalmological examination was performed at first. DRDSE was presented on a tablet. We estimated and compared the sensitivity and specificity of all stereotests. For statistical analysis, we used custom made MATLAB software. DRDSE with VLD had a 100% sensitivity for amblyopia and with LD had 83% sensitivity. Specificity was 80% in a VLD and 69% in a LD. The sensitivity and specificity of the stereotests were as follows: Lang II 48% and 98%, TNO 84% and 85%, Stereofly 83% and 91%, and Frisby 77% and 82%. DRDSE test is highly effective for the detection of amblyopia compared with other stereotests.
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A Stereoacuity Test Using a Head-Mounted Display

Hyosun Kim[1], Rangkyun Mok[1], Yongwoo Yi[1], Young-Jun Seo[1], Sungkook Park[1], Byeonghwa Choi[1], Sungchan Jo[1] and Jinu Han[2]
[1]Samsung Display, Yongin-si Republic of Korea
[2]Yonsei University, Seoul, Republic of Korea

This study was explored in order to evaluate the validity and test–retest reliability of a contour-based stereoacuity test using a Head-Mounted Display (HMD). Thirty-two normal adult subjects (age range: 23–47 years) were

recruited. Contour-based circles (crossed display: 1,960 to 195 arc of seconds [arcsec]) were generated as separate images on a high-resolution phone display (Galaxy S7) using an HMD (Galaxy Gear VR). Two images were independently projected to each eye as graded circle with random-dot background. While the position of the stimulus changed from among three possible locations, the subjects were instructed to select the circle with disparity by pressing the corresponding position on a keypad. The results of the new HMD stereotest were compared with those from standard Randot and TNO stereotests. The HMD stereotest showed good concordance with the Randot and TNO sterotests and relatively good test–retest reliability, supporting the validity of the HMD stereotest. In addition, the intraclass coefficient was 0.54 ([0.055, 0.775], 95% CI) between the initial HMD stereotest and retests. Although fine steropsis cannot be assessed using HMD stereotest, this newly developed HMD stereotest can be used as a useful and novel tool for quantitative assessment of real binocular sensory abnormalities.

Priming of Target Feature Probabilities: Effects of Feature Distributions on Intertrial Priming

Arni Kristjansson[1,2], Joy Geng[3] and Sabrina Hansmann-Roth[1]
[1]University of Iceland, Reykjavík, Iceland
[2]National Research University Higher School of Economics, Moscow, Russia
[3]University of California, Davis, CA, USA

Visual memory has remarkably large effects on visual search. In particular, when target features are repeated, search times become faster. Similar effects are also found for repeating distractors. On the other hand, when a distractor feature suddenly becomes a target, search times are slowed down (so-called role-reversals). Recent studies have revealed that the visual system is not only sensitive to a distractor feature per se but distributions of distractor features. Changes in RT are determined not only by whether that particular feature characteristic was a distractor but also the frequency of that feature over consecutive trials. Most probable distractors produce the strongest role reversal, while less probable distractors produce weaker role reversals. Here, we investigated the effects of target probabilities on priming strength. Over long trial blocks, participants searched for an oddly colored target. On each trial, target colors were drawn from either a Gaussian or uniform distribution. The results confirmed that priming is not only sensitive to the repetition of a target feature but also the probability of that feature in a sequence. These results not only confirm the existence of internal representation of feature distributions of targets but also the integration of distribution information over time.

The Neural Substrates of Identity Perception From Face Movements

Katharina Dobs[1,2], David Beeler[1], Isabelle Berry[3,4] and Leila Reddy[2]
[1]Massachusetts Institute of Technology, Cambridge, MA, USA
[2]CerCo, CNRS, UMR 5549, Universite´ de Toulouse, France
[3]Inserm Imagerie ce´rebrale et handicaps neurologiques UMR 825, Toulouse, France
[4]Centre Hospitalier Universitaire de Toulouse, Pôle Neurosciences CHU Purpan, Toulouse, France

Humans extract various cues from facial movements, such as the emotional state, direction of attention, or even the identity of a person. While previous evidence revealed the neural substrates involved in the perception of identity and expressions from facial form and movements, respectively, the mechanisms underlying the perception of identity from face movements are still unknown. Here, we used fMRI to measure the neural representations of identity information in facial movements. Subjects ($n = 11$) performed an identity discrimination task (two-alternative forced choice) on two previously learned facial identities with distinct facial forms and movements. Crucially, in the scanner, subjects had to discriminate the identities based on stimuli that solely varied in the amount of face movement information (10 motion morph steps) but were animated on an average form and thus did not contain form information. Using representational similarity analysis, we find that the face-sensitive area in the right posterior superior temporal sulcus (rSTS) and motion-processing area MT, but not the occipital or fusiform face areas, correlate with the behavioral and physical representational distances ($p < .05$; bootstrap test). These findings suggest that MT and rSTS are involved in the extraction of identity from face motion, thereby providing important constraints on neural models of face perception.

Imagery Vividness Influences the Perception of Faces in Visual Noise

Johannes Salge[1] and Reshanne R. Reeder[1,2]
[1]Institute of Psychology, Otto-von-Guericke University, Magdeburg, Germany
[2]Center for Behavioral Brain Sciences, Magdeburg, Germany

Visual hallucinatory experience is widely unexplored in the normal population mainly because it is highly subjective and variable across individuals. We suggest that some of the reported variability is due to individual differences in

visual mental imagery vividness. Hallucinations can occur when there is increased confidence in mental images over perceptual input. We hypothesized that the ability to activate a vivid mental image influences the extent to which the mind's eye is mistaken for perception. To investigate hallucination-like experiences under controlled experimental conditions, we adopted a paradigm that induces illusory face perception, or pareidolia. In three experiments, we asked subjects to detect faces in high-contrast pure Gaussian noise images, to explore the influence of imagery vividness on pareidolia proneness. We found a reliable correlation between imagery vividness and pareidolia experiences that cannot be explained by instruction bias or response bias. This correlation holds up even when subjects are given very few expectations about the faces that are purported to appear in the noise. Nevertheless, a rich sensory environment that allows for the misinterpretation of noise patterns is necessary for pareidolia to occur. These results indicate that the subjective vividness of mental imagery is an important influence on perceptual experience.

The Role of Adaptation in Estimating and Steering Motion

Linda Bowns
University of Cambridge, UK

Adaptation can be observed as a change in sensitivity to a stimulus, or some aftereffect following the presentation and subsequent removal of a stimulus. Motion aftereffects are well documented, but our understanding of adaptation that gives rise to these effects is limited. Simulated models of motion facilitate examination of adaptation in terms of possible function, site of adaptation, type of adaptation, and provides the opportunity to assess adaptation on simulated performance. Translating random pixel patterns that varied in direction over time were used to investigate performance by the Component Level Feature Model (Bowns, 2018) using various forms of adaptation. Preliminary results show that performance is significantly improved following adaptation. A good candidate for the primary function of adaptation is to enhance sensitivity to changes in velocity over time; the site at which adaptation is most effective is at the level where Gabor filter responses are combined (assumed area MT); and the type of adaptation is to drop out earlier MT responses in favour of more recent MT responses. The CLFM was used because it is built in MATLAB and easily adaptable to more complex translating patterns; however, the conclusions are equally relevant to spatiotemporal energy models.

Effects of Handedness on Early Perceptual Processing in Faces Reflected by the P100 ERP Component

Mitsuyo Shibasaki and Yuki Morita
Meisei University, Tokyo, Japan

Previous studies revealed that handedness affects perceptual processing in faces reflected by the N170 event-related potentials (ERP) component. However, according to recent ERP studies, configural processing of faces may occur before N170 and it is unknown whether handedness influences face processing during the earlier latency period. We investigated the effects of handedness on early perceptual processing of faces using the P100 ERP component. Nineteen right-handed and 14 left-handed healthy adults performed target detection tasks with upright and inverted faces or clocks as target stimuli. During the tasks, electroencephalographic data were recorded from nine scalp electrodes for ERP extraction. P100 amplitudes for inverted faces were significantly larger than those for upright faces at bilateral occipital regions (O1, O2) in the right-handed group, but there was no significant face inversion effect on P100 amplitudes in the left-handed group. In addition, P100 amplitudes for inverted faces at O2 were significantly reduced in the left-handed group compared with the right-handed group, and face inversion effect on P100 amplitudes at O2 was significantly correlated with degree of handedness. Handedness may affect early configural facial processing in the occipital regions around 100 milliseconds after facial stimuli onset.

Do Developmental Prosopagnosics Process Faces Holistically?

Maria Tsantani and Richard Cook
Birkbeck, University of London, UK

Face recognition ability is thought to be determined by the degree to which individuals process faces holistically. Whereas people with excellent face recognition are thought to process faces as a unified whole, people with poor face recognition may employ a piecemeal analysis. To date, empirical tests of this hypothesis have yielded inconsistent findings. In this study, we investigate the effect of disrupting holistic face processing in neurotypical controls and in individuals with developmental prosopagnosia (DP)—a condition characterised by lifelong face recognition difficulties. In the whole-face condition, target faces were briefly presented in their entirety. In the aperture condition, a dynamic viewing window moved over the target revealing the face one region at a time. We compared the effects of whole-face and aperture viewing on participants' ability to categorise the nationality of

celebrity faces (Experiment 1) and to categorise the gender of unfamiliar faces (Experiment 2). Preliminary results show that, as expected, neurotypical participants performed better in the nationality and gender categorisation tasks than the DPs. In both experiments, however, the DPs exhibited a whole-face advantage comparable with typical controls. These findings argue against the view that DPs and neurotypical observers process faces in qualitatively different ways.

Brain Regions That Respond to Faces, Voices, and People

Olga Korolkova[1], Maria Tsantani[2], Nadine Lavan[3] and Lúcia Garrido[1]
[1]Brunel University London, UK
[2]Birkbeck, University of London, UK
[3]University College London, UK

We aimed to identify brain regions that respond to people, independently of the modality (auditory/visual). In two functional magnetic resonance imaging studies, participants completed three functional localizers: visual (silent videos of nonspeaking faces vs. scenes), auditory (voices vs. environmental sounds), and audiovisual (videos with speaking people vs. scenes with sounds). Using data from Study 1 ($N = 30$), we conducted a conjunction analysis of the three localizers to identify regions that responded more to faces, voices, and audiovisual faces voices than to control stimuli. The right posterior STS showed most consistent people-selective activation in 24/30 participants. In Study 2 ($N = 22$), we identified the people-selective rpSTS in each participant, and extracted mean activation and multivoxel response patterns in this region from independent data. The rpSTS responded significantly more to audiovisual stimuli than to faces or voices and more to voices than faces. While face- and voice-responsive patterns correlated moderately, the correlations were significantly higher between the audiovisual patterns and the face- or voice-responsive patterns. These results suggest that not all voxels in the people-selective rpSTS respond to faces and voices similarly. The rpSTS may contain multimodal voxels that respond to people independently of modality, but also unimodal voxels that respond only to faces or to voices.

The Good, the Bad, and the Average: Characterizing the Relationship Between Face and Object Processing Across the Face Recognition Spectrum

Rebecca K. Hendel[1], Randi Starrfelt[1] and Christian Gerlach[2]
[1]Department of Psychology, University of Copenhagen, Denmark
[2]Department of Psychology, University of Southern Denmark, Odense, Denmark

Face recognition skills vary considerably both in the normal population and in various clinical groups, and understanding the cognitive mechanisms contributing to this variability is important. Here, we examine whether good face recognisers (high performers, HPs) perform better than controls on tests of face, object and word recognition, and whether these domains may be dissociated in HPs. Also, we address the same questions in a group of developmental prosopagnosics (DPs) using the same tests. HPs performed significantly better than matched controls on tests of face and object recognition, as well as a reading test, and there was no evidence of dissociation between these domains. In the DP group, we did find a significant dissociation between face and object recognition and reading performance, indicating that face processing was disproportionally affected in this group. This suggests that face recognition in DPs may be qualitatively different from the normal population. In contrast, the superior performance of HPs is not specific for faces but persists across visual domains. On this basis, we propose that superior face processing in HPs relies on more general cognitive or perceptual processes shared with object processing. These may be conceived as a general factor in the visual domain.

The Effects of Script System on Face Processing: A Comparison of German and Chinese Children in Second Grade

Xiaoli Ma[1], Jing Kang[2], Xinran Li[1], Xiaohua Cao[2] and Werner Sommer[1]
[1]Institut für Psychologie, Humboldt-Universität zu Berlin, Berlin, Germany
[2]Department of Psychology, Zhejiang Normal University, Jinhua, China

Reading is a cultural activity in which contemporary humans undergo considerable training. By exercising efficient visual perception for quickly processing print, learning to read may induce effects on general visual abilities, for example, holistic perception. To address this question, we recorded event-related potentials (ERPs) to faces, words, and other stimuli in 42 German and 35 Chinese 2nd grade children. The German and Chinese script system differ

strongly in terms of the complexity and number of symbols to be acquired. Preliminary analyses showed larger N170 amplitudes to face stimuli in Chinese children at the right hemisphere. P100 and P200 component amplitudes were indistinguishable between groups. However, topographic analyses indicated different scalp distributions between groups for the P100 and P200 components. These results suggest that (a) visual training in different written language acquisition may affect face processing, possibly mediated by stronger demands on holistic vision during Chinese reading and (b) head/brain shape differences between ethnicities may modulate scalp topographies of some ERP components.

Disfiguring Features and Visual Attention to Faces

Luc Boutsen[1], Nathan A. Pearson[2] and Martin Juttner[1]
[1]Aston University, Birmingham, UK
[2]University of Warwick, Coventry, UK

Observers can form negative impressions about and behave differently toward, persons whose face contains a disease-signalling or disfiguring feature (e.g., a scar). Given that first impressions from faces form rapidly, the presence of a disfiguring feature might alter the way in which observers attend to faces. We addressed this question by studying the influence of disfiguring features on responses and oculomotor behaviour in different task contexts: (a) free exploration of a peripheral face, (b) spatial cueing effects in the presence of distractor faces, and (c) pro- and antisaccade tasks. Unfamiliar faces were manipulated to include a simulated disfiguring feature (resembling a portwine stain) or a control feature —an occluding textured shape—that was empirically matched for visual salience to the disfiguring features. Our results suggesting that observers' overt, but not covert, attention is differentially affected by disfiguring features. We also show that pro- and antisaccade latencies are affected by the presence of disfiguring features in a face. We discuss the implications of these findings in relation to the question whether the disease-signalling nature of disfiguring features impacts the distribution of attention to a face.

The Role of Host and Heritage Acculturation in Face Preferences

Joanna Wincenciak and Aishwarya Iyer
University of Glasgow, UK

There are considerable cross-cultural variations in face preferences and attractiveness judgement. Hypothetical explanations for these variations include, for example, variable exposure to pathogens, or familiarity and visual experience to specific facial features. However, less is known how stable are cultural influences on face perception. Here, we investigated the influence of acculturation, as a process of psychosocial adjustment to a new culture resulting from a prolonged exposure to a cultural environment, on face preferences. Acculturation toward heritage and host (United Kingdom) culture explored in 65 participants, who also provided attractiveness ratings 40 Caucasian opposite-sex faces experimentally manipulated to contain high and low levels of for facial symmetry, averageness, health and sexual dimorphism. Acculturation toward host culture was found to be significantly related to variance in face preferences across all facial traits in females but no males. In contrast, acculturation toward heritage culture acculturation was found to be significantly related to face preferences in males. These results illustrate the potential of the sex differences within acculturation to U.K. culture, and its influence on face preferences.

Spontaneous Strategies to Resolve Face Naming Failures

Serge Brédart and Marie Geurten
Université de Liège, Belgium

Personal names are particularly susceptible to retrieval failures. A recent review of studies describing people's spontaneous strategies for resolving failures in face naming indicates that people frequently use spontaneous strategies based on a mental search for semantic information (biographical details) or contextual about the target person. However, both cueing and priming experimental studies have shown that providing phonological information may help resolve a name recall failure, whereas providing semantic information is usually not helpful. Unfortunately, a major difficulty with most of these studies is that it is hard to be sure that participants based their responses only by reporting information they strategically searched for and not information that were involuntarily retrieved. To eliminate or, at least, reduce this bias, very explicit instructions specifying that the study focused on voluntary search for information were included in this study. Despite this methodological precaution, the results of this study confirm that middle-aged people (40–66 years) strategically use to search for semantic/contextual

strategies when they try to resolve a name retrieval failure more often than they search for phonological/orthographic information. In addition to frequency of use, participants rated the perceived ease of use and the perceived efficacy of strategies.

Processing of Horizontal and Vertical Spatial Relations in Human Faces for Younger and Older Adults: Modulation of Internal and External Facial Features

David Kurbel, Bozana Meinhardt-Injac, Malte Persike and Günter Meinhardt
Johannes Gutenberg University Mainz, Germany

Face inversion in a horizontal and vertical relations manipulation task results in an asymmetry of recognition performance for younger adults (YA). Relational changes of the eye region on a horizontal axis do not cause notable processing impairments, while changes on a vertical axis do. Current findings reveal that the horizontal/vertical asymmetry arises from different face cue dependencies. The extent to which older adults (OA) depend on certain cardinal facial features when recognizing a face remains unclear. In this study, we compared a sample of YA with OA in a facial feature deletion task with horizontal and vertical manipulation. Results revealed that OA showed stronger impairments in recognizing horizontal and vertical manipulations than YA for conditions that contained internal features only or internal with external features. However, presentation of external features improved OA performance significantly, compensating the deletion of several internal features across conditions. In conclusion, the results show that, while general performance drops with increasing age, OA seem to utilize adjusted strategies when recognizing faces compared with YA. While YA mainly rely on internal facial features, OA integrate external facial information more strongly, while there is weaker spatial integration of internal cues.

Insights Into Face Expertise—Clues From Early Face Orientation Classification

Marie L. Smith[1], Ines Mares[1], Michael Papasavva[1], Fraser Smith[2] and Louise Ewing[2]
[1]Department of Psychological Sciences, Birkbeck College, University of London, UK
[2]Department of Psychology, University of East Anglia, Norwich, UK

There is large and reliable variability in the ability of neurotypical adults to recognise faces. Studies relating neural activity to standardised behavioural measures remain scarce, particularly for time-sensitive approaches. Here, we employ Multivariate Pattern Analysis to explore the time course of the neural representation of faces and for the first time directly relate this metric to individuals' broader face processing ability. Twenty participants viewed faces and houses presented upright and inverted, while their ongoing neural activity was measured via electroencephalography. These individuals were split into high and low ability groups based on their Cambridge Face Memory Test (CFMT) scores. Significant decoding of face orientation was observed for both groups, with earlier and more accurate decoding in participants with stronger face expertise. This orientation sensitivity of the neural response was face selective, with no such effect observed with houses. We found a significant relationship between CFMT ability and peak decoding accuracy ($r = .67$, $p = .001$, 95% CI [0.31, 0.86]) and sustainability of decoding ($r = .51$, $p = .023$, 95% CI [0.08, 0.77]), with an indication of a relationship with decoding onset ($r = -.43$, $p = .061$, 95% CI [−0.73, 0.02]). No significant relationship between decoding and ability was found for classification of stimulus category (faces vs. houses).

The Effect of Viewpoint on Unfamiliar Face Identity Discrimination With EEG Frequency-Tagging

Joan Liu-Shuang[1], Charles C.-F. Or[2] and Bruno Rossion[1,3,4,5]
[1]Institute of Research in Psychology, University of Louvain, Belgium
[2]Division of Psychology, School of Social Sciences, Nanyang Technological University, Singapore
[3]Université de Lorraine, CNRS, Nancy, France
[4]Université de Lorraine, CHRU-Nancy, Service de Neurologie, F-54000, France
[5]Institute of Neuroscience (IoNS), University of Louvain, 1348, Belgium

Are faces better identified when they appear full-front, in profile or at intermediate head viewpoints (depth rotations), and are there differences among individuals in preferred viewpoint for identity recognition? We compare

identity discrimination responses to faces varying across 11 viewpoints (from left to right profile views: 0°, ±15°, ±30°, ±45°, ±60°, ±90°) with EEG frequency-tagging. Observers completed an orthogonal fixation task while they viewed 1-min sequences containing one face identity repeating at 6 Hz, with different face identities (B, C, D...) interleaved every 7th face (AAAAAABAAAAAACAAAAADAA...). Responses at the identity change frequency (6 Hz/7 = 0.86 Hz) indexed face identity discrimination and were significant in all participants. Importantly, these right occipito-temporal responses were modulated by viewpoint. At the group level, responses followed an inverted U-shape peaking over full-front faces and faces slightly turned rightward. At the subject-level, however, response profiles differed between individuals. Some participants showed strongest face identity discrimination around full-front and three-fourth profile views, while others appeared to discriminate identity equally well across nearly all viewpoints. However, far profile views (90°) consistently elicited the lowest identity discrimination responses at both group- and individual subject levels. These findings potentially reveal another dimension of interindividual differences in human face identity recognition.

Pinpointing Individual Differences in Perception Across the Visual Hierarchy by Means of Fast Periodic Visual Stimulation Electroencephalography

Jaana Van Overwalle[1,2], Sofie Vettori[3,2], Laurie-Anne Sapey-Triomphe[1,2], Bart Boets[2,3] and Johan Wagemans[1,2]
[1]Brain & Cognition, KU Leuven, Belgium
[2]Center for Developmental Psychiatry, KU Leuven, Belgium
[3]Leuven Autism Research Consortium, KU Leuven, Belgium

Fast Periodic Visual Stimulation (FPVS) during scalp EEG has been widely used in vision science. Based on the principle that visual stimulation at a constant frequency rate leads to an EEG response at that exact same frequency, the main advantage of FPVS EEG is that automatic discrimination processes can be investigated objectively and implicitly with less decisional or motivational bias. Accordingly, FPVS has recently been applied to investigate individual differences among a number of visual processes. However, these studies have typically been constrained to only one subdomain of visual processing such as high-level (e.g., face discrimination and categorization) or low-level (e.g., contrast sensitivity and visual acuity) perception. Moreover, the interrelation between these various EEG measures and the association between behavioral and neural measures have barely been investigated. In this preliminary study, subjects participated in a series of well-validated high-level (discrimination and categorization of facial identity), mid-level (discrimination and categorization of objects), and low-level (contrast sensitivity and visual acuity) perceptual experiments using FPVS EEG and psychophysical measures. In addition, personality traits were measured using questionnaires. Using this battery of tests and questionnaires, we aim to investigate individual differences at different levels of the visual hierarchy.

Learning of Statistical Priors in a Spatial Localization Task: Differential Effects on Pro- and Antisaccades

Barbara Feulner[1], Danilo Postin[1], Caspar Schwiedrzik[2,3,4] and Arezoo Pooresmaeili[1,3]
[1]Perception and Cognition Group, European Neuroscience Institute Goettingen, Germany
[2]Neural Circuits and Cognition Lab, European Neuroscience Institute Goettingen, Germany
[3]Leibniz Science Campus "Primate Cognition," Goettingen, Germany
[4]Perception and Plasticity Group, German Prim

In the face of ambiguity in sensory inputs, prior knowledge can be used to guide perceptual decisions. Only little is known about how statistical priors are learned. Here, we investigate the dynamics of prior learning in an oculomotor task. Participants had to find a hidden target location based on probabilistic cues and to indicate their guess by either looking at the location (prosaccade) or by looking in the exact opposite direction (antisaccade). Our experimental setup allowed us to investigate how learning of statistical priors unfolds over time and in different task contexts. The results show that although pro- and antisaccades differed in the amount of motor errors during visually guided saccades, they were performed equally well when participants had to base their choices on the probabilistic information collected over time and retrieved from memory. Interestingly, pro- and antisaccades differed in how the priors were updated: whereas in prosaccades higher weights were assigned to the current line position in each trial, antisaccades showed a stronger dependence on the previous trial's estimates. We propose that this difference is due to the distinct mechanisms through which pro- and antisaccades are programmed, with the latter relying on the inhibition of reflexive responses to visual targets.

Effects of Probabilistic Stimulus–Response Associations on Motion Direction Categorization Tasks

Bilyana Zaharieva Genova, Simeon Stefanov Stefanov, Miroslava Dimitrova Stefanova and Nadejda Bogdanova Bocheva
Institute of Neurobiology, Sofia, Bulgaria

Category learning is a crucial survival skill in the ever-changing environment. To characterize learning behavior by trial-and-error, we used a psychophysical task of classifying different motion directions. The stimuli consisted of 50-frame motion sequences of dots moving with constant speed. The stimulus directions varied in the range 0° to 315° at intervals of 45°. Motion direction coherence was 20% in Experiment 2 and 75% in Experiments 1 and 3. We varied stimulus–response associations and assigned randomly the motion directions to a category by a probabilistic rule of 79% true answers. Ten healthy observers had to classify the eight motion directions into eight categories with one exemplar (Experiments 1 and 2) or into two categories each with four exemplars (Experiment 3). The results show that regardless of a wide variety of strategies adopted by the observers: (a) The accuracy improved more at the initial than at the later stages of the learning process; (b) accuracy and response time changed at a different rate during learning; (c) the rate of improvement differed between the experiments. The findings imply that the learning performance depends predominantly on the complexity of the rule of stimulus–response associations and to a lesser extent on the difficulty of the task.

The Comparison of the Effectiveness of Learning Using Virtual Reality and Traditional Educational Methods

Artem Kovalev and Julia Rogoleva
Lomonosov Moscow State University, Russia

Virtual reality (VR) technologies allow users to get a lot of visual information in a short time and it is an important feature to use VR in education. This study was aimed to evaluate the effectiveness of VR in learning of previously unknown information. The participants (29 students: 22 females and 7 males) received three types of stimuli: text, two-dimensional video, and VR. The efficiency of learning was tested with questions before and after each experiment. VR stimuli were presented by Samsung Gear VR. The results showed that the number of correct answers significantly changed from the baseline to the test after the learning session only in "text" ($t = 4.4$, $p < .001$) and "VR" ($t = 3.7$, $p < .001$) conditions. The number of correct answers increased and significantly differed between "VR" and "2D" ($t = 0.398$ $p < .001$), "text" and "2D" ($t = 0.29$, $p < .001$). Thus, it was obtained that text and VR were more efficient for studying than 2D video. We can assert that VR offers an effective method to improve the process of learning but the traditional teaching methods keep playing the important role in education. Funding: The research was supported by grant from RFBR No. 18-29-22049.

Perceptual Expertise of Lifeguard Visual Search and Methods of Training Drowning Detection

Victoria Laxton, David Crundall, Duncan Guest and Christina J. Howard
Nottingham Trent Universty, UK

Visual search studies in dynamic environments indicate search advantages for domain experts. For instance, experienced lifeguards are better at identifying drowning targets in a pool setting compared with nonlifeguards. However, it is currently unclear what the nature of this lifeguard expertise is. We present two studies that, first, explore lifeguard and nonlifeguard performance in a Multiple Object Avoidance task and a Functional Field of View (FFOV) task. Based on the results of Study 1, the second study aimed to explore methods of training drowning detection. Results of the first study demonstrated that only target performance in the FFOV task (identifying whether an isolated swimmer was drowning or not) predicted lifeguard performance in a subsequent drowning detection task. This suggests that superior drowning detection in lifeguards is due to better classification of drowners. Based on these results, we designed a training intervention that required participants to identify drowners, through repeated exposure to videos of isolated drowning targets and nondrowning targets. Nonlifeguards, trained via this intervention, showed improvement in a subsequent drowning detection task compared with untrained controls, who completed an active-control task. The results provide a blueprint for a novel training protocol to improve lifeguard skills.

Pathology Detection Performance in Radiology: Is There an Effect of Expertise on Gaze Behavior?

Stephanie Brams[1], Ignace Hooge[2], Thomas Debrouwere[3], Johny Verschakelen[3] and Werner Helsen[1]
[1]KU Leuven, Belgium
[2]Utrecht University, the Netherlands
[3]UZ Leuven, Belgium

Around 70% of the errors in radiology can be categorized as perceptual errors, that is, errors due to failures in visually detecting the pathology. In medical image interpretation, holistic processing is the basis for proper perception and expert performance, which is based on a global-local search strategy. Due to an extended visual span that evolves with experience, the global scene will be perceived in one glance, followed by a quick local detection of the pathology. In this study, eye-tracking measures were collected from students with different levels of experience in inspecting RX-thoraxes during the completion of a pathology-detection task. In line with the holistic processing hypothesis, results indicated that the visual span extended with experience ($p < .001$). Furthermore, students with practical experience in inspecting RX-thoraxes, fixated longer, but made less eye-movements, compared with students with only theoretical knowledge about RX-thoraxes ($p < .001$). In the most experienced students, the number of eye movements strongly decreased when inspecting thoraxes with pathologies (323.31 ± 95.93) compared with healthy thoraxes (746.77 ± 186.73). These results suggest an efficient adaptive visual search strategy in highly experienced students. This study provides new insights to improve training interventions that might significantly decrease perceptual errors in radiology.

Reward and Cue Effects on Orientation Judgements: A Gaze Contingent Eye-Tracking Study

Britt Anderson and Christie Haskell Marsh
University of Waterloo, Canada

Participants located, fixated, and reported the orientation of a striped patch. The contrast of the patch was adjusted to make localization difficult. A luminance cue appeared on most trials with 50% validity. The target remained visible until 60 milliseconds after fixation. Participants reported the orientation manually. Based on their accuracy, participants received points that could earn them a bonus. The shape of the point:performance function was either sharply peaked or broadly peaked. Participants needed fewer eye movements to fixate the target on validly cued trials. No-cue trials led to later first saccades but the same fixation accuracy as cue valid trials. Despite a constant target viewing time across all cue conditions, the precision reports on validly cued trials were more accurate. The shape of the reward:performance function did not affect the precision of orientation reports or the shape of the error distribution, but it did affect response time. Participants took longer to make their orientation judgements when the reward:performance function was sharply peaked. In summary, cue validity and reward:performance contingencies have independent effects on orientation judgments. Valid cuing leads to more precise judgements that cannot be explained by viewing time or saccade preparation.

Conjunction Search in Perspective Depth Surface Elicits Unique Eye-Movement Patterns

Michael Wagner[1], Tomer Elbaum[1] and Thomas Papathomas[2]
[1]Ariel University, Israel
[2]Laboratory of Vision Research, Department of Biomedical Engineering, Rutgers University

Unlike most visual-search studies, implementing two-dimensional (2D) displays, we turned gray-"rings" and green-"plus" shapes into "volumetric" perspective objects ($2^1/_2$D), placing 24 or 42 on a subjective-perspective "floor" surface (far=up), with a gray "plus" object as target. Identical objects attached to "wall" control surfaces were far=right/left. We studied binocular eye-movements (EyeLink-1000), and target-detection measures while performing visual conjunction search, comparing 2D (fronto-parallel) with virtual depth surfaces ($2^1/_2$D—"floor" and "Wall" surfaces, 50% "no-target" trials $N = 15$). Eye-movement analysis revealed unique search patterns of $2^1/_2$D versus 2D surfaces. In $2^1/_2$D surfaces, first-fixation tended to land at the perceived far region, while 2D search began without up\down preference. Binocular disparity-analysis indicated differences between "near" and "far" target fixations. These patterns were only found with "target absent" and 42-distractors trials but not with 24 distractors. Reaction time was separated into "view period" (from key press to release) and "response period" (key release to choice reaction). "View period" RT's revealed set-size and target-presence effects but not surface-type effect. This suggests that even though search patterns were influenced by surface type, cognitive decision processes remained unaffected. Our results suggest that $2^1/_2$D conjunctive search patterns reflect common underlying mechanisms of vision for action in natural three-dimensional environments.

Examination of Individual Differences in Eye Movement Dynamics During Mouse- and Gaze-Foraging

Jérôme Tagu[1] and Árni Kristjánsson[1,2]
[1]Icelandic Vision Laboratory, School of Health Sciences, University of Iceland, Reykjavík, Iceland
[2]National Research University Higher School of Economics, Moscow, Russia

During finger-foraging tasks, observers change their strategy according to the crypticity of the targets. During feature-based foraging involving two target types (e.g., red and green dots) among two distractor types (e.g., yellow and blue dots), observers select the two target types randomly. However, in more cryptic conjunction-based tasks (e.g., green dot and red square targets among red dot and green square distractors), observers mainly select targets in two long runs, by exhausting one entire target category before turning to the second one. Some observers were, however, considered "super-foragers" because they switched randomly between target types even during conjunction-foraging. In this study, we recorded eye movements of observers during mouse-selection and gaze-selection-based foraging, expecting that oculomotor dynamics should vary according to the foraging strategy that is used. Our preliminary results indicate that the ability of "super-foragers" to switch between the two target types in conjunction-search comes both with costs and benefits. We report individual differences in foraging strategies and eye movement dynamics that provide important insights into how observers orient in the visual world and about the optimal strategies for efficient foraging.

Effect of Practice and Chromatic Information on Gaze Patterns During Visual Search

Natsuko Wasaki[1], Tatsuto Takeuchi[1] and Sanae Yoshimoto[2]
[1]Japan Women's University, Tokyo, Japan
[2]Hiroshima University, Japan

Deliberate practice in the comprehension of visualizations, such as sports, medicine, and transportation, enhances performance in visual search of the trained domain with modification of gaze patterns. Meanwhile, chromatic information is known to enhance the visual search of various types of images. The purpose of this study is to determine whether the gaze patterns after deliberate practice is similar to that observed while searching colored images by using the same category of image; a metro map. In the practice condition, we trained participants to search the target stations in grayscale metro maps. After the training, the participants showed reduced time to first fixation and fewer fixation counts, whereas fixation duration and dwell time were not modified. In chromatic information condition, the participants searched the target station on the colored or grayscale metro maps seen for the first time. The gaze patterns for the colored map showed reduced time for first fixation, shorter fixation duration and dwell time, and fewer fixation counts in comparison to the grayscale map. Thus, the gaze patterns were different between practice and chromatic conditions. These results suggest that the underlying mechanisms of enhancing the performance of visual search by practice and color would be different.

Recognising Materials Over Time

Ellen E. M. De Korte[1], Andrew J. Logan[2] and Marina Bloj[1]
[1]School of Optometry and Vision Science, University of Bradford, UK
[2]Department of Vision Sciences, Glasgow Caledonian University, UK

Materials change over time; colours fade and surfaces are scratched. These changes alter the retinal input and yet we still recognise them as the same material. When textiles are washed and laid out to dry, we still identify them as the same fabric even though their colour visibly changes. This study evaluated the appropriateness of an existing calibrated photograph set as a stimulus for studying the perception of appearance changes of materials over time. Participants ($N = 4$) reported which of the two pairs of images shown displayed the largest perceptual difference. Images were blocked (210 trials per block and participant) by material (Banana, Copper, Granite, Quilted Paper). Individual observers' perceptual scales, estimated with Maximum Likelihood Difference Scaling via the General Linear Model estimation method, for each material were similar and showed that some, but not all, photographs were perceptually distinct. Thus, the calibrated photographs seem suitable for our purposes. Next steps will include image-based manipulations to establish which parameters drive the development of perceptual scales. Specifically, this will involve converting images to grayscale and manipulate image marks, such as brown staining in Banana images, in order to test the effects of colour and characteristic marks, respectively.

The Neural Basis of Learning in Different Stages of the Visual Processing Hierarchy During a Visual Game

Stefanie Duyck and Hans Op de Beeck
Brain and Cognition, KU Leuven, Belgium

Becoming an expert takes around 10,000 hours of deliberate practice. Studies showed "near transfer" of a specific skill to similar domains. We tested the neural basis of learning in low- and high-level vision, focusing upon feature and retinal location specificity across low- (i.e., gratings) and high-level (i.e., novel objects) visual features. Twenty nongamer subjects were trained with a gamified perceptual learning paradigm for fifteen hours, spread over 20 days. In the game, subjects were trained on an orientation discrimination task with one orientation reference at two retinal locations and on a novel object categorization task with one novel object at two orthogonal retinal locations to the ones used during the orientation task. Stimuli were only presented at one location per trial. Before and after training, they participated in an fMRI scan session, (one-back go/no-go task), and a behavioral perceptual learning task-set (orientation discrimination task and novel object categorization task, with the trained and untrained orientation/object reference and retinal locations). Participants show improved performance when comparing post- with pre-training. In further analyses, we will investigate how the neural patterns of trained and untrained stimulus features and retinal locations change from pre- to posttraining in early visual cortex and lateral occipital cortex.

Flexible Suppression on Probability Cueing of Distractor Locations

Bei Zhang, Fredrik Allenmark, Heinrich Rene ́. Liesefeld, Zhuanghua Shi and Hermann J. Müller
General and Experimental Psychology, Department of Psychology, LMU Munich, Germany

Our attention can be captured by salient task-irrelevant distractors, but this capture effect could be reduced if the salient distractor is spatially predictable. The reduced interference may arise from (implicit) learning driving positional suppression. However, it is debatable how and at which stage the suppression operates. Wang and Theeuwes (2018) argue for priority-map-based suppression resulting in slowed processing of the target when it appeared at the more likely distractor location. However, Sauter et al. (2018) provided evidence for a dimension-based suppression account by showing that the target (e.g., shape-defined) is unaffected by distractor suppression when the salient distractor is defined in a different dimension (e.g., color-defined). By unearthing the differences between these two studies and changing the paradigm (e.g., making the target appear equally often at each location and making the distractor/nondistractor color assignment consistent), this study demonstrated that the target location effect was abolished when distractor/nondistractor colors were kept constant and was also much reduced with practice even with swapping of distractor/nondistractor colors. These findings support the notion of a flexible locus of spatial distractor suppression—priority-map- or dimension-based—depending on the prominence of distractor "cues" provided by the paradigm.

Quantitative Evaluation of the Relation Between Blink Features and Apparent Task Engagement

Serina Koyama, Zeynep Yucel and Akito Monden
Okayama University, Japan

In e-learning, it is common to expose disengaged users to various stimuli for recovering engagement. Obviously, this requires automatic assessment of users' engagement state, for example, based on certain signs of embodiment of "mind wandering" (Schooler et al., 2011). In that regard, we propose several features derived from eye blinks, which are shown to enhance perceptual decoupling, that is, disengagement from outside stimuli in favor of internal processing (Smilek et al., 2010). As a data set enabling continuous observation of evolution of engagement, we use video recordings of users performing three tasks with different levels of user involvement: passive (viewing), semiactive (requiring listening comprehension, reasoning, inference skills), and active (requiring strategic planning, organized search, modulation of impulsive responses). The set is assessed for level of engagement by professional teachers. From the videos, we derive facial landmarks and apply real-time blink detection (Soukupova and Cech, 2016). Using polyserial correlation coefficient rho, we demonstrate that number and duration of blinks have negative correlation with engagement ($\rho = -0.36$ and $\rho = -0.25$, respectively), whereas normalized eye size and eye aspect ratio have a—somewhat stronger—positive correlation ($\rho = 0.61$ and $\rho = 0.62$, respectively), agreeing with (Smilek et al., 2010).

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Ignored Stimuli Create Negative Dependence in Perception

Mohsen Rafiei[1], Andrey Chetverikov[2], Sabrina Hansmann-Roth[1], David Whitney[3] and Árni Kristjánsson[1,4]
[1]Department of Psychology, University of Iceland, Reykjavík, Iceland
[2]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands
[3]Department of Psychology, The University of California, Berkeley, CA, USA
[4]Faculty of Psychology, Higher School of Economics, National Research University, Moscow, Russia

What we perceive is strongly affected by recent perceptual history. With brief presentations, observers' estimates of simple features, such as an orientation, are biased toward previously presented stimuli (serial dependence effect). Attention is thought to be "gating" the serial dependence: When stimuli are unattended, they do not affect the perception. Here, we provide evidence that in addition to this positive bias from attended stimuli, there is also a negative bias created by the ignored ones. In two experiments, observers searched for an odd-one-out target among the set of distractors. Previously, we have shown that after several trials, observers learn the probability distribution of distractors as to-be-ignored (feature distribution learning). In Experiment 1, following several search trials, observers estimated the orientation of the last visual search target. Experiment 2 was identical except that observers reported the orientation of a single line briefly presented following the visual search trials in each block. We found that the perceived orientation was affected by both distractors and the previously presented target with no interaction between the two. The results show that rather than "gating" the serial dependence, attention directs it so that information from both attended and ignored items is combined to create continuity in perception.

Serial Dependencies in Virtual Reality

Kyriaki Mikellidou and Marios Avraamides
Department of Psychology, University of Cyprus, Nicosia, Cyprus

A great deal of psychophysical evidence has demonstrated that serial dependence (SD) is one of the mechanisms facilitating temporal continuity, helping us maintain a stable visual percept. The human brain appears to be sensitive to serial correlations, abundant in visual scenes, inducing strong drifts in observer responses toward previously seen stimuli. Successive stimuli of all kinds, including orientation and numerosity patches, facial expressions and many more, appear to be more similar than they really are. Cicchini et al. (2018) showed that SD depends on the similarity between successive stimuli and leads to a two-fold functional advantage by minimizing reproduction errors and yielding faster reaction times. Here, we investigate whether SD effects are evident under realistic conditions by presenting three-dimensional stimuli in virtual reality environments in the central and peripheral visual field. When the visual sensitivity of stimuli is equalized between the centrally and peripherally presented stimuli, in terms of just-noticeable-difference, SD effects are of equal size and also similar to those observed under constrained experimental settings using simple Gabor patches (10%). This study provides evidence of SD effects in the central and peripheral visual field with realistic stimuli, demonstrating the potential importance of such a mechanism in everyday life.

Psychophysical Testing in Virtual Reality: The Future Lab Setting or Misleading Garden-Path?

Katharina Knebel, Alexander Pastukhov and Claus-Christian Carbon
University of Bamberg, Germany

Virtual Reality (VR) offers an opportunity to combine naturalistic viewing and interaction with the rigorously controlled experimental setup. Here, we investigated whether participants are able to utilize stereoscopic depth cues using a VR headset (HTC Vive-Pro) to estimate distance to an object. To this end, participants viewed a sequential presentation of two cubes facing one edge. Participants were instructed to report whether the edge moved toward them or away from them. Cubes were intentionally either identical or different in size to prevent observers from using apparent cube size as a proxy measure for distance. In addition, we eliminated visual cues such as shadows, floor, and object texture, and we fixed cube location relative to the head, preventing participants from utilizing motion parallax. Participants viewed the display either dichoptically or monocularly (eye patch). Preliminary results indicate that some participants are able to use stereoscopic depth and correctly report change in the distance even when cubes were inconsistent in size. However, other participants' reports were based solely on the change in the apparent size. Our results imply that stereo information provided by VR is useful, yet we suggest that an interaction rather than simple reports may account for more significant findings.

The Limits of Visual Perception in Immersive Virtual Reality: A Change Blindness Study

Chiara Bassano, Fabio Solari and Manuela Chessa
University of Genoa, Italy

Change Blindness, the inability to detect a change between two different images, is one of the paradigms that has a role in demonstrating the limits of visual cognition. We aim to study the limits of visual perception in immersive Virtual Reality. We measured Change Blindness in static virtual scenes, by considering the variation of the number of items (4, 8, 10, and 12), the horizontal field of view (FOV) (40°, 80°, and 120°), the spatial layout (vertical; horizontal with perspective cues) and the observation time (0.3 and 0.9 s). We studied participants' ability to recognize changes (addition, removal, and no changes) between two consecutive scenes. Results show that the percentage of correct answers decreases as the number of items increases ($p < .05$), confirming previous studies, and improves as observation time increases. The analysis of the capacity, the number of items at which accuracy begins to drop below 80%, highlights the effect of FOV: results at 40° and 80° are comparable, those with 120° tend to worsen ($p < .05$) though participants had sufficient time to observe the entire scene by turning their heads. Better performances have been found in the removal case and with the vertical layout ($p < .05$), suggesting a combined influence of spatial arrangement and task.

Testing Allocentric and Egocentric Spatial Representations Using the CAVE Technique

Olga Saveleva, Galina Menshikova, Boris Velichkovskiy and Grigory Bugriy
Lomonosov Moscow State University, Russia

It is necessary to develop a new tool for testing the mental spatial representations of the environment. Two types are identified: egocentric representations (ESR), encoding object locations relative to the observer, and allocentric representations (ASR), specifying the relative positions between objects. There are very little data on the accuracy of ESR and ASR processing in working memory. Six unique virtual scenes were constructed each consisting of seven objects. Thirty six participants (22 females, 14 males, age range 18–26 years) were tested. Their task was to remember the scene, which was shown for 25 seconds using the CAVE technique and then to reproduce it in a virtual environment using the given viewpoint: "the front" (to reproduce the memorized scene from the egocentric position), "the left" and "the above" (from the left or above imaginary allocentric positions). Object locations were recorded. The accuracy of ESR and ASR cording in terms of metric, topology and depth parameters was calculated. The ESR cording ("the front" viewpoint) was more accurate in comparison with the ASR ("the left" and "the above"). The topological accuracy was much better than the metric and depth accuracy regardless of the viewpoints.

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Eye Movement on Blank Displays: Effects of Difficulty in Preceding Visual Tasks and Mental State

Ayumi Takemoto[1], Atsushi Nakazawa[2] and Takatsune Kumada[2]
[1]OMRON, Kyoto, Japan
[2]Kyoto University, Japan

In the existing research, it has been mainly reported that eye movements are affected by visual stimuli and mental state of observers, such as mind wandering, drowsiness, and fatigue. In this study, we investigated eye movements while a blank display is presented after a visual task. Especially, we focused on how much the preceding visual-task difficulty or mental state affected observers' eye movement while they watched a blank display. In the experiment, 25 healthy participants performed a visual search task with various seach difficulties. In each trial, participants were required to complete a visual task and then to watch a blank display for 10 seconds. In some trials, they reported the state of mind wandering. As a result, participants moved their eye on blank displays irrespective of no visual task. The frequency of saccade on the blank display decreased after difficult visual search tasks relative to easy tasks. Moreover, It also decreased in trials that participants reported mind wandering. We discuss that the implication of nongoal directed eye movements on blank displays.

A Dynamic Scenario Toward Mind Wandering: Implications From Slow and Fast Dynamics of Thought Generation

Chie Nakatani[1] and Cees van Leeuwen[1,2]
[1]KULeuven, Belgium
[2]TU Kaiserslautern, Germany

In our everyday life, we continuously generate and evoke thoughts. In particular, spontaneously generated thoughts have been discussed as the key factor for the process of mind wandering. When in the process do spurious

thoughts affect to the path of our mind? Do these thoughts disappear after the mind wandering state has passed? Repeated experience sampling in real life showed that the number of thoughts goes through regular 4- to 6-hour cycles in the wakeful hours. Mind wandering episodes tend to start about 1 hour after the cycle of thought generation begins to rise. Cognitive control, in contrast, dramatically falls after having been up for an extended period. When this occurs, mind wandering appears. An EEG experiment showed the dynamics in a finer time scale. For 60 minutes, participants struggled to keep focus on a simple-and-repetitive tone counting task. Meanwhile, the number of their thoughts oscillated in a 10- to 14-minute cycle. The cycle was negatively correlated with the alpha-band amplitude of EEG signals in temporal and occipital electrodes. This suggests that when number of thoughts was high, control over information processing in medial temporal lobules was low. Further implications of the results regarding to cognitive control will be discussed.

Recreating ERPs Using Large-Scale Cortical Traveling Waves

Kevin Vanbecelaere, David Alexander and Cees van Leeuwen
KU Leuven, Belgium

An assumption in nearly all cognitive neuroscience research is that of space-time separability. It assumes that the mechanisms constituting the cortical signal are functions of space and time, and that these dimensions of signal can be treated separately. This line of reasoning underlie trial-averages such as the ERP, implying that the part of the signal that is not consistent in time (over trials) is noise. A growing literature focuses on the spatiotemporal dynamics of cortical activity in the form of traveling waves. Traveling waves have been shown to be functionally significant at the single-trial level (Alexander et al., 2006; Alexander et al., 2009) and at multiple spatial scales of cortex (Klimesch et al., 2007; Nauhaus et al., 2009; Takahashi et al., 2011). We reanalyzed the results as found in Akyürek et al. (2010) in the context of temporal event integration. By building a traveling wave model for EEG oscillatory phase at the single-trial level, we found that not amplitude but phase jitter is responsible for the difference in P3 component between correct and wrong trials, the added value of amplitude information to the ERP was minimal (Alexander et al., 2013).

Does the Spatial Organization of Brain Oscillations Modulate Perceptual Rhythms?

Camille Fakche[1,2] and Laura Dugué[1,2]
[1]CNRS (Integrative Neuroscience and Cognition Center, UMR 8002), Paris, France
[2]Université Paris Descartes, Sorbonne Paris Cité, France

Our ability to perceive the world appears to be periodic. The probability of stimulus perception would alternate between favorable and less favorable moments, encoded in "good" and "bad" phases of theta (4–7 Hz) and alpha (8–12 Hz) brain oscillations. Here, we assess whether the phase effect on perceptual performance is modulated by the spatial organization of brain oscillations. We used a psychophysics paradigm based on Sokoliuk and VanRullen (2016) in which participants performed a threshold (50% detection) visual detection task, while their brain activity was recorded with EEG. A small oscillating disc was concurrently presented in the periphery (7.5° eccentricity) to entrain brain oscillations at low frequencies (4, 6, 8, and 10 Hz). The target appeared between the fixation cross and the disc at one of three possible eccentricities (4.1°, 4.5°, and 4.9°). We tested whether (a) the entrained oscillation, which originates from a precise retinotopic location, modulates detection performance periodically at each target location; (b) the preferred phase shifts as a function of target location; and (c) the frequency of the entrained oscillation modulates this phase effect. Our results provide systematic characterization of the influence of the spatiotemporal organization of low frequency oscillations on visual perception.

Parietal Gamma-Band Activity During Mental Rotation Task Reflects Individual Performance in Vehicle Driving

Sunao Iwaki
National Institute of Advanced Industrial Science and Technology (AIST), Ibaraki, Japan

The performance of vehicle driving is affected by various factors including cognitive, behavioral, and demographic characteristics. In this study, we tested whether EEG responses recorded during the mental rotation task, which reflects individual performance in manipulating mental imagery in the 3-D space, can be used for an indicator to predict driving performance as measured by the robustness of lane keeping while driving in the simulated environment. The results of the correlation analyses between EEG event-related synchronization (ERS) recorded during the mental rotation task and the driving behavior measured during driving simulation showed that there was significant correlation between 30 Hz gamma-

band power during the mental rotation task and the driving performance under low visibility condition. As the gamma-band ERS in the frontoparietal regions during the mental rotation task is often interpreted as a successful visuospatial processing in the mental image manipulation, the current results suggest that the ability to process mental imagery in the three-dimensional space plays an important role in keeping adequate driving performance under lower visibility conditions. The results also imply that the EEG measures obtained during the offline cognitive task could be used to predict individual differences in driving performance in realistic situations.

Neuromodulation of Temporal Dynamics in Online Visuomotor Control by Anodal HD-tDCS Over the Left Intraparietal Cortex

Borja Rodriguez-Herreros[1], Serafeim Perdikis[2], Andrea Serino[3,4], Robert Leeb[5] and Silvio Ionta[1]
[1]Sensory-Motor Laboratory, Department of Ophthalmology/ University of Lausanne, Jules-Gonin Eye Hospital/Fondation Asile des Aveugles, Switzerland
[2]School of Computer Science and Electronic Engineering, University of Essex, Colchester, UK
[3]Laboratory of Cognitive Neuroscience, Brain Mind Institute, School of Life Sciences, Swiss Federal Institute of Technology (EPFL), Campus Biotech, Geneva, Switzerland
[4]Center for Neuroprosthetics, Swiss Federal Institute of Technology (EPFL), Campus Biotech, Geneva, Switzerland
[5]Defitech Chair in Brain-Machine Interface (CNBI), Center for Neuroprosthetics (CNP), Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Online visuomotor control is the ability to produce precise adjustments during the execution of movements in response to unexpected environmental perturbations. The medial intraparietal sulcus (mIPS) plays a key role within the cortical network that encodes the sensorimotor transformations required to update a movement. Whereas previous studies showed the disruption of online visuomotor control following the administration of magnetic pulses over the mIPS, neuromodulatory effects after high-definition transcranial direct current stimulation (HD-tDCS) remain unexplored. Here, we investigate whether the increase of cortical excitability within the left IPS affected online visuomotor control in healthy right-handed participants, using a goal-directed reaching task where target position could change after initiating the movement. After anodal HD-tDCS (1.5 mA, 20 minutes), we observed a significant reduction of the time needed to start the adjustment relative to the total movement time, concomitant with an increase of successful adjustment rate. The spatial dimension of the movement remained, however, unchanged after the stimulation. This differential impact hints at a critical neural processing time to succeed when adjusting the movement, rather than estimating an "adjustment" zone independent of the movement kinematics. Furthermore, our findings add evidence on tDCS facilitatory motor aftereffects, opening up novel perspectives in neurorehabilitation and motor restoration.

The Within-Trial Time Course of Visual Backward Masking Effects in RT and Accuracy: Testing Predictions of Object Substitution Theory

Sven Panis[1], Johan Wagemans[2] and Thomas Schmidt[1]
[1]University of Kaiserslautern, Germany
[2]University of Leuven, Belgium

Visual backward masking refers to the impaired perception of a target stimulus that is followed by a masking stimulus in close spatiotemporal proximity. Here, we analyze response time (RT) and timed accuracy data using discrete-time hazard functions of response occurrence combined with micro-level speed-accuracy-trade-off functions to study the temporal dynamics of visual backward masking effects. We test two predictions of object substitution theory: (a) the masking effect in a common-onset paradigm should increase with increasing RT, and (b) there is an early object formation stage sensitive to the nature of the masking stimulus (due to target-mask contour overlap and lateral inhibition), that is followed by a later object substitution stage which is insensitive to the nature of the masking stimulus but sensitive to the distribution of attention. The results from three experiments show that masking effects change over time, that integration effects affect early responses while interruption/substitution effects affect early and late responses, and that common-onset masking occurs for a single attended target. Our distributional data provide strong constraints for theories and computational models of masking.

Multiple Spatial Summation Mechanisms Revealed by Pattern Masking Paradigm

Chien-Chung Chen[1], Chia-Hua Chien[1] and Christopher Tyler[2]
[1]National Taiwan University, Taipei
[2]Smith-Kettlewell Eye Research Institute, San Francisco, CA, USA

We investigated the mechanisms underlying spatial summation with a masking paradigm. The targets and the mask were Gabor patterns placed at 3° eccentricity to the fixation and elongated along an arc of the same radius. The

task of the observer was to indicate whether the target in each trial was on the left or the right of the fixation. The Ψ staircase procedure was used to measure the threshold at 75% accuracy. At low mask contrasts, the target threshold first decreases with size with slope-1 until target length reached 45′ half-height full-width (HHFW) and further decreased with slope −1/2 on log–log coordinates. At high mask contrasts, the threshold also showed a −1 slope up to 45′ HHFW. However, the threshold was constant between 45′ and 210′ HHFW, followed by another −1 slope drop, indicating a second summation channel. The results can be explained by a divisive inhibition model in which a second-order filters sums nonlinear responses across local channels. The divisive inhibition from high-contrast masks swamps the response and eliminates the summation across local channels, which accounts for the −1/2 slope decrease but not the summation within the receptive field of one channels, which accounts for the −1 slope.

Crowding Stimulus Contingencies Are Task-Dependent

John Cass[1] and Erik Van der Burg[2]
[1]Western Sydney University, Australia
[2]Vrije Universiteit, Amsterdam, the Netherlands

Peripherally presented visual objects are more difficult to identify when presented within close proximity of nearby flanking stimuli which share similar features to the target object. In this study, we investigate whether these stimulus dependencies (critical target-flanker separation and similarity) depend upon the task. Two experiments were conducted to compare the effects of task, both using identical stimuli. Each experiment employed a near vertical green luminance-defined Gabor target, flanked by either four green or four red Gabor stimuli, all vertical or all horizontal. In one experiment, subjects performed a target luminance discrimination task, and in the other experiment, an orientation discrimination task. Target-flanker separation was manipulated in each condition. Performance on each task was characterised by a unique set of stimulus contingencies linked to the featural similarity between the different flanking features and the task performed. Specifically, for the luminance task, classic critical spacing effects were observed with green flanking stimuli, with no crowding observed with red flankers. For the orientation discrimination task, crowding was strongest when using vertical flankers of either colour. That the effects of featural similarity should depend on task implies that crowding occurs prior to the perceptual binding of an object's constituent features.

Effects of a Human-Like Cartoon Character Presented by Augmented Reality Technology on Young Children's Behaviors

Nobu Shirai[1], Ryoko Sato[2] and Tomoko Imura[3]
[1]Niigata University, Japan
[2]Niigata University of International and Information Studies, Japan
[3]Japan Women's University, Tokyo, Japan

Effects of a human-like cartoon character displayed by augmented reality (AR) technology on younger ($N = 36$, 5- to 7-year-olds) and older ($N = 36$, 8- to 10-year-olds) children's behaviors were investigated. Children were invited to an experimental room and were asked for engaging in a game task (adopted from Piazza et al., 2011, *Journal of Experimental Child Psychology*) alone in the room. Although the children were instructed to follow severe rules of the game task, it was almost impossible to succeed the game task without any "cheating." Thus, the latency of "cheating" was used as a main dependent variable in this study. The children were divided into three experimental conditions; AR condition (children were presented a human-like AR cartoon character who looked at the children before engaging in the game task), TV condition (children were presented the cartoon character displayed on a TV screen), and a control condition (no presentation of the character was made). Results indicated that younger children under AR condition showed significantly shorter latency for cheating behaviors in the game task than younger children under the TV and control conditions. The results suggest that human-like cartoon character displayed by AR technology could have some impacts on young children's behaviors.

Developing a New Set of 128 Images Illustrating Activities and Objects for Treatment Processes in Aphasia

Claire Reymond, Christine Mueller and Indre Grumbinaite
FHNW Hochschule für Gestaltung und Kunst, Basel, Switzerland

Word production is stimulated by images in treatment processes for individuals with aphasia, both for formal and informal assessment purposes (Aphasiology, *21*, 883–900; Heuer & Hallowell, 2007). Although stimulation through images has a long tradition in aphasia therapy, there is a lack in research on which image stimuli are the most suitable for this purpose (Brown & Thiessen, 2018, *American Journal of Speech-Language Pathology*, *27*, 504–515). Current research assumes that stimulation via photographic images evokes better and more direct retrieve of searched words, than stimulation by illustrations (Heuer, 2016, *30*(8), 943–961). However, the illustrations investigated hitherto mostly comprise black and white line drawings and there

are no studies investigating possible effects of different image styles in relation to clear naming. In addition, hardly any pictorial material to provoke the evocation of verbs is available in aphasia therapy. We developed a visual concept of illustrated images enabling clear determinability of activities and objects. The 128 designed images were rated by 68 undergraduate students on a 5-point scale for name agreement, visual complexity, and image agreement. This study was designed as a prestudy and will be followed by a study analyzing naming correctness in illustrations and photographic stimuli in individuals with aphasia.

The Body Inversion Effect in Chimpanzees (Pan troglodytes)

Jie Gao[1,2] and Masaki Tomonaga[1]
[1]Kyoto University, Japan
[2]Japan Society for the Promotion of Science, Tokoyo, Japan

Bodies are important social cues to animals. The body recognition in humans is deteriorated by inversion. This inversion effect suggests the configural processing of bodies. However, this is not clear in nonhuman primates. We tested seven chimpanzees using upright and inverted chimpanzee body stimuli and other stimuli in matching-to-sample tasks to examine the body inversion effect. Experiment 1 used chimpanzee bodies and houses. Experiment 2 used intact bodies, bodies with blurred faces, and faces with blurred bodies. Experiment 3 used intact bodies, bodies without faces, only faces, and body silhouettes. Experiment 4 used intact bodies, bodies with abnormal body part arrangement, and bodies with abnormal proportions. They showed the inversion effect to all intact body conditions, indicating the configural body processing. Chimpanzees perceive bodies in a special way that is different from the way used for other objects. They showed the inversion effect to faces with blurred bodies in Experiment 2 and to silhouettes in Experiment 3, suggesting the roles of faces and body contours in the inversion effect. The inversion effect was gone for bodies with abnormal arrangements but not for those with abnormal proportions in Experiment 4, suggesting chimpanzees are sensitive to body structures to some extent.

Higher Order Visual Areas as Part of the Mouse Posterior Parietal Cortex

Sara Gilissen[1], Karl Farrow[2], Vincent Bonin[2] and Lut Arckens[1]
[1]Laboratory of Neuroplasticity and Neuroproteomics, KU Leuven, Belgium
[2]Neur\Electronics Research Flanders, Leuven, Belgium

The posterior parietal cortex (PPC) is an associative brain region responsible for the processing of sensory and motor signals, in order to plan and execute movements, as well as cognitive tasks like spatial reasoning and attention. To carry out these functions, the PPC needs to receive information from all sensory modalities. In human, it exists of a superior and inferior part, separated by the intraparietal sulcus. Research into the mouse PPC has so far been limited with a delineation of three regions: mPtA, lPtA, and pPta, whether or not with a partial overlap into higher order visual areas RL, A and AM. These latter regions, who were first determined as higher visual order regions, could be part of the PPC in full. Even in humans, specific PPC subregions show retinotopy, most of them focused around the intraparietal sulcus. To know to what extend areas RL, A, and AM belong to the mouse PPC, we investigated their connectivity. We determined their sensory inputs as well as motor and prefrontal inputs, and their subcortical output. We revealed that they indeed have different projection patterns originating from sensory cortex, and typical input/output patterns for multisensory cortical regions encompassing the posterior parietal cortex.

Modelling Symmetry Perception With Banks of Quadrature Convolutional Gabor Kernels

C. Alejandro Parraga[1], Xavier Otazu[1] and Arash Akbarinia[2]
[1]Computer Science Department, Computer Vision Centre, Universitat Autònoma de Barcelona, Spain
[2]Department of General Psychology, Justus-Liebig Universität Giessen, Germany

Although the task of detecting symmetrical objects seems effortless for us, it is very challenging for computers (to the extent that it has been proposed as a robust "captcha" by Funk & Liu in 2016). Indeed, the exact mechanism of symmetry detection in primates is not well understood: Symmetrical shapes activate specific higher level cortical areas (Sasaki et al., 2005) and psychophysical experiments suggest symmetry perception is influenced by low-level mechanisms (Treder, 2010). Here, we look for plausible low-level mechanisms that might form the basis for symmetry perception using a simple model containing banks of (a) odd-symmetric Gabors (resembling edge-detecting V1 neurons) and (b) larger odd- and even-symmetric Gabors (resembling higher visual cortex neurons), that pool signals from the "edge image" (Akbarinia et al., ECVP2017). When convolved with these kernels across several spatial scales, symmetric objects produce a minimum in one and a maximum in the other (Osorio, 1996), and the rectification and combination of these signals create lines which hint of mirror symmetry in natural images. Our results suggest that such multiscale combination might form the basis for the HVS's symmetry detection and representation.

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