

**39<sup>th</sup> European Conference on  
Visual Perception (ECVP)  
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## ***Legend***

### **For Posters**

Example: **1P002**

First number is the day (1 = Monday 2 = Tuesday 3 = Wednesday 4 = Thursday); P=poster; 002= poster number

For example: 2P145: Second day poster number 145

### **For talks and symposia:**

Examples: 12S203; 11T101

First number is the day (1 = Monday 2 = Tuesday 3 = Wednesday 4 = Thursday);

Second number is the period: Period 1 = morning (9-11) 2 = midday (14-15:30); 3 = afternoon (17-18:30)

Letter S=symposia; T=talk

Third number: Hall (Pau Casals Hall 1; Oriol Martorell Hall 2; Tete Montoliu Hall 3)

Fourth and five number: sequence of talks within the session with format 0#.

**13T101** = (1 First day; 3= afternoon (17-18:30); T=Talk; 1=Hall 1 (Pau Casals); 01=talk # 1 in that session)

## ***Monday August 29th Poster presentations***

[1P001] Contingent affective capture: manipulating top-down search goals induces involuntary capture by threat

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Prominent mainstream models of attention have characterised attention as reflecting competition between top-down goals and bottom-up salience. It remains unclear, however, how involuntary attentional capture by motivationally salient (e.g. threatening or rewarding) stimuli fits into such models. While such effects have traditionally been held to reflect bottom-up processes, the well-established phenomenon of ‘contingent capture’ highlights that top-down goals can not only guide voluntary attention, but also lead to involuntary attentional capture by goal-congruent yet task-irrelevant stimuli. Hence, attentional capture by motivationally salient stimuli, such as threat, could alternatively reflect top-down rather than bottom-up prioritisation processes. Here we test this possibility by combining the classic ‘contingent capture’ and ‘emotional blink’ paradigms in an RSVP task with either positive or threatening target search goals. Across experiments, task-irrelevant threat distractors were presented in peripheral and central locations. At all distractor locations, we found that attentional capture by irrelevant threatening distractors was contingent upon the adoption of a search-goal for threat. This ‘contingent affective capture’ appeared to extend only to the specific category of threat being searched for. These findings have implications for accommodating motivationally salient stimuli within mainstream models of attention, as well as applied relevance to attentional biases found in affective disorders.

[1P002] Can attentional templates operate in a spatially-localised format during visual search? An electrophysiological investigation

**Nick Berggren, Michael Jenkins, Cody McCants, Martin Eimer**

Psychological Sciences, Birkbeck University of London, UK

Target-defining features act as attentional templates, guiding attentional allocation during search. Although multiple feature templates (e.g., two colours) can be maintained, they are assumed to operate in a spatially-global fashion at task-relevant and irrelevant locations. Here, we assessed attentional guidance during a task that encouraged the operation of spatially-localised feature templates. Participants searched for two laterally presented target rectangles defined by a colour/location combination (e.g., red upper and blue lower visual field). On some trials, targets were accompanied by two objects in the reverse arrangement (e.g., blue upper and red lower visual field) in the opposite hemifield. Search displays were preceded by spatially-uninformative cues that contained colours at task-relevant locations (e.g., red above blue; matching cues) or in the reverse arrangement (e.g., blue above red; reverse cues). Behavioural cueing effects were only elicited by matching cues, but electrophysiological evidence demonstrated that both cue types initially attracted attention. For search displays containing target and reverse nontarget pairs on opposite sides, spatial biases towards the target only emerged after approximately 300 ms. These results show that rapid feature-based attentional selection processes do not operate in a spatially-localised fashion, but that spatially-selective templates can control subsequent object identification processes within visual working memory.

Funding: Economic and Social Research Society (ESRC) grant

[1P003] Fixation-related potentials in overt visual search for multiple targets

**Hannah Hiebel, Joe Miller, Margit Höfler, Anja Ischebeck, Christof Körner**

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To date, little is known about the neural mechanisms underlying overt visual search. In two experiments, we concurrently recorded EEG and eye movements while participants searched for two identical targets amongst a set of distractors. In such a multiple-target paradigm, participants must continue the search after finding the first target and memorize its location. We investigated neural correlates of item processing in different stages of the search using fixation-related potentials (FRPs). Results of Experiment 1 showed that the detection of the first target elicited a P3-like component absent in distractor fixations. Furthermore, finding the first target influenced FRPs in continued search: a sustained negativity was observed for distractor fixations following the first target fixation, likely indicating the involvement of memory. In Experiment 2, display size was manipulated systematically (10, 22, 30 items). Eye

movement analysis showed that the average number of fixations preceding the first target detection varied as a function of display size. We present FRPs for target fixations and discuss the influence of the number of preceding distractor fixations on their morphology. In addition, we analyzed the post-target negativity over longer time intervals and report on its temporal properties and functional role.

Funding: This work was supported by the Austrian Science Fund (FWF), grant P27824.

#### [1P004] The Role of Working Memory in Serial Overt Visual Search: A Combined Eye Tracking and fMRI Study

**Joe Miller, Hannah Hiebel, Margit Höfler, Anja Ischebeck, Christof Körner**

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When searching for multiple targets, we must process the current object while maintaining representations of previously located targets (Körner & Gilchrist, 2008). It is unclear which brain regions are involved in these processes, and how recruitment of these regions changes during the task. In this experiment, subjects were presented with a letter display containing between 0 and 3 targets ('T's) amongst up to 20 distractors ('L's), and were asked to respond with the number of targets present. We used a combination of eye tracking and fMRI to measure dynamic shifts in brain activation as working memory load changes during a visual search. Information from eye tracking was used to estimate working memory load based on target fixations. Imaging data were divided into epochs based on presumed working memory load. Preliminary data suggest that recruitment of working memory regions during multiple target visual search changes dynamically according to the demands of the task. This suggests that only relevant visual information is stored in short term memory. With further analysis, we expect to show increased activation in prefrontal and parieto-occipital regions when at least 1 target has been fixated, and that these activations will be greater when 2 targets have been fixated.

Funding: FWF grant

#### [1P005] The attentional salience of a reward cue outlasts reward devaluation

**Matteo De Tommaso, Tommaso Mastropasqua, Massimo Turatto**

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Reward cues have been shown to attract attention. These stimuli possess an increased attentional salience because they anticipate positive outcomes. However, the motivational value of rewards changes when the organism has the possibility to expend the reward. Hence, an interesting issue is whether the attentional salience of reward cue persists after reward devaluation. In Experiment 1, thirsty human participants learned cue-liquid reward associations by means of an instrumental task. Then, while thirsty, participants performed a visual search task under extinction, where target and distractor letters were presented within the previously reward cues. Experiment 2 was identical to the first one, but participants drank ad libitum before the visual search task. The results of Experiment 1 showed that in the visual search task attention was preferentially deployed toward the stimulus that was the best reward predictor in the previous conditioning phase. Crucially, Experiment 2 revealed that an attentional bias of the same magnitude was still present after reward devaluation. Our study provides compelling evidence showing that the attentional salience of a reward cue outlasts reward devaluation. This might explain why drug cues remain salient stimuli that trigger compulsive drug-seeking behavior even after a prolonged period of abstinence.

#### [1P006] Inhibition of irrelevant objects in repeated visual search?

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When we search the same display repeatedly, not all items from a previous search may be relevant for the subsequent search. Here, we tested whether inhibition of saccadic return (ISR) works for all items similarly or whether ISR operates on irrelevant items only. Participants searched the same display with letters of two colours twice. In the first search, the target colour could be pink or blue, while in the second search, the target was always of one colour. Hence, half of the items in the first search were irrelevant for the second search. We measured ISR during the first and at the beginning of the second search by presenting a probe at an item that was either relevant or not for the second search. The probed item was either previously inspected (old probe) or not (new probe). Participants were instructed to saccade to the probe and then to continue the search. Preliminary results showed that ISR operated in the first search regardless

of item relevance: Saccadic latencies were longer to old probes than to new probes. No ISR was observed at the beginning of the second search. These findings suggest that item relevance does not affect the occurrence of ISR.  
Funding: FWF Grant: P 28546

[1P007] Gaze fixations and memory in short and massive repeated visual search.

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Our day-to-day experience suggests that, with repeated exposure, we can easily acquire information about our environment. However, it is not clear how much exposure is needed for information to be useful for task performance. To analyze this issue, we employed a repeated visual search paradigm, and tested whether previous searches on a set of items facilitated search for other items within the same set. A total of 72 colored letters (12 letters x 6 colors) were used as targets and distracters. In each trial a target letter was presented at fixation for 1 second, followed by the search display. Participants pressed the space bar when the target letter was found. In Experiment 1, twelve different displays were generated by placing all the letters at random locations on the screen. Participants searched for six different target letters on each display (short repeated visual search task). In Experiment 2, only one of the previously created displays was used, and participants searched for all the letters on that display (massive repeated visual search task). RT and eye movements were registered in each trial. Analysis of RT and number of fixations showed that display repetition had no effect in either experiment.

Funding: Research supported by grant PSI2013-43742.

[1P008] Distraction in visual search is driven by neutral information as well as association with reward

**Luke Tudge, Torsten Schubert**

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In visual search, an irrelevant distractor draws participants' gaze if the distractor is physically salient (i.e. is of a different color, luminance or orientation from other items), or if it signals the availability of reward (i.e. predicts a monetary payoff). We propose that these two phenomena can be unified under the more general concept of information. Physical contrasts contain local spatial information that a homogeneous background does not, and reward cues offer information about the probable satisfaction of desires. We test this claim in a visual search experiment in which the distractor carries information but is neither physically salient (it is one of many, differently-colored, shapes), nor associated with reward (no money was offered). Instead, the distractor was predictive of an irrelevant event (the appearance of an image). Despite neither physical salience nor association with reward, this distractor draws participants' gaze, though the effect is considerably smaller. We propose that visual search is at least sometimes driven by a 'dispassionate' motivation to gather information about the future, even where that information is neither physically salient nor relevant to reward. We propose future research to measure the relative weight accorded to physical salience, reward and information in visual search.

Funding: Luke Tudge is supported by the Berlin School of Mind and Brain PhD scholarship

[1P009] Visual search during navigation in complex virtual environments: an eyetracking study

**Chris Ramsey, Christos Gatzidis, Sebastien Miellet, Jan Wiener**

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Visual search in real situations often involves head and body movement through space. We present results from a visual search task where participants were required to actively navigate through virtual complex scenes whilst searching for a target object. Using a large, complex virtual environment, eye-movements were recorded for three distinct phases; static visual search, visual search during navigation and locomotion without search. Movement through the virtual environment was characterised. By these means we are able to disentangle the specific contributions search and locomotion have on gaze behaviour and analyse how gaze behaviour differs, depending on the form of trajectory. In addition to the benefits of allowing participants to navigate freely through the virtual environment, we show further benefits of integrating eye-tracking with virtual environments by demonstrating how we go beyond the screen and translate 2D gaze coordinates to actual 3D world coordinates, allowing for novel analysis. We investigate how gaze control behaves within the virtual environments during visual search. For example, the distance into the environment of a fixation or gaze point and the distance between a fixation and target object in the virtual environment are two

measures that go beyond standard 2D analysis of eye-recordings.

[1P010] Saccades performance in a center-periphery visual task

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Computer screens present visual stimuli with a temporary frequency that depends on monitor refresh rate. It determines a temporary modulation that can be or not perceived by the observer. This modulation could affect eye movements (EM) that the subject performs. As a result, a point within the visual field may appear as a sequence of points on the retina, being perceived multiple images during a fixation. In a preliminary research we showed the influence of the refresh rate in visual search task efficiency and EM using 60, 75 and 100 Hz refresh frequencies. As eccentricity of the target is another factor in visual task performance, we evaluate the influence of stimulus temporary modulation when the objective appears in the center or in the periphery. The task is to identify a random number accompanied by distractors of the same category, located in different positions on a computer screen. Objectives appear, in randomized sequence and location, at 0°, 6° and 12°. We analyzed task time, number and length of saccades and fixations time, for 60, 75 and 100 Hz monitor refresh rates. Results show that at lower frequency, the number of short saccades increases when the stimulus is far from the center of the screen.

[1P011] Intertrial Priming and Target Certainty Both Affect Singleton Distractor Interference During Visual Search

**Jacquelyn Berry**

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Visual perception research has shown that what drives attentional capture can be determined by internal factors, such as strategic goals, or by external factors, such as stimulus salience. Proponents of the role of strategic factors point to differences between responses to constant and variable targets during visual search. When the target is constant, and its identity certain, subjects may use a “feature search mode” which is less susceptible to interference by irrelevant stimuli such as a singleton distractor. When the target is variable subjects must employ a wider, “singleton search mode”, which is more susceptible to singleton distractor interference because subjects must be prepared to respond to any item that is visually distinct. In several experiments, we manipulated variable targets regarding: (1) target certainty- the target identity was certain or uncertain, and (2) intertrial priming- the target and singleton distractor shapes were sometimes interchangeable across trials. Intertrial priming was the most important in determining singleton distractor interference and the two interacted producing (1) greater singleton distractor interference when target identity was uncertain and target and singleton distractor shapes were interchangeable, and (2) no singleton distractor interference when target identity was certain and target and singleton distractor shapes were not interchangeable.

[1P012] Search for symbolic images of real-life objects: An eye movement analysis

**Irina Blinnikova, Anna Izmalkova, Maria Semenova**

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In the current study we modeled a web site search task. Subjects (n=39) were to find «icons» - symbolic images of real-life objects (such as butterfly, cactus, book, etc.) among a variety of other objects. Instructions to find target stimuli were given either in written or in graphic form. It was presented for 1 sec, then a rectangular full screen stimulus matrix (9x9) was presented. The target was situated in one of 8 quadrants (the central one was not used). We varied the color and the shape of the stimuli framing. Search time and eye movement data were recorded. In case the target was introduced as a word the search took more time compared to a picture-based search. Moreover, in this case the search time did not depend on the color and the shape of the stimuli in the matrix, and relatively long fixations and short slow saccades were observed. When the test stimulus was introduced as a picture, the search process was determined by physical characteristics of the stimuli in the matrix. The search was performed faster in case the stimuli were square and colored. In this case shorter fixations and longer faster saccades were observed.

Funding: This study was sponsored by the Russian Foundation of Basic Research (№ 14-06-00371)

[1P013] Selective attentional bias to explicitly and implicitly predictable outcomes

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Expectations of an event can facilitate its neural processing. One of the ways we build these expectations is through associative learning. Besides, this learning of contingencies between events can occur implicitly, without intention and awareness. Here we asked how a learned association between a cue and an outcome impacts the attention allocated to this outcome, and particularly when this association is irrelevant to the task at hand and thus implicit. We used an associative learning paradigm where we manipulated predictability and relevance of the association upon streams of cue-outcome visual stimuli, while stimulus characteristics and probability were held constant. To measure the N2pc component, every outcome was embedded among distractors. Importantly, the location of the outcome could not be anticipated. We found that predictable outcomes showed an increased spatial attention as indexed by a greater N2pc component, and surprisingly, even when the learned association was irrelevant to the main task. A later component, the P300, was sensitive to the relevance of the outcome (intention to learn). The current study confirms the remarkable ability of the brain to extract and update predictive information, including implicitly. Associative learning can guide a visual search and shape covert attentional selection in our rich environments.

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[1P014] Attentional capture by subliminal onsets - Stimulus-driven capture or display wide contingent orienting?

**Tobias Schoeberl, Ulrich Ansorge**

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Recent studies attributed cueing effects of subliminal onsets to stimulus-driven attention. They presented a cue as one placeholder with a very short lead time prior to a target and two additional placeholders. Due to the short lead time, participants saw all items appearing at the same time, remaining unaware of the cue. Although the cue was different from targets in color, singleton status and luminance, attention capture by its onset was found: Response times were shorter when cue and target were at the same position than at opposite positions. Here, we investigated whether this cueing effect could have reflected display-wide top-down contingent orienting rather than stimulus-driven capture. Participants might have searched for cue and placeholders as signals for target onsets. We manipulated the contingency between the onsets of cue/placeholders and targets. Presenting cue and placeholders after targets or leaving out the cue in a majority of trials did not change cueing effects, but auditory warning signals in advance of the cues mitigated the cueing effect. In conclusion, our results still favor the stimulus-driven capture hypothesis although auditory warning signals might have been so strong as to bail out small spatial cueing effects on top of it.

[1P015] Entire valid hemifield shows IOR during reference frame task

**Liubov Ardasheva, Tatiana Malevich, W. Joseph MacInnes**

Social sciences (Psychology), National Research University, Higher School of Economics, Russia

We perceive the outside world as stable, however our eyes make about three movements each second causing constant recalibration of the retinal image. The question of how this stability is achieved is still an active research question. Coding of visual input information happens mostly in retinotopic coordinates but must be understood in real world, spatiotopic coordinates. Inhibition of return (IOR) represents the involuntary delay in attending an already inspected location and therefore facilitates attention to seek novel locations in visual search. IOR would only be helpful as a facilitator if it were coded in spatiotopic coordinates, but recent research suggests that it is coded in both frames of reference. In this experiment we manipulated the location of the cue and the target with an intervening saccade and used a continuous cue-target onset asynchrony (CTOA) of 50 – 1000 ms. We found IOR at all locations of the valid, vertical hemifield, including the spatiotopic, retinotopic and neutral frame of reference. This could mean two things: either participants attended the entire valid hemifield or the gradient of IOR is large enough to encompass multiple locations. Finally, we found no differences in IOR for manual and saccadic responses.

[1P016] Task dependency of audio-visual semantic congruency effect on spatial orienting

**Daria Kvasova, Salvador Soto-Faraco**

DTIC, Universitat Pompeu Fabra, Catalonia

Combined information from different senses can affect the deployment of attention in space. For example, attention can be captured automatically by synchronized audio-visual onsets, using simple stimuli. Further, in real-world environments semantic relations between sounds and visual objects might have an influence on attention capture. Recent studies have addressed the role of crossmodal semantic congruency on spatial orienting. However, the results of these studies are mixed, some suggesting that semantic congruency has an effect of attracting attention (Iordanescu et al, 2010; Mastroberardino et al, 2015) and some suggesting that it does not (Nardo et al, 2014). Variations in task-relevance of the crossmodal stimuli (from explicitly needed, to completely irrelevant) and visual perceptual load of the task may account for these differences. Here we aim at investigating how task constrains may modulate the effect of cross-modal semantic congruency on attracting spatial attention. We designed three experiments where the stimuli and the perceptual load are constant, and the only variations are based on task relevance constrains. In this way, we aim to reproduce, within the same paradigm, conditions of explicit, implicit or no task relevance of the multisensory pair, and hence be able to directly compare them.

[1P017] Continuous CTOAs in a cuing task experiment bring about Inhibition of Return, but not early facilitation

**Tatiana Malevich, Liubov Ardasheva, W. Joseph MacInnes**

Social Sciences (Psychology), Higher School of Economics, Russia;

Cueing effects, i.e. an early facilitation of reaction time and inhibition of return (IOR), are well-established and robust phenomena characterizing exogenous orienting and widely observed in experiments with traditional Posner cueing paradigm. However, their specific nature and origin are still a subject for debate. One of the recent explanations proposed for the facilitatory and inhibitory effects of peripheral cues by Krüger et al. (2014) treats them as the result of the cue-target perceptual merging due to re-entrant visual processing. In order to specify the role of these feedback mechanisms in the peripheral cueing effects, the present experiment was conducted, using a modified cuing task with pre- and post-cue trials at the valid and invalid location and random cue-target onset asynchrony ranging from -300 to +1000 ms. Analysis of the manual reaction time distribution showed a well-pronounced IOR effect in the valid pre-cue condition, but no early facilitation of reaction time was observed, neither in the pre-cue nor in the post-cue condition. These results run counter the outcomes of the traditional experiments with cue-target spatial overlap.

[1P018] Location based processing in object substitution masking

**Iiris Tuvi, Talis Bachmann**

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According to Pöder's (2013) object substitution masking model there are two stages of processing in object substitution masking (OSM). First stage is an unselective stage where attention is distributed and target signal must be detected from the noise originating from other signals. The second stage is a selective stage where attention is directed to the target location and noise from more restricted space around the target location may contribute to the masking effect. Here, we explored how close to the target location the mask must be in order to influence the OSM effect and found that a single dot mask in the target location was as influential as were the distracters next to the target location despite that these objects differed in size and complexity. When the attention directing cue appeared after the target offset and the identification relied on the visual short-term memory performance dropped about 20% compared to the simultaneous attentional selection condition. The results support Pöder's OSM model and favor location based processing explanation of OSM since distracters next to the target location appear to be the source of masking noise in the trailing mask stage.

[1P019] Attentional capture by unexpected onsets depends on the top-down task-set

**Josef G. Schönhammer, Dirk Kerzel**

FAPSE, University of Geneva

Many studies showed that attentional capture by peripheral, spatially unpredictable precues is contingent on the task-set that observers establish in response to the target display. In contrast, a recent study reported that infrequent onset cues (a single new object in the display) captured even when the targets were red color singletons (a red item among white nontargets) and also when the targets were red non-singletons (a red target among one green and several white nontargets). This suggested that unexpected onsets capture independently of task-sets (Folk & Remington, 2015). In our Experiment 1, we replicated these findings. In Experiment 2, however, rare onset cues did not capture when the

target was a red item among a single white nontarget. This finding suggests that the target display did not only induce a positive task-set for the target property (red color), but also suppression of the nontarget property (local onset or its achromatic color). Hence, the nontarget properties in Experiment 2 probably required suppression of those properties that defined the onset cue, which eliminated capture. Thus, unexpected onsets do not capture attention independently of the task-set. Previous studies in favor of this hypothesis used tasks that did not require suppression of adequate properties.

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[1P020] Testing three systems of attention with saccadic and manual responses

**Alena Kulikova, W. Joseph MacInnes**

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The idea of three attentional networks (Posner & Peterson, 1990) illustrates how systems of anatomical areas in the cortex execute specific functions of attention, such as alerting, orienting, and executive control. The Attentional Network Test (ANT) was designed to test for interactions between these systems (Fan et.al., 2002). In Experiment 1 we use a version of the ANT with an auditory trigger (Callejas, Lupiáñez, & Tudela, 2004) by adding an eye-tracker to control for eye movements. Only two main effects were found: participants were quicker to respond in congruent versus incongruent trials, and in cued versus uncued trials. Also, an interaction between congruency and validity was observed. In a Experiment 2, we modified the ANT for a saccadic response instead of a manual response by replacing the congruency task with an anti-saccade task that is believed to be performed under executive attentional control (Vandierendonck et.al., 2007). Main effects of alerting, orienting, and executive control were observed. Additionally, alerting interacted with orienting, with alerting effects only observed for valid and neutral cues. The congruency/validity interaction in Experiment 2 was different from Experiment 1, which suggests that networks might not be the same for each executive control task.

[1P021] Visual strategies of viewing flow visualisations under different workload conditions and representation types

**Vladimir Laptev<sup>1</sup>, Pavel A. Orlov<sup>2</sup>, Ulyana M. Zhmailova<sup>1</sup>, Vladimir Ivanov<sup>1</sup>**

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Flow visualization is used to provide dynamic representation of data structure. It is especially valuable in big data analysis and serves a useful component of control interfaces and visual analysis tools. This paper is focused on visual strategies of data flow perception by human subjects under a workload of difference intensity. The study employed three representations of Sankey diagrams: a solid flow; separated flows; and discrete flows composed of equally sized countable modules. The workload was determined by the number of flows: three, four, and five. This allowed to estimate the impact of data structure complexity. The correct answers were less frequent under lighter workload, their number being independent from the type of representation. The subjects counted the modules in discrete flows only when the workload increased. This caused faster task solving with a smaller number of gaze fixations. The attention map for discrete flows was different from that for the other types: the subjects did not look at the single starting flow when comparing the split flows. Meanwhile, when analysing the other flow types, the subjects were switching attention to the beginning of the chart in order to compare flows' sizes with starting unsplit flow.

[1P022] Orientation-Contrast-based Retinotopy

**Frans W Cornelissen, Funda Yildirim**

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Orientation-selective neurons abound throughout visual cortex. Nevertheless, in human fMRI, the assessment of orientation selectivity is still relatively uncommon. Here, we use fields of oriented Gabor patches as a means to map and characterize properties of early visual cortex. In "orientation-contrast-based retinotopy (OCR)", participants view arrays of gabors composing a foreground (a bar) and a background that can only be distinguished by gabor orientation. We compared the population receptive field (pRF) properties obtained using OCR and classic luminance-contrast-based retinotopy (LCR). Visual field maps for LCR and OCR were highly comparable. Explained variance (EV) of the

pRF-models for OCR was lower than for LCR. Yet, for OCR EV remained constant over eccentricity while for LCR it tended to drop with eccentricity. This was most marked in visual areas LO1 and LO2. For V1-V4, pRF eccentricity for LCR and OCR was comparable, yet OCR resulted in smaller pRFs. For LO1 and LO2, both pRF eccentricity and size differed substantially between LCR and OCR, with lower eccentricity and smaller sizes estimated for OCR. We discuss why OCR may result in more accurate pRF estimation, and may therefore be the method of choice, in particular when characterizing higher order visual areas.

Funding: Graduate School Medical Sciences Groningen

[1P023] Locally-directed visual attention as assessed by the attentional blink: Does video game experience really matter?

**Travis C Ting, Nicole H.L. Wong, Dorita H.F. Chang**

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Studies have demonstrated the potential visuo-cognitive benefits of action video gaming, e.g. reduced attentional blink (Green & Bavelier, 2003), although such effects are controversial (e.g. Murphy & Spencer, 2009). It is unclear whether visual-attentional benefits, if present, hold when attention is restricted and directed locally, in the presence of potentially conflicting global information. Here, we investigated the role of action video game experience on locally-directed visual attention by testing video-gamers ( $n = 18$ ), and non-video-gamers ( $n = 18$ ) on an RSVP sequence composed of congruent and incongruent Navon figures. Participants were asked to selectively attend to local aspects of the stimuli only and identify the first target and the presence of a second target. Attentional blink (AB) was quantified as the impairment in detection of a second target. Results indicated a pronounced attentional blink in both groups, with no significant difference in the magnitude of AB between groups. This is in contrast to a significant advantage for video-gamers versus non-gamers if attention is instead globally-directed (Wong et al., unpublished data). The findings suggest that visual-attentional advantages as traditionally reported for extensive video-gaming experience does not extend to a restricted local system that may tap into a slower parvocellular (P)-pathway.

[1P024] Attending to external feedback in goal-directed pointing: Differences in attention allocation based on feedback

**Aoife Mahon, Constanze Hesse, Amelia Hunt**

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While attention is usually automatically allocated to movement targets during action planning, consciously attending automated actions can negatively impact accuracy. Allocating attention to external locations of feedback can benefit these actions. We investigated whether attention allocation to movement goals is enhanced due to this being the location from which the most reliable feedback about movement accuracy is obtained. Participants pointed to a cued target while discriminating a perceptual target that could occur at the movement location, an independent feedback location or a task-irrelevant location. In Experiments 1-2, feedback about movement accuracy was provided immediately after the movement. In Experiment 3, feedback was provided during the movement. Experiment 1 was performed visually closed-loop while vision of the hand was prevented in Experiment 2 and 3. In all experiments, discrimination performance was enhanced at movement locations, confirming attention allocation to the movement target. Perceptual enhancement was larger when visual feedback from seeing one's hand was removed. When feedback was given after the movement, perceptual performance was not enhanced at feedback locations, however there was enhancement if feedback was provided during the movement. This suggests that attention is needed both for movement target selection and for monitoring feedback during movement execution.

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[1P025] The role of perceptual factors in the reflexive attentional shift phenomenon

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The presence of a cue in the visual scene that orients attention can interfere with what we report to see. It has been suggested that this interference effect is affected by socially-relevant characteristics of the cue (social model of

interference); for instance when attention is biased by the presence of a cue to whom a mental state is attributed (e.g. another person). This paper examines whether perceptual features of the cue, readily detected by visual processes (perceptual model of interference), are sufficient to elicit the interference effect. To compare the social and perceptual models of interference, an experiment was conducted which systematically manipulated the mental state attribution to the cue. The results show that interference persists even when a mental state is not attributed to the cue, and that perceptual expectations are sufficient to explain the reflexive attentional shift, thus supporting a perceptual model of interference.

[1P026] Perception of backward visual masking in a patient with bilateral frontal leucotomy  
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J.R., a patient that had most of the prefrontal cortex disconnected from the rest of the brain after receiving a bilateral frontal leucotomy in his youth, participated in a series of backward masking experiments conducted at the Institute Pere Mata, a psychiatric hospital in Reus, Catalonia, Spain. Visual stimuli were presented on a computer screen and consisted of vertical bars, where the central bar (target) was abutted by two flanking bars (masks). J.R. conducted multiple sessions of a 2-alternative forced choice (2-AFC) task, where he indicated which of two targets, presented on the left and right sides of the screen, was longest, by pointing at the corresponding side of the screen. Experimental conditions included left vs right presentation on the screen, 2 target durations (34 ms and 100 ms), 3 target and masks lengths (3, 4, and 5 dva), and 6 stimulus onset asynchronies (SOAs) between target and masks (0ms, 34ms, 67ms, 100ms, 134ms, no masks). J.R. also indicated verbally whether he thought that the left and right targets were 'equal' or 'different' in each trial. The 2-AFC results indicated significant masking at 0ms, 34ms and 67 ms SOAs. Yet, J.R.'s complementary verbal reports suggested unawareness of the targets.

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[1P027] Reading in visual noise in developmental dyslexia and autism spectrum disorders  
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Neurodevelopmental conditions as autism spectrum disorders (ASD) and developmental dyslexia (DD) are characterized by a different specific pattern of behavioural and learning difficulties. However, important common feature of both conditions is limited performance efficiency induced by external sensory noise. The present work studied visual noise effect on reading performance in individuals with ASD or DD. We compared reading durations and error rates for real words and pseudowords in presence or absence of text degradation produced by random displacement of letters above or below the horizontal reading line. Observers with ASD, DD and typically developing controls showed similar reading durations for non-degraded real words. However, reading durations as well as error rates increased proportionally to the noise variance increase. The positional noise affected most strongly reading performance in ASD. Likewise, the time for reading pseudowords was similar for the three groups of observers (insignificantly longer in DD). Increasing vertical displacement of pseudowords letter position, the reading duration and error rates increased most strongly for ASD observers. Deteriorated reading performance in visual noise for ASD and DD could be a marker for increased sensitivity to sensory noise or dysfunction in a mechanism responsible for grouping object elements and constructing global percepts.

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[1P028] Autistic traits indicate characteristic relation between self-body, others-body, and spatial direction  
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Previous study has shown the difficulties of visual perspective taking in persons with autism. To examine the effect of autistic traits on these cognitive features about self-body, others-body, and visual space, we asked participants to

complete left-right discriminations with different perspectives. An avatar, which was accompanied with flowers on both left and right sides, was displayed on a PC monitor. The avatar took one of three postures (front, back, and front with arm-crossing). At the beginning in each trial, participants were instructed the direction (left or right, side of left hand or right hand) and perspective (own or other person's); they had to touch an either flower as soon and accurately as possible. All participants were right-handed. We analyzed response time and error rate at each condition. In the result, persons with higher autistic traits didn't have advantages on the response time in the situation that they could project themselves onto the back view of avatar easily when they had to change the perspective to the other person's. They tended to use body parts of the avatar as cues to discriminate the directions. These results suggested that characteristic tendency about self-body, others-body, and space is associated with autistic traits.

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[1P029] Neurotechnologies for rehabilitation of the patients in neurological and psychiatric clinics

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For the recovery of mental and motor functions, we created an experimental setup. Our system was made of modules that connected in various combinations, depending on the task. Stimulation module consists of a panoramic 3D-display to demonstrate virtual scenes with adjusted spatial and temporal frequencies. The crucial approach was the selective activation of magno- and parvo-channels of the visual system. The human state control module includes EEG, ECG, eye-tracking system, and the system to capture and describe body movements, facial expressions. Setup uses API software and our own software that synchronize the given signals and the whole complex of the measured parameters. The system to capture and describe body movements, which is important for neurological clinic [Adar Pelah, i-Perception, 3(4), 2012], includes a treadmill, and software that form a statistical model of human movements. The system permits the rehabilitation of patients with disorders of motor activity after a stroke, patients with psychosis (schizophrenia), psychopathy and neurosis. Rehabilitation works on the principle of optical feedback and importance of magno- and parvo-channels stimulation in natural scenes, which permit us to reactivate neuronal networks in subjects, including schizophrenia patients. Pilot studies have shown the effectiveness of this hardware-software complex.

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[1P030] Visual rehabilitation in chronic cerebral blindness: a randomized controlled crossover study

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The treatment of patients suffering from cerebral blindness following stroke is a topic of much recent interest. In the current study twenty-seven chronic stroke patients with homonymous visual field defects received a visual discrimination training aimed at vision restitution. Using a randomized controlled crossover design, each patient received two successive training rounds, one directed to their affected hemifield (test) and one round directed to their intact hemifield (control). Goldmann and Humphrey perimetry were performed at the start of the study, and following each training round. In addition, reading performance was measured. Goldmann perimetry revealed a statistically significant reduction of the visual field defect after the test training, but not after the control training or after no intervention. For both training rounds combined, Humphrey perimetry revealed that the effect of a directed training (sensitivity change in trained hemifield) exceeded that of an undirected training (sensitivity change in untrained hemifield). Reading speed revealed a significant improvement after training and was related to the extent of field recovery measured by Goldmann after test training. These findings demonstrate that our visual discrimination training can result in reduction of the visual field defect and can lead to improvements in daily life activities such as reading.

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[1P031] How the lack of vision impacts on perceived verticality

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Estimation of verticality can be biased depending on the encoding sensory modality and the amount of head and body roll tilt relative to the gravitational vector. Less is known on how these factors influence haptic perception of verticality in visually impaired people. In the present work, we had sighted and non-sighted participants with their head and body roll tilted 90° relative to gravity and asked them to perform orientation adjustments and discrimination tasks using a motorized haptic bar positioned in different locations along their body. Consistently with previous findings, sighted participants show that their perceived verticality is biased towards the opposite direction of their roll tilt. On the other hand, visually impaired individuals show a different pattern of verticality estimations compared to the sighted group. Results suggest that long-term absence of vision might lead the brain to rely mostly on internal references that are centered on the head (e.g. vestibular based) thus leading to verticality estimates towards the roll tilt. Factors influencing these differences can be ascribed to age, capacity of echolocation and visual impairment onset (either acquired or congenital). These findings throw light on the role of vision in multisensory calibration involving vestibular sensory information and body based perception.

[1P032] Word and text processing in developmental prosopagnosia

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The ‘many-to-many’ hypothesis [Behrmann & Plaut (2013). Trends in Cognitive Sciences, 17(5), 210-219] proposes that processes involved in visual cognition are supported by distributed circuits, rather than specialized regions. More specifically, this hypothesis predicts that right posterior fusiform regions contribute to face and visual word processing. However, studies testing visual word processing in acquired prosopagnosia have produced mixed results. In this study, we evaluated visual word and text processing in subjects with developmental prosopagnosia, a condition linked to right posterior fusiform abnormalities. Ten developmental prosopagnosic subjects performed two tasks: first, a word-length effect task and, second, a task evaluating the recognition of word content across variations in font and handwriting style, and the recognition of style across variations in word content. All prosopagnosic subjects had normal word-length effects. Only one had prolonged sorting time for word recognition in handwritten stimuli and none were impaired in accuracy. These results contrast with prior findings of impairments in processing style in acquired prosopagnosia and suggest that the deficit in developmental prosopagnosia is more selective than in acquired prosopagnosia, contrary to predictions derived from the many-to-many hypothesis.

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[1P033] Dysfunction of parvo-systems and its stimulation in patients with schizophrenia with early stage of the disease

**Svetlana V Muravyova, Galina Moiseenko, Marina Pronina, Eugene Shelepin, Yuriy Shelepin**

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These electrophysiological and psychophysical studies, we conducted on a group of patients with paranoid form of schizophrenia, disease duration 1 - 3 years, mild and medium severity of the disease, showed a dominant dysfunction of parvo-system. The work consisted of 3 stages. The first stage: measurement of cognitive visual evoked potentials and measurement of contrast sensitivity of spatial stimuli and images of objects that are processed using wavelet filters for the low and high spatial frequencies. The second stage was the impact on the visual system of patients by presenting of virtual environment - video that simulates the ride on the bike in the first person through the varying landscape with different terrain. The task of the patient included a careful review of spatial images (stimulation of magno-system) and the individual objects on the monitor (stimulation of parvo-system). The third stage was the repeated measurement of cognitive visual evoked potentials and contrast sensitivity. We can conclude that in patients with schizophrenia disease duration of 1 to 3 years there was a dysfunction of the parvo-system, and the virtual environment improved the efficiency of this system by stimulating the object vision.

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[1P034] Impaired cognitive functioning in first-episode patients

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The first psychotic episode is an important period for prevention of cognitive and social deterioration in schizophrenia. Cognitive deficits are of particular interest since they are evident even before a proper diagnosis can be made. Interestingly, there is a relation between cognitive deficits and social functioning. Here, we investigated the changes in cognitive and social functioning during one year and determined also the association of social functioning with cognitive impairments and psychopathological symptoms in first episode patients. 32 patients with a first psychotic episode and 32 healthy controls were investigated. Cognitive functions such as visual perception, executive functions, sustained attention, were tested with visual backward masking (VBM), the Wisconsin Card Sorting Test (WCST), and the Continuous Performance Test (CPT). Follow up tests were carried out after 6 and 12 months. Social functioning of the patients was evaluated by Health and Outcome Scale (HoNOS). Cognitive functions of patients were impaired compared to the healthy controls in all 3 tests. Performance in the cognitive tests did not change significantly during the year. Treatment compliance, however, improved social and symptom indicators.

[1P035] Inverted saccade adaptation in Parkinson's disease.

**Mark R Harwood<sup>1</sup>, Alicia Perre-Dowd<sup>2</sup>, Annabelle Blangero<sup>3</sup>**

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Parkinson's disease (PD) is most known as a limb and body movement disorder, but it can also affect the initiation, dynamics and amplitude of saccadic eye movements. Multiple small 'staircase' saccades, each undershooting the desired target location, are commonplace in reflexive PD saccades. We hypothesized that this might result from an abnormal amplitude-increasing adaptation mechanism ('saccade adaptation' usually corrects consistent landing errors). To test this hypothesis we recorded 20 PD patients with age-matched controls using a brief intertrial interval, reflexive saccade paradigm. In separate sessions in the same subjects, we stepped the target forward (backward) by 20% of the initial target amplitude during the saccade towards it. We found significant amplitude-reduction in both sessions in the PD subjects, revealing an inverted saccade adaptation response to forward intrasaccadic target steps. This apparently maladaptive response might explain the persistence of 'staircase' saccades in PD.

Funding: National Science Foundation

[1P036] Gaze fixation during the slowing down presentation of handwriting movement in adults with autism spectrum disorders

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Autism spectrum disorders (ASD) are neurodevelopmental disorders characterized by impairments in social communication, restrictive interests and behavior (DSM-5, APA, 2013). Some of these impairments can be owed to a too fast surrounding world (Gepner & Feron, 2009). Previous studies of children with ASD suggest better information processing when the presentation of dynamic facial expressions is slowed down (Charrier, 2014). We hypothesized that a visual slowing down of the presentation of handwriting movement (HM) could help adults with ASD to improve their handwriting, due to a better information processing. Indeed, HM in adults with ASD is a domain poorly investigated in spite of the difficulties (Beverdors et al., 2001). We showed movies of dynamic handwriting of non-letters and non-words to adults with ASD and to two paired control groups on chronological age and non-verbal mental age. We manipulated presentation speed (real time speed, slow and very slow) and handwriting complexity. Gaze fixation, for the ASD group at slow speed and complex non-words, showed that there are more significant fixations on the word and less fixations on the hand compared to real time speed. This result could indicate that it facilitates the selection of relevant information for HM.

[1P037] Effect of unconscious fear-conditioned stimuli on eye movements

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The efficient detection and evaluation of threat from the environment is critical for survival. Accordingly, fear-conditioned stimuli receive prioritized processing and capture attention. Although consciously perceived threatening

stimuli have been shown to influence eye movements, it is unknown whether eye movements are influenced by fear-conditioned stimuli that are presented outside of awareness. We performed a classical fear-conditioning procedure with fearful faces using an aversive noise as the unconditioned stimulus. In a subsequent test phase, participants' eye movements were recorded while they were exposed to these fear-conditioned stimuli that were rendered invisible using interocular suppression. Chance-level performance in a manual forced-choice-task demonstrated participants' unawareness. Differential skin conductance responses and a change in participants' subjective ratings of the fearfulness of the faces indicated that the conditioning procedure was effective. In contrast, eye movements were not specifically biased towards the fear-conditioned stimulus. These results suggest that (I) the initiation of eye movements towards fear-conditioned stimuli requires awareness, or (II) a saccadic bias towards fear-conditioned stimuli in the absence of awareness hinges on the stimulus feature that is conditioned: While fear-conditioning contingent on high-level features, such as face identities, may abolish overt attentional selection without awareness, it may still occur for fear-conditioned low-level features.

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[1P038] The dynamics of gaze trajectory when imagining a falling object

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Despite known neural delays involved in the perception-action cycle, humans show impressive abilities when interacting with moving objects. Allegedly the brain capitalizes on physical regularities by developing internal models which aid and guide the processing of dynamic information. In striking contrast, humans show significant deviations from normative physics when asked to reason about dynamic events. To date, few inquiries have been made into how humans process dynamic information at intermediate levels between sensorimotor and cognitive stages. The present work aims at filling this gap: participants were shown animations depicting a basketball being launched from the top of a brick wall, with heights varied, at different speeds. The ball disappeared just before falling or 350ms after leaving the wall. Participants were asked to vividly imagine that the ball continued its motion and to indicate when they thought it would reach the floor while their eye movements were recorded. The visual information about the first 350 ms had remarkable positive effects on the eye trajectory but not on the temporal accuracy. The gaze followed paths in close agreement with the physical trajectory, except for a deceleration of eye movements in the final phase, which might account for an overestimation of time judgements.

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[1P039] Does conceptual quantity of words affect the spatial coding of saccade responses, like a SNARC effect?

**Alexandra Pressigout, Agnès Charvillat, Alexandra Fayel, Viktoriya Vitkova, Karine Doré-Mazars**

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The spatial-numerical association of response codes (SNARC) effect has abundantly been documented with numerical quantity for Arabic numbers. In the present study, we tested whether the representation of conceptual quantity in words ("IDOLE" versus "LEGION") is automatically activated and spatially coded in the same way as numerical quantity. On the basis of saccade responses, we examined gaze durations both in a baseline condition where participants had to judge the parity of number words (from zero to nine) and in a condition where they had to judge the gender of words expressing small versus large quantities. Preliminary results show the expected SNARC effect elicited by numerical quantity (i.e. faster gaze durations to leftward/rightward responses with small/large numbers, respectively). Surprisingly, a different pattern was found for conceptual quantity with a gender-space interaction (i.e. faster gaze durations for leftward/rightward responses with masculine/feminine words, respectively) which tends to interfere with a SNARC-like effect. Results are discussed in terms of multiple stimulus-to-response mapping conflicts involving the semantic and grammatical levels of word processing.

[1P040] Identifying information processing strategies during the picture completion test from eye tracking data

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The Picture Completion Test (PCT) is a visuospatial cognitive task in which an important missing portion of a picture must be identified. The PCT is included as a sub-test in Binet and Wechsler intelligence tests and is thought to involve the use of a wide range of abilities including long-term memory, knowledge, and reasoning. However, few studies to date have examined the cognitive processing involved in the PCT. In the present study, we administered our own version of the PCT to 20 adults (mean age: 21.61 years, SD: 1.62) and analyzed eye tracking data during the test. We analyzed whether patterns of gaze toward areas including missing portion of a picture (Critical Areas of Interest : CAOI), by examining the relationship with assumed visual information processing subtypes of the PCT. In many of the pictures, the relative extent of gazing toward the CAOI was linked to successful performance of the test. Furthermore, using mean first fixation time on the CAOI and the difficulty of each picture as indicators, our findings suggested that differences in information processing strategies can be determined.

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[1P041] The role of eye movements during image learning and recognition

**Polina Krivykh, Galina Menshikova**

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The aim of our study was to reveal eye movement characteristics when performing two tasks: A) to memorize a set of images and B) to recognize them among other images. In session A the participants were shown a short comic strip (15 pictures, each for 5000 ms) and asked to learn them. In session B they were shown a set of the same 15 images added on 5 unfamiliar but related story images included in a strip. The participants were asked to recognize the images learned in session A. During the performance of both sessions eye movements were recorded. It was shown that for learned stimuli fixation durations, fixation counts and saccade counts during correct recognition were significantly lower in comparison with the same eye movement characteristics for incorrect answers. As to unfamiliar stimuli eye parameters during their perception were similar to those revealed in a session A. The data showed also that the features selected in the first and second fixations during learning session were not recapitulated during recognition session. Our results indicate that the eye movement characteristics may be considered as reliable indicators of learning processes.

[1P042] Fixations on human face: cross-cultural comparison.

**Kristina I Ananyeva, Ivan Basyul, Alexander Demidov**

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We studied cross-cultural differences in eye movement characteristics with 49 Russian and 60 Tuvan subjects viewing 14 color images of Russian and Tuvan still faces in two conditions: (1) free viewing of face, and (2) identification of race of face. Registration was made using SMI RED-m 120 Hz eye-tracker. Average duration and number of fixations in different facial areas were counted. In free viewing condition, Russians demonstrated significantly longer duration of fixations in left and middle parts of face when viewing both Tuvan and Russian faces. Tuvans demonstrated significantly more fixations in these areas, and longer average duration of fixations in midface area of Russian faces. Russians showed significantly more fixations in midface area of Tuvan faces. In race attribution task, Russians showed significantly shorter duration of fixations and larger number of fixations in all facial areas in comparison with free viewing condition. Tuvans showed similar duration of fixations in the left, right and midface area, and number of fixations in midface and right areas, and, compared to Russians, significantly longer duration of fixations and smaller total number of fixations in all facial areas.

Funding: The study was supported with the Russian Federation Presidential grant for young scientists, project no. MK-7445.2015.6.

[1P043] Is the remote distractor effect on saccade latency greater when the distractor is less eccentric than the target?

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The remote distractor effect (RDE) shows that saccades are initiated with a longer latency when their target is displayed with a foveal, and/or remote, distractor stimulus (Walker et al., 1997). It has been attributed to a competition between a fixation, gating, system, whose activity is enhanced when a stimulus falls within an extended foveal region, and a move system, associated with peripheral stimulation. According to this hypothesis, the critical variable to

account for saccade latency is the distractor-to-target-eccentricity ratio. However, while some studies suggest that inter-stimulus distance might be the relevant variable, the ratio has never been manipulated independently of inter-stimulus distance. Here, we manipulated orthogonally the distractor-to-target-eccentricity ratio and the angular separation between the stimuli. The target, always on the horizontal axis, appeared either alone or with a distractor on the same or a different axis, with the distractor eccentricity, and hence the ratio, being also manipulated. As expected, we observed that the presence of a distractor systematically delayed saccade onset (the RDE), compared to a singleton target condition. Interestingly this effect tended to decrease as the distractor-to-target-eccentricity ratio increased, irrespective of the angular separation between the stimuli. These findings provide further evidence for the fixation-move hypothesis.

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[1P044] The correlation between visual perception and verbal description of painting

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This study focuses on the perception and verbalization of visual information. Our aim was to investigate if there is any correspondence between visual perception and verbal description of complex images. Eye movements were recorded while 30 subjects were looking at the classic painting of genre scene (free viewing), and then they were asked to compose its coherent verbal description. Comparative analysis revealed the strong correlation between the eye-movements patterns (fixations distribution and duration) during free viewing and the following narration: the more and the longer the gaze was directed to the certain region of the picture, the more words were dedicated to this region in the verbal description. Furthermore our results showed the correlation between the ordinal sequence of fixations on depicted objects and the order these objects are mentioned in the narrations. Although paintings and verbal texts have different structures (the latter are composed of discrete units and have linear structure, the former are not divided into discrete units and are not linear), our data show that there is a relationship between the way humans perceive visual information and the way they express it in natural language.

[1P045] Do sunglasses hide your feelings?

**Priscilla Heard, Hannah Bainbridge**

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Twenty two participants viewed Nimstim and Ekman emotional faces. Half the faces had their eyes covered with sunglasses. Participants fixated a cross while the face was presented 15 degrees to the right or left of fixation. They made a seven alternative forced choice response of one of the standard emotions. Once this emotion recognition had been made participants were allowed to free view the face centrally and name another emotion if they so wished. The observer's eyes were tracked to check the fixation was maintained and monitor where the eyes moved when free viewing was permitted. Emotion recognition 15 degrees in the periphery was overall 60% correct for the normal faces but only 52% for the faces wearing sunglasses. When centrally viewed the emotion recognition went up to 80% for the normal faces but was only 67% for those wearing sunglasses. The happy face was the most recognized emotion under all conditions. Eye tracking data will be reported.

[1P046] Planning functional grasps of tools. What can eye movements tell us about motor cognition?

**Agnieszka Nowik, Magdalena Reuter, Gregory Kroliczak**

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The visual structures and/or the perceived functional characteristics (i.e., affordances) of tools are thought to automatically “potentiate” relevant actions. Is this also the case for eye movements in the absence of overt tasks? This idea was tested directly by asking participants skilled in tool-related actions to freely view pictures of tools or to watch them with a view to planning functional grasps that enable immediate use. SMI RED eye-tracker was utilized to study the patterns of eye movements. The stimuli were high-resolution photos of workshop, kitchen, and garden tools shown at three angles (0, 135, and 225 degrees) in their foreshortened perspectives, emulating 3D viewing. Although as expected, the number of saccades did not differ between tasks, there was a significant interaction between task and the inspected object part (i.e., affording grip vs. enabling action). Namely, when participants planned functional grasps,

their attention was drawn significantly longer to parts affording appropriate grips. This was not the case during free viewing wherein fixations were distributed more equally across parts. These outcomes indicate that the visual exploration of tools is quite sensitive to task requirements. Therefore, other cognitive factors must contribute to automatic action potentiation when tools are encountered.

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#### [1P047] Testing the level of knowledge of a foreign language using Eye-Tracking technology

**Maria Oshchepkova, Galina Menshikova**

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The aim of our work was to create a method for testing the level of knowledge of English language of Russian students using eye-tracking technology. Three types of images were constructed consisting of: 1) two English words one with correct-incorrect spelling located right and left of the fixation point; 2) the English word and four (1 correct and 3 incorrect) translations into Russian; 3) the Russian word and four (1 correct and 3 incorrect) translations into English. The images were presented for 5000 ms. The participant's task was to choose the right variant. During the execution eye movements were recorded. The results showed that fixation durations and fixation counts during the fixation on the correct word were significantly larger than on the misspelled word. The same eye activity was shown during the choice of correct word translation into Russian or English. Our results were in good agreement with the E-Z Reader Model (Reichle et al. 1998). Thus eye movement characteristics allow developing the method of testing the level of knowledge of a foreign language.

#### [1P048] Eye movements in second language vocabulary acquisition

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We used eye tracking technique to investigate the process of reading SL texts. To date, studies of eye movements in SL reading have focused on the influence of contextual characteristics - frequency, word familiarity, etc. (Williams & Morris, 2004; Rayner et al., 2011). It remains largely unknown, however, how SL vocabulary acquisition techniques are reflected in eye movements. Eye movement data of 26 Russian-speaking students was recorded as they read an English (SL) text with 10 implanted low-frequency words. We classified vocabulary acquisition techniques the subjects reported based on the work of H.Nassaji (2003): using contextual, morphological or discourse knowledge. We also analyzed the mistakes Ss made when asked to translate the words into their native language. The coefficient of contingency between the techniques and the mistakes was 0.43 ( $p < .05$ ). Significant distinctions were found in eye movement patterns when different vocabulary acquisition techniques were used: most fixations and returns to the words were made if the use of contextual knowledge was reported, whereas using discourse knowledge resulted in fewer fixations on the words and shorter saccadic amplitude. The findings indicate that subjects use different vocabulary acquisition techniques, which are consistent with recall mistakes and are reflected in eye movement characteristics.

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#### [1P049] Evolutive Gradient Face Compositing using The Poisson Equation

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Face compositing aims to create images resembling the faces seen by witnesses for forensic or law goals. Composites have allowed the identification of offenders and are accepted as a trial evidence. State-of-the-art systems for face compositing, as the EvoFit system, are based on the evolution of the Principal Component Analysis (PCA) coefficients of a sample of images according to participant selections. Given that image gradient represents image features in a more reliable way, we present an evolutive method where images are represented by the complex PCA coefficients of their gradient instead of the pixel ones. To translate the gradient representation into the pixel domain we solve the corresponding Poisson equation relating the image Laplacian and the image pixels using Neumann boundary conditions. This method is amenable for real world applications. We performed a within-subjects design controlling for the distinctiveness of target identities to compare the perceived results of using pixel and gradient methods in evolutive face compositing. Participants perceive a higher likeness between the resulting composites and the target

identity when they were built using the gradient representation.

[1P050] Combined TMS and fMRI demonstrates a Double dissociation between face and motor functional brain networks

**David Pitcher<sup>1</sup>, Daniel Handwerker<sup>2</sup>, Geena Ianni<sup>2</sup>, Peter Bandettini<sup>2</sup>, Leslie Ungerleider<sup>2</sup>**

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The brain contains multiple brain networks specialized for different cognitive operations that support human thought. The extent to which these functional networks are functionally independent and segregated is unclear. We addressed this issue by causally disrupting two functional brain networks with thetburst transcranial magnetic stimulation (TBS) and measuring the effects of this disruption across the entire brain with resting-state functional magnetic resonance imaging (rs-fMRI). Over two sessions sixteen participants were scanned using rs-fMRI before and after TBS was delivered over the face-selective right superior temporal sulcus (rpSTS) or the hand region in the right motor cortex (hMC). Results revealed that TBS delivered over the rpSTS selectively reduced connectivity in the face network more than connectivity in the motor network. While TBS delivered over the hMC selectively reduced connectivity in the motor network more than connectivity in the face network. These results demonstrate that brain networks that support different types of cognitive operations are spatially and functionally independent and can be selectively dissociated by neural disruption to component cortical regions. We propose that systematically disrupting functional networks with TBS will facilitate our understanding of how the brain supports cognition.

Funding: NIMH Intramural

[1P051] Spatiotemporal dynamics of view-sensitive and view-invariant face identity processing

**Charles C Or, Joan Liu-Shuang, Bruno Rossion**

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How humans differentiate faces across substantial variations in head orientation is not well understood. Using fast periodic visual stimulation in electroencephalography (EEG), we investigated face individualization in 20 observers across 7 ranges of viewpoint variations: 0° (no change), ±15°, ±30°, ±45°, ±60°, ±90°. Stimulation sequences (60s each) consisted of one face identity varying randomly in viewpoint at F = 6 Hz (6 faces/s) interleaved with different face identities every 7th face (F/7 Hz = 0.86 Hz). Periodic EEG responses at 6 Hz captured general sensitivity to faces; those at 0.86 Hz and harmonics captured face individualization. All observers showed general face-sensitive responses, with a view-sensitive pattern emerging over occipito-temporal regions with viewpoint variations. Face-individualization responses, also present in all observers, decreased linearly over occipito-temporal regions with increasing viewpoint variations (responses at ±90° were < 50% of those at 0° variation), suggesting reduced face-identity discrimination. Analyzing the face-individualization responses in the time-domain revealed a dissociation between an early (~200–300 ms), view-sensitive response and a later (~300–600 ms), view-invariant response. These findings suggest that an initial reduced ability to discriminate face identities due to viewpoint variations is compensated partly by a later view-invariant process.

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[1P052] Holistic Processing of Static and Rigidly Moving Faces

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Unlike most everyday objects, faces are processed holistically—they tend to be perceived as indecomposable wholes instead of a collection of independent facial parts. While holistic face processing has been demonstrated with a variety of behavioral tasks, it is predominantly observed with static faces. Here we investigated three questions about holistic processing of moving faces: (1) are rigidly moving faces processed holistically? (2) does rigid motion reduces the magnitudes of holistic processing? and (3) does holistic processing persist when study and test faces differ in terms of facial motion? Participants completed two composite face tasks (using a complete design), one with static faces and the other with rigidly moving faces. We found that rigidly moving faces are processed holistically. Moreover, the magnitudes of holistic processing effect observed for moving faces is similar to that observed for static faces. Finally, holistic processing still holds even when the study face is static and the test face is moving or vice versa. These results

provide convincing evidence that holistic processing is a general face processing mechanism that applies to both static and moving faces. These findings indicate that rigid facial motion neither promotes part-based face processing nor eliminates holistic face processing.

Funding: The study was supported by the Max Planck Society.

[1P053] Face inversion reveals configural processing of peripheral face stimuli

**Petra Kovács<sup>1</sup>, Petra Hermann<sup>2</sup>, Balázs Knakker<sup>2</sup>, Gyula Kovács<sup>3</sup>, Zoltán Vidnyánszky<sup>2</sup>**

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Sensitivity to configural properties of face stimuli is a characteristic of expert face processing and it can be unveiled by changing the orientation of foveal face stimuli, resulting in impaired face perception and the modulation of the amplitude and latency of the N170 component of ERP responses. However, to what extent configural face processing is preserved in the periphery remains to be explored. Here we addressed this question by measuring 3AFC face identity discrimination performance and ERP responses to upright and inverted face stimuli presented foveally or peripherally (10 deg to the left or right from the fixation). The results revealed significant face inversion effects on the behavioural and ERP responses both in the case of foveal and peripheral face stimuli. Furthermore, the strength of behavioural as well as N170 face inversion effects showed a strong correlation when conditions with left and right visual field presentation were compared. Whereas we failed to show an association in these measures between the foveally and peripherally presented face conditions. These findings provide evidence for configural face processing in the periphery and suggest that foveal and peripheral configural processing of faces might be subserved by different neural processes.

[1P054] Five Commonly Used Face Processing Tasks Do Not Measure The Same Construct

**Elizabeth Nelson, Abhi Vengadeswaran, Charles Collin**

Psychology, University of Ottawa

Researchers have used a variety of tasks to examine holistic/configural processing in face recognition, with the implicit assumption that they are all measuring the same construct. However, there is a lack of consensus with respect to how recognition performance correlates across the most common tasks. Additionally, there is a lack of evidence demonstrating what each task is actually measuring: featural, configural, or holistic face processing, or some combination thereof. Our hypothesis is that the most commonly-used tasks measure different constructs, or different components of face processing. We conducted a correlational analysis of efficiency scores across the following tasks: the Complete Composite Effect Task, the Partial Composite Effect Task, the Face Inversion Effect Task, the Configural/Featural Difference Detection Task, and the Part Whole Effect Task. Results demonstrate that performance is most strongly correlated within each task, with little correlation across tasks. This suggests that each task is measuring a unique component of facial recognition. The two versions of the Composite Effect Task were moderately correlated with each other. Implications for the face recognition literature will be discussed.

Funding: NSERC

[1P055] The Timecourse of Expression Aftereffects

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We investigated the timecourse of the expression aftereffect, an adaptation aftereffect that biases perception of facial expressions towards the opposite of the adapted expression. In Experiment 1 we examined the effect of the duration of adaptation and test stimuli on the size of the aftereffect. We found that the aftereffect builds up logarithmically and decays exponentially, a pattern also found for facial identity and figural face aftereffects, and for lower-level visual aftereffects. This “classic” timecourse is consistent with a perceptual locus for expression aftereffects. We also found that significant aftereffects were still present as long as 3200ms after adaptation. We extended our examination of the longevity of the aftereffect in Experiment 2 by inserting a stimulus-free gap between adaptation and test. A significant expression aftereffect was still present 32 seconds after adaptation. The persistence of the aftereffect suggests that this effect may have a considerable impact on day-to-day expression perception.

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[1P056] Fast and objective quantification of face perception impairment in acquired prosopagnosia

**Joan Liu-Shuang, Katrien Torfs, Bruno Rossion**

IPSY - IONS, University of Louvain

The assessment of perceptual deficits, common in many neurological conditions, is challenging. Fast periodic “oddball” stimulation coupled with electroencephalographic (EEG) recordings allows for objective and sensitive quantification of visual perception without requiring explicit behavioural output. In this paradigm, base stimuli appear at a fast fixed rate (6 Hz, SOA=170 ms) with target stimuli inserted at regular intervals (1/5 stimuli = 6/5 Hz). Periodic EEG responses at 1.2 Hz and its harmonics (2.4 Hz, 3.6 Hz...) reflect perceptual discrimination between base and target stimuli at a single glance. We tested this approach with PS, a well-described patient specifically impaired at face recognition following brain damage (prosopagnosia). We first presented sequences containing “object” stimuli interleaved with “face” stimuli (sequence: ObjObjObjObjFaceObjObjObjObjFace...). Conformingly to her preserved ability to detect faces, PS showed periodic face-selective responses within normal range. However, when testing face individualisation with “different” face identities (B, C, D...) inserted into sequences containing a “same” face identity (A; sequence: AAAABAAAACAA...), face individualisation responses were absent for PS. By contrast, significant responses found in all age-matched controls. These observations result from only 8-12 min of recordings and demonstrate the value of fast periodic visual stimulation in EEG to assess visual perception in difficult-to-test populations.

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[1P057] Vertically oriented cues to face identification are susceptible to color manipulations

**Kirsten Petras, Laurie Geers, Valerie Goffaux**

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Face-identity processing has been suggested to primarily rely on horizontally-oriented cues. However, most evidence for this horizontal advantage comes from experiments using grayscale photographs, discarding the potential contribution of the color cues which characterize natural viewing conditions. We tested behaviorally whether color cues influence the horizontal dependence of facial identity processing. Participants were familiarized with two computer generated, full color human face avatars. In a subsequent testing period these familiar faces appeared with their native color-spectrum (color-congruent condition) in half of the trials and with the color spectrum of the other identity (color-incongruent condition) in the remaining half. All images were filtered to preserve either horizontally-oriented information, vertically-oriented information or a combination of both. Filtered faces were presented together with decreasing levels of grayscale noise in order to obtain the psychometric function of face identification in each participant. We found that the recognition of vertically-filtered but not of horizontally-filtered faces suffers from color-incongruence resulting in a disruption of identity discrimination, even in the absence of noise. Our results suggest that vertically-oriented information may be instrumental in conveying color cues to face identity. These findings highlight the importance of considering the color properties of face stimuli when investigating identity recognition.

[1P058] The contribution of spatial transformations in the estimation of the psychological characteristics of people by facial expressions

**Vladimir A Barabanschikov, Irina Besprozvannaya**

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E. Brunswick's (1956) studies of perception of schematic faces show that transformation of eye locations, nose length and mouth height make possible to design experience of different emotional states and personality traits. V.A. Barabanschikov and E.G. Jose (2015) showed that the tendencies of induced perception described by Brunswick preserved when photos of real faces are perceived. Our study was focused on the estimation of psychological features of facial images with configurational changes in the structure (sadness and joy). Images of male and female faces from the Pictures of Facial Affect Base by P. Ekman subjected to linear transformation of four configuration features were used as stimuli. The study involved 103 participants. Type of configurational transformations was the independent variable; the dependent one was the estimation of psychological qualities using bipolar scales. In the estimation of

psychological characteristics by faces with different transformational change, significant differences were received for a number of scales. “Neutral faces” were estimated as more charming, strongly active, resolute and confident. “Sad faces” were estimated as more unsociable and insincere. “Happy faces” were estimated as talkative, conscientious, open and vigorous.

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[1P059] Skilled face recognizers have higher contrast sensitivity in the right hemifield

**Simon Faghel-Soubeyrand, Frédéric Gosselin**

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We tested the hypothesis that individual differences in face recognition ability can be accounted for by systematic, qualitative variations in the use of spatial information. In experiment 1, 75 participants were submitted to a Bubbles face gender discrimination task. Group classification image of observers from the top performance tercile, as indexed by the quantity of samples required to reach target performance, revealed the use of the eye on the right of the face images while the group classification image from the bottom tercile shows the use of the eye on the left of the face. In experiment 2, we asked whether these better face recognizers have higher contrast sensitivity in their right hemifield. Thirty participants completed the same task as in experiment 1 as well as an orientation discrimination task (horizontal/vertical) with Gabors that spanned 5 deg and ranged from 0.25 to 12 cpd at 2.2 deg left, right, and under fixation cross. Right eye usage was linked to higher maximum sensitivity threshold in the right ( $r=.49$ ,  $p=.007$ ) but not in the left hemifield ( $r=-0.19$ ,  $p=.34$ ). These results indicate for the first time a link between the lateralization of a low-level visual ability—contrast sensitivity—and face recognition ability.

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[1P060] Face-responsive ERP components show time-varying viewing angle preferences

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In our everyday life, we encounter faces from a variety of viewing angles. Despite our ability to generalize across views, selected angles can provide behavioral benefits. For instance the 3/4 view has been described as advantageous in face identification. To test the physiological substrate of these effects, we presented faces shown from a large variety of viewing angles and examined changes in amplitude in the classical EEG face processing components. Neural responses were recorded using high density, 128 channel EEG, while subjects viewed images of four identities, seen from 37 angles presented in a random sequence from left to right profile view. The experimental task was kept condition-orthogonal by asking the subjects to respond to occasional color-changes in the central fixation-dot. Our cluster permutation tests and post-hoc pairwise t-tests revealed significant effects of viewing angle, even after controlling for low-level contrast of the stimulus quadrants. Unexpectedly, while the P100 exhibited a dominant preference for viewpoints close to 45°, the face-selective N170 and C250 did not. The N170 showed strongest activation for profile and front facing viewpoints, whereas the C250 exhibited no clear viewpoint preference. Together, these findings suggest shifting preferences for distinct viewing angles and increasing viewpoint-invariance over time.

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[1P061] Interaction effect between length of nose, viewing angle of face, and gender in estimation of age

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There have been studies reporting that length of nose, viewing angle of a face, and gender of a face influenced estimation of age. These previous studies, however, used two-dimensional facial images in frontal or oblique views and presented those photos to participants. No studies have used digitally averaged three-dimensional representations. We digitally generated three-dimensional images of male and female averaged faces as controlled facial stimuli and manipulated independent variables such as length of the nose and angle of view of the face. Participants were then asked to estimate the age of the faces. Results showed that the estimated age of the averaged faces was higher than the mean of the actual age of the original faces, suggesting that averaging faces has an effect on the increment of age

estimation. Also, the estimated age of averaged male faces was higher than those for female faces in all conditions. When the faces were presented from different angles the estimated age of averaged male faces reduced when compared to a purely frontal view. Moreover, the estimated age of faces with lengthened noses was higher than faces with other nose lengths.

#### [1P062] The Improved Discrimination on Facial Ethnicity Induced by Face Adaptation

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Adaptation to a face is reported to bias the perception of various facial dimensions and improve the sensitivities of neuronal populations tuning the face. In the present study, we examined whether the face adaptation could influence the discrimination on facial ethnicity. Facial ethnicity was manipulated by morphing between Asian and Caucasian faces. We measured the just-noticeable differences (JNDs) for an Asian/Caucasian face after subjects adapted to an Asian face, a Caucasian face, or blank stimuli, with Asian subjects. The results suggest that adaptation to a Asian or Caucasian face could improve ethnicity discrimination for the faces at the adapted level, and this effect could transfer across the changes in the image size and location. Moreover, the improvement effect is slightly stronger for Asian subjects in the Caucasian face adapting condition than that in Asian face adapting condition. Our results indicate that the recent visual experience could calibrate the high-level visual system and selectively improves the discrimination at the adapted characteristic.

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#### [1P063] Painted features transform the shape of 3-D surfaces they are painted on – the case of faces

**Thomas V Papathomas, Attila Farkas**

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Humans parse the world using objects (e.g., when searching for an item), as well as surfaces (mainly in nature, e.g., running in uneven terrain). Certain Patrick Hughes’s paintings, such as “Forced into Reverse Perspective (2008)” [Papathomas et al., *iPerception*, 2012], “Day Dreaming” (2008) [Papathomas, “Innovating perspective”, in *A New Perspective: Patrick Hughes*, Flowers Gallery Publishing, 2014; Papathomas, *ECVP* 2014] afford compelling illustrations of object superiority over surfaces. Different objects in these paintings are painted in forced-, flat- or reverse-perspective, and they appear to rotate in different directions, even if they are painted on the same planar surface, thus “breaking” the surface into parts that exhibit disjoint motions. We report on a similar phenomenon in which realistically painted facial features drastically transform the 3-D shape of the underlying human facial geometry. For example, these painted features can mask imperfections and distortions of facial parts (nose, cheeks, lips, etc.), thus changing significantly the overall appearance of faces. Remarkably, this 3-D transformation is much more powerful if the features are painted on the concave side of the mask and the viewer experiences the “hollow-mask illusion”, rather than when the features are painted on the convex side of the mask.

#### [1P064] Center-surround unconscious visual contour integration

**Hongmei Yan, Huiyun Du, Xiaoqiao Tang**

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Contour integration is a fundamental function of human vision to generate a coherent representation of visual objects. Traditional views believed that contour process follows the Gestalt rules, which implies that contour integration is accomplished at higher cortical areas. But others provided evidences that contour integration can occur as early as V1 (Bauer et al., 2002; Li et al., 2006; Gilad et al., 2013). A recent study suggested a model of contour integration involving an almost concurrently bidirectional cortico-cortical loop (Li et al., 2014). However, whether contour integration process must be achieved in participation of consciousness or not, there is no conclusion. In this study, a binocular rivalry flash suppression paradigm is applied to study whether peripheral contour clues could influence central contour perception under the state of awareness and unawareness. The results showed that, like visible collinear surrounding contour cues in one eye could improve the performance of central contour integration in the other eye and visible disordered Gabor surroundings could interfere the performance of central integration, invisible surrounding collinear information in one eye could also facilitate the contour integration in the other eye unconsciously. We deduced that contour integration may occur without the consciousness.

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[1P065] The influence of a (physical or illusory) barrier on motion correspondence

**Elisabeth Hein, Bettina Rolke**

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A major task of the visual system is to organize its input in a way that elements that belong together are represented together. Here we investigated whether a physical and/or illusory barrier can influence this correspondence process. To this end we used an ambiguous apparent motion display (the Ternus display), in which three elements are presented next to each other, shifted by one position from one frame to the next. Depending on how correspondence between elements is established, this display can be perceived as one element jumping across the other two (element motion) or as all three elements moving coherently together as a group (group motion). A barrier was introduced using rectangles in the background of the Ternus display that were positioned in a way that one side of the rectangle was presented between the Ternus elements. The rectangle borders were either physical or illusory (using Kanizsa-type inducers). Participants reported to see more element motion when a barrier was between the elements, no matter whether this barrier was physical or perceived. The results suggest that barriers can influence the correspondence process, and in particular that this process happens after modal completion is achieved.

[1P066] The Global Precedence Effect is not affected by background colour

**Jan L Souman, Sascha Jenderny, Tobias Borra**

Experience & Perception Research, Philips Lighting

In the evaluation of hierarchical stimuli, the processing of the global shape has been found to interfere more with that of the local elements than vice versa (Global Precedence Effect, GPE). Michimata et al. (1999) reported that this effect disappeared when stimuli were presented against a red background. They explained their results in terms of suppression of the magnocellular pathway by red light. In an experiment with 18 participants, using the same stimuli as in Michimata's original study, we failed to replicate this colour dependency of the GPE. It occurred for red as well as green and grey backgrounds. Since the stimuli in the original study were not optimally suited to differentially activate the magnocellular pathway, we performed a second experiment in which we used Gabor patches with either a high (~4 cpd) or a low (~0.5 cpd) spatial frequency as local elements, aligned horizontally or vertically to constitute global shapes. These were presented against equiluminant red, green or blue backgrounds. Again, we observed the GPE for all three background colours. Spatial frequency only mattered on a blue background, where the GPE only occurred with the higher frequency. Our results cast doubt on the magnocellular explanation by Michimata et al.

[1P067] Neurophysiological investigation of the role of (reflection) symmetry in figure-ground segregation

**Giulia Rampone, Marco Bertamini, Alexis David James Makin**

Department of Psychology, University of Liverpool

Reflection symmetry detection and contour integration are mediated by similar extrastriate networks, probably due to symmetry acting as a cue in figure-ground segregation. We used unfamiliar shapes (reflection vs. random) defined by collinear Gabor elements positioned along the outline of a closed contour. We measured the magnitude of a symmetry-related EEG component ("Sustained Posterior Negativity", SPN) over lateral-occipital area. In Experiment 1 contour shapes were either embedded in an array of randomly oriented Gabors (Exp. 1a) or presented against a uniform background (Exp. 1b). Reflection elicited a negative deflection compared to random in both cases. This confirmed SPN as a symmetry-sensitive component. In Experiment 2, Gabors arrays containing a shape (reflection, random) were interleaved to Gabors arrays without a shape (noShape). We identified greater N1 amplitude for both shapes vs. noShape condition. The reflection vs. random SPN was observed bilaterally. Interestingly, there was also an SPN for reflection vs. noShape over right hemisphere. Our results suggest that figure-ground segregation preceded symmetry detection. However, it is also possible that symmetry facilitated this process. The later component of SPN may instead reflect regularity-specific processes that are not related to grouping processes in general, and that are mainly right lateralized.

[1P068] Local and Global Amodal Completion: Revealing Separable Processes Using A Dot Localization Method

## **Susan B Carrigan, Philip Kellman**

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Differing theories of amodal completion emphasize either global influences (e.g. symmetry, familiarity, regularity) or geometric relations of local contours. These may reflect separate processes: a bottom-up, local contour interpolation process, and a top-down, cognitive process of recognition from partial information. These can be distinguished experimentally if only the local process produces precise boundary representations. Previously, we used dot localization to measure precision and accuracy of perceived boundaries for partially occluded objects with divergent local and global symmetry completions. Results revealed that local contour interpolation produces precise, accurate, and consistent representations, but responses based on symmetry do not. Here we extend the approach to completion based on familiarity or regularity. In two experiments, participants completed familiar logos (i.e. Apple, Pepsi, Playboy, Puma brands) or objects with regularly alternating borders either locally or globally. On each trial, a dot flashed on the occluder, and participants reported the dot's location relative to the occluded boundary. Interleaved, 2-up, 1-down adaptive staircases estimated points on the psychometric function where the probability was .707 the dot would be seen as inside or outside the occluded object. Results support a clear distinction between local contour interpolation processes and global processes based on recognition from partial information.

## [1P069] Task-dependent effect of similarity grouping and proximity on visual working memory

### **Jiehui Qian, Shengxi Liu**

Department of Psychology, Sun Yat-Sen University

The visual working memory (VWM) is responsible for temporarily holding, processing, and manipulating visual information. Research suggests VWM is facilitated by Gestalt grouping principles, e.g., proximity and similarity, but it remains unclear how these factors interact with task. This study employed a pre-cued change detection paradigm to investigate the effect of task, proximity, and similarity grouping (SG) by color and shape. The memory array consisted of a 2 x 3 array of colored items, each being a circle or a triangle, following a cue presented at one item location. After a blank interval, a test item was presented at one of the locations: cued, near-cue, or far-from-cue. The test item in the latter two conditions shared the color, the shape or neither feature with the cued item. The participants performed different tasks, judging whether the color, the shape or either had changed for the test location. The results show that: 1) color SG greatly benefits the capacity of VWM regardless of task and cue-test distance; 2) shape SG does not seem to affect VWM; 3) proximity benefit VWM for the shape judgment but not for color. These suggest that features may differ in grouping effectiveness and the effects are task-dependent.

## [1P070] No evidence for perceptual grouping in the absence of visual consciousness

### **Dina Devyatko, Shahar Sabary, Ruth Kimchi**

The Institute of Information Processing and Decision Making, University of Haifa, Israel

In this study we examined whether perceptual grouping can unfold in the absence of visual consciousness. In two separate experiments, participants were presented with a prime consisted of dots organized into rows or columns by luminance similarity (Experiment 1) or by element connectedness (Experiment 2), followed by a target composed of lines, the orientation of which could be congruent or incongruent with the orientation of the prime. The prime was rendered invisible using continuous flash suppression (CFS), and the prime-target SOA varied (200/400/600 or 800 ms). On each trial participants made speeded discrimination of the orientation of the target lines and then rated the visibility of the prime using a scale ranging from 0 to 3. Unconscious grouping of the prime was measured as the priming effect (of the prime-target congruency) on target discrimination performance, on trials in which participants reported no visibility of the prime. In both experiments, and across all prime-target SOA, there were no priming when the prime was reported invisible; significant priming was observed when the prime was reported visible. These findings suggest that perceptual grouping by luminance similarity and by element connectedness does not take place when the visual stimulus is rendered nonconscious using CFS.

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## [1P071] The effect of color contrast on Glass pattern perception

### **Yih-Shuan Lin<sup>1</sup>, Chien-Chung Chen<sup>2</sup>**

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We used a variant of Glass patterns composed of randomly distributed tripoles, instead of dipoles, to estimate the influence of color contrast on perceptual grouping. Each tripole contained an anchor dot and two context dots. Grouping the anchor dot with one of the context dot would result in a global percept of a clockwise (CW) spiral while grouping with the other dot, a counterclockwise (CCW) spiral. All dots in each pattern were modulated in the same color direction but in different contrasts. There were four types of patterns, modulating in +/- (L-M), and +/- S respectively. The observer was to determine whether the spiral in each trial was CW or CCW. The probability of the anchoring point grouping with one of the context dot increased with the color contrast of that context dot to a critical level and was a constant as context dot contrast further increased. The grouping probability, however, decreased with the contrast of the other dot. This trend was the same for all isoluminance color direction tested but was different from the inverted U-shaped function for luminance contrast as previously reported. Our result cannot be explained by existing models for perceptual grouping but a divisive inhibition model.

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[1P072] Modelling the Effects of Spatial Frequency Jitters in a Contour Integration Paradigm

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Contour integration (CI), the bounding of elements into a coherent percept, has been studied under several regimes, usually pertaining to Gestalt laws. The bounding/grouping, of elements into a percept has been investigated in terms of the effects of good continuation, similarity, etc. Similarity can be defined in numerous ways, however, defining similarity of Gabor patches (the edge elements typically employed in CI paradigms) in terms of spatial frequency (SF) is one of the most interesting ways. The effects of SF jitters on CI have been extensively quantified (Persike & Meinhardt, 2015a,b). We have shown that the effects found in human observers are reproducible with a probabilistic model based on association fields. When an extension to Ernst et al. (2012) is added to account for SF similarities we see similar patterns of performance improvement as those reported by Persike & Meinhardt (2015a,b). This new model can help settle the questions raised by Persike and Meinhardt on whether the process of CI can lead to a non-linear dependency between two independent physical properties of a stimulus, and whether the resulting gains given by the combined presence of these two physical properties are summed as information summation (Machilsen & Wagemans, 2011) would suggest.

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[1P073] A model of border-ownership assignment accounting for figure/hole perception

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One of the major problems on perceptual organization is how the visual system assigns figure/ground regions in the retinal image. Zhou et al. (2000) manifested that the brain uses border-ownership (BO) coding in order to represent figural side against contours. After this finding, many models have proposed so far to explain emergence of BO coding. Among them, the author of this study proposed previously a neural network model of BO coding based on local geometric information such as contour curvature and outer angle of corners (Kikuchi and Akashi, 2001). Though the model can assign BO for arbitrary closed contours, it cannot explain the figure/hole perception for certain patterns found by Nelson and Palmer (2001). This study proposed the revised version of the BO model by Kikuchi and Akashi (2001), which can account for the figure/hole perception found by Nelson and Palmer. The key point is to introduce the nature of saturation property for neuron's output function by using the sigmoid function, instead of rectified linear function. The ability of the model was confirmed by computer simulation.

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[1P074] The simplest visual illusion of all time? The folded paper-size illusion

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Visual illusions are fun, but they are also insightful—the great pedagogic value behind such illusions is that most readers while being amused do also experience perceptual insights which assist the understanding of rather complex perceptual processing. Here I present a very simple illusion: Just take two sheet of paper (e.g. A4), one original sized, one halved by folding, and compare them in terms of area size by centering the halved sheet on the center of the original one! We perceive the larger sheet by far less than double (i.e. 100%) the size of the small one, typically only being about 66.5% larger (Cohen's  $d=1.05$ )—even rotating and aligning it at one side does not dissolve this very large perceptual effect ( $d's>0.80$ ), here documented by data from 88 participants. The only way of escaping this strong visual illusion is to align two sides of both sheets. This point to a potential explanation: we face a general incapability of validly comparing more than one geometrical dimension at once—in everyday-life we circumvent this perceptual bottleneck by aligning geometrical forms as close as we can. If we do so, we validly estimate area sizes, if not, we evidently fail.

[1P075] Shooting at the Ponzo - effects and aftereffects.

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Three groups of 20 participants with equally good shooting skills were required to shoot at the central oval of one of two 'snowmen' targets displayed on a computer screen 1.5m away. During the training session, the target size was 46x39mm for both the experimental and control group 1 and 33x39mm for control group 2. However, the target for experimental group looked smaller due to a superimposed Ponzo figure. During the subsequent test session, the target size for all groups was 33x39mm. Experimental group participants were the least accurate during training session. During the test session, participants in control group 1 were the least accurate. There were no differences between experimental and control group 2. This suggests that the lines of Ponzo illusion acted as distractors for the experimental group, but the illusory diminishing of 'snowman' target had an additional effect on the experimental group's shooting abilities due to training on a smaller (real or illusory) target. These results suggest that the real size of the target plays an important role in the accuracy of shooting (as might be expected) but that the Ponzo illusion, and hence the subjective impression of the target's size, is also important for shooting accuracy.

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[1P076] Interest is evoked by semantic instability and the promise of new insight

**Claudia Muth, Claus-Christian Carbon**

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Interest is qualified by a yet unfulfilled promise (Berlyne, 1971; Silvia, 2005): we enjoy musical tensions leading to resolutions or take a closer look at enigmatic artworks. In a previous study interest for artworks increased with the plurality of meaning and the strength of insights they offer (Muth, Hesslinger, & Carbon, 2015). Furthermore, interest increased already shortly before moments of Gestalt-insight when watching indeterminate artistic movies (Muth, Raab, & Carbon, 2015). In the present study, we presented 30 ambivalent photographs (depicting scenes of unclear valence) to be rated twice on interest, valence, and ambivalence. During an intermediate elaboration phase participants described all possible positive and negative interpretations of a subset of these photographs. Whereas interest for elaborated stimuli increased after elaboration, non-elaborated stimuli induced less interest when rated a second time. Taken together, these findings suggest that interest evolves with the potential for new experience, be it sudden detections of Gestalt, complex insights into an artwork, or new facets of a photographed scene. A wide spectrum of artworks and pieces of music offer such ever-pending promises of new interpretations eventually sparking waves of interest. Our recent study suggests that this potential is dynamic and can be heightened by elaboration.

[1P077] Tell me about your Ponzo and I will tell you who you are

**Lukasz Grzeczowski, Aaron Clarke, Fred Mast, Michael Herzog**

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Unlike in cognition, audition and somatosensation, performance between various visual tasks does not correlate. Surprisingly, even tasks that appear similar, like visual acuity and line bisection task do not share much common variance. Similar results were found for visual illusions. For example, the Ebbinghaus and the Müller-Lyer illusions correlate very weakly. The high intra- and inter-observer variability in visual perception is possibly due to perceptual learning, i.e., individual experience shaping perception throughout one's life time. Here, we studied the relationship

between illusion strength and high-level factors such as personality traits (O-Life) and the vividness of mental imagery (VVIQ). In line with previous findings, we found only few correlations between the magnitudes of the visual illusions, despite having high test-retest reliability. More interestingly, we found a high, positive correlation between the magnitude of the Ponzo illusion and vividness of mental imagery. Moreover, the magnitude of the Ponzo illusion was negatively correlated with cognitive disorganization personality trait. These results were specific to the Ponzo-type illusions. Principal component analysis revealed one factor, with high weights mainly on the Ponzo-type illusions, cognitive disorganization and the vividness of mental imagery.

[1P078] Influences on the perception of the morphing face illusion

**Sandra Utz, Claus-Christian Carbon**

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Van Lier and Koning (2014) reported that the perceived change in a morphing face sequence was dependent on eye movements: with a moving fixation dot, changes were perceived significantly smaller than with a stationary fixation dot between the eyes. To further investigate the phenomenon, we used real faces and faces of different species, ethnicity and with emotional expressions. Additionally to the originally used fixations, we also had a stationary fixation dot on the tip of the nose. Results of 30 participants showed strongest underestimation of the real morphing range (two faces) with Caucasian faces with no significant difference to other-race or other-species faces. Strongest overestimation happened for emotional expressions. Regarding type of fixation, the stationary dot led to a clear overestimation and the moving dot to a clear underestimation (similar to Van Lier & Koning, 2014). However, with fixating at the nose, the range was correctly estimated. Therefore, expertise seems not to influence estimation, whereas emotional expressions enhance the perception of changes in the sequence. Correct estimations resulting from the fixation at the nose might be due to the fact that at that location more important information for processing faces in a configural way can be perceived simultaneously.

[1P079] The PhiTOP Gelatinous Ellipsoid Effect

**Kenneth Brecher**

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A two dimensional image of an ellipse slowly rotating on a surface can seem to distort and appear gelatinous or fluid like. This effect can be seen on the “Project LITE: Light Inquiry Through Experiments” web site at <http://lite.bu.edu/vision-flash10/applets/Form/Ellipse/Ellipse.html>. The flat ellipse can also appear to be rotating rigidly, or even appear as a circular disc twisting in three dimensions. A three dimensional version of the effect was first reported in the literature by the physicist Ernst Mach in 1886. A recently developed ellipsoidal spinning top, the PhiTOP, beautifully elicits the three-dimensional version of the effect. A video of this can be seen on the PhiTOP website at <http://www.thephitop.com>. By slowly spinning the PhiTOP with a magnetic stirrer, the effect can be controlled and studied quantitatively. The results of these studies will be reported. A number of theories have been offered to explain the so-called “gelatinous ellipse” effect (in our case, the gelatinous ellipsoid effect), beginning with Mach (1886), Musatti (1924), Hildreth (1988), Nakayama and Silverman (1988) and continuing to recent proposals by Weiss and Adelson (2000, 2002). Whether these author’s computational models that involve either or both short-range and long-range effects explain the observed phenomena is still unclear.

[1P080] Effects of edge orientation and configuration on sliding motion

**Nobuko Takahashi<sup>1</sup>, Shinji Yukumatsu<sup>2</sup>**

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An apparent sliding motion arises in a large square pattern made up of small squares with black and white edges in rows and columns, depending on the polarity combination of two L-shaped adjacent edges of the same polarity of the small squares in the central area of the large square and those in the surround, and, on the angles of the L-shaped parts. When the orientations of implicit diagonals of the L-shaped parts in the central and in the surround are orthogonal, sliding motion in the central area is perceived, and it is enhanced or reduced by the angles (Pinna and Brelstaff, 2000; Pinna and Spillman, 2005, Takahashi and Nishigaki, 2015 ECVP). To investigate the role of the implicit local orientation and the contrast polarity, we systematically manipulated the angles, the distance between black and white L-shaped parts, and their configuration. The direction and magnitude of apparent sliding motion were measured. The results showed that stronger sliding motion was perceived when the angles were obtuse, which was different from what

the orientation of the implicit diagonal of the L-shaped parts of the same polarity predicts. We discuss the role of the edge orientation and their configuration on sliding motion.

[1P081] How to turn unconscious signals into visible motion: Modulators of the Motion Bridging Effect.  
**Maximilian Stein<sup>1</sup>, Robert Fendrich<sup>2</sup>, Uwe Mattler<sup>1</sup>**

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When a ring of dots rotates sufficiently fast, observers perceive a continuous circular outline and are unable to judge the true direction of rotation. Nevertheless, a conscious percept of the true direction can be recovered by presenting a subsequent stationary ring of dots after a short delay. This motion bridging effect (MBE, Mattler & Fendrich, 2010) indicates that the motion direction of the rapidly rotating ring is being encoded although the motion is not consciously visible. To elucidate the processes that generate the MBE its stimulus dependencies need to be clarified. Here, we assess the MBE as a function of the ring diameter and the angular velocity of the rotation. We replicate earlier findings on the effect of velocity, and find the MBE, measured by the increased ability of observers to judge the rotating rings' direction when a stationary ring is presented, increases with increasing ring diameter. These findings are considered in the context of current theories of motion perception.

[1P082] The Greenback Illusion: a new geometrical illusion

**Kenpei SHIINA**

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Take a picture of a 3D - rotated banknote and then superimpose a straight line that is perpendicular to one of the sides of the banknote. Whereas the added line and the side of the banknote should form a right angle, actually one angle looks obtuse and the other acute. See <http://kshiina.web.fc2.com/newfile.html>. We call this bias in angle evaluation the greenback illusion. Because the effect still occurs if we remove the pattern on the banknote, the illusion is a type of geometrical illusion arising from the configuration of the trapezium and the line. Further, we can make simpler versions by erasing the part of the trapezium: for example, erasing may produce a 45° rotated Greek cross with two parallel short lines attached to the endpoints of a line of the cross. Even in this case the two lines of the cross do not appear to intersect at a right angle. Overall the more the image is interpreted as a 3D scene, the stronger the angle misperception, so the illusion seems to tell us that the miscomputation of the angles in 2D images reflects the tendency of our visual system to restore true angles in 3D world.

[1P083] Perceptual filling-out induced by a preceding mask on the stimulus boundary

**Shuichiro Taya**

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Here I report a new illusory filling-out phenomena. When a stimulus circle, which is filled with low-contrast texture pattern and presented at the central visual field, is preceded by a second stimulus which masks the contour of the textured circle, the foveal texture pattern subjectively propagates and fills up the non-textured homogeneous peripheral visual field. This mask induced filling-out (MIF) is unlikely to be explained by visual adaptation (e.g. Troxler effect) because the filling-out can be induced by a very brief (50 ms) presentation of the mask stimulus. I also found that the direction of the texture filling is always from the centre to the periphery, but not vice versa. For example, when a homogeneously coloured circle is presented at the central visual field against the textured background, the following mask induces the propagation of the foveal colour to the peripheral visual field instead of the filling-in of the peripheral texture. I suggest that the MIF might reflect a complement mechanism which compensates the achromatic and blurry peripheral visual field with the chromatic and high-resolution foveal information, and that may help us to see our entire visual field sharply and with colour.

[1P084] Fluttering-heart Illusion Occurs in Stimuli Consisting of Only Contours

**Kazuhisa Yanaka, Masahiro Suzuki, Toshiaki Yamanouchi, Teluhiko Hilano**

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We examined the mechanism of the fluttering-heart illusion. This illusion is a phenomenon in which objectively synchronized motion between outer and inner figures is observed as unsynchronized motion. In our previous studies (Suzuki & Yanaka, APCV 2014; Yanaka & Suzuki, ECVP 2014), we hypothesized that the fluttering-heart illusion was caused by the different latencies of edge detection between outer and inner figures. We also tested this hypothesis by conducting experiments using stimuli consisting of filled figures, and the results obtained from the experiments supported the hypothesis. In this study, we tested our hypothesis by conducting experiments using stimuli consisting of only contours. The contours of outer figures in the stimuli had high contrast of luminance, whereas the contours of inner figures had low contrast of luminance. Both outer and inner figures were moved on a circle. Observers adjusted the phase difference between the movements of the outer and inner figures to watch both movements synchronize. The results obtained from the experiments indicate that the fluttering-heart illusion occurs in stimuli consisting of only contours. The findings of this study support our hypothesis. Therefore, the fluttering-heart illusion is caused by the different latencies of edge detection between outer and inner figures.

[1P085] Vibration condition that strengthens the illusory motion of the Ouchi illusion

**Teluhiko Hilano, Kouki Kikuchi**

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The Ouchi illusion consists of a ring and a disc, each of which is filled with mutually perpendicular oblong checkered patterns. It is an illusory figure that can be perceived only if the middle disc is floating and moving autonomously. This illusory motion is strongly perceived when it is vibrated by human hands. In the analysis of the conditions of vibration, which maximize the illusory motion, controlling the stroke and frequency of vibration by human hands is difficult. In this work, we developed vibration equipment using a positive mechanical constraint cam that can change the frequency through the revolution of the electric motor to direct advance movement at the ditch cut into a disk. The stroke can be changed by shifting the revolving center from the center of the disk. This equipment facilitates the observation of the effects of stroke conditions and vibration frequency. We printed several types of the figure with a size of 20 cm. We then changed the colors of the oblong checkered patterns and observed them from a distance of 90 cm. We determined that the optimized vibration frequency is between 2 and 3 Hz when the stroke of vibration is 1 cm.

[1P086] Straight edges are not enough to overcome the tilt blindness

**Takashi Ueda<sup>1</sup>, Takashi Yasuda<sup>2</sup>, Kenpei Shiina<sup>1</sup>**

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We sometimes have difficulty in detecting the tilt of objects. The tilt blindness occurs due to many factors including the relationships between figures and background frames, or between observers' posture and the allocation of objects, or objects themselves. In this study, we focused mainly on the shape of objects, in particular on their contours and edges. We hypothesized that the tilt of an object was more easily detected if the figure was simple in shape. In the experimental trials, the voluntarily participated observers were required to choose the target figure that has the same tilt as the standard stimulus on the center, from among eight circumjacent located comparative stimuli, seven of which are the distractors. The result showed that the observers most accurately detected the tilt of the rectangle-shaped figure which had both vertical and horizontal edges, followed by other geometrically shaped figures, and non-geometrical shapes. The tilt detection was easier when the shape of a figure was oval than diamond. These results suggested that the straightness, which was resistant to the tilt blindness, constitutes only one part of simplicity. We also discussed what the simplicity of a shape is.

[1P087] Effect of eccentricity on the direction of gradation-induced illusory motion

**Soyogu Matsushita**

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Luminance gradation patches induce smooth and slow illusory motion. Previous studies have asserted that such illusory motion occurs from a high contrast area to a low contrast area within a patch. However, Kitaoka and Ashida (2004) also reported some illusory figures in which the patches appeared to move from low to high contrast. The present study examined the effect of eccentricity on the perceived direction of illusory motion. The stimuli were white-to-black gradation patches on a white background. The results demonstrate that although the patches in the peripheral vision appeared to move from black to white, those in the foveal vision moved in the opposite direction. Thus, the pictorial properties of illusory figures and the manner of observation are both significant in determining the perceived direction

of such an illusory motion.

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[1P088] Curvy is the new straight: Kanizsa triangles

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The cortical representation of figure and ground still seems to be a partly solved puzzle. Based on psychophysically mapped contrast sensitivity fields within closed boundaries, it has been suggested earlier that symmetry related surface representations might be relevant in addition to co-linear activation along the path of a contour (Kovács & Julesz, 1994). Here we test the classic illusory figures (Kanizsa triangles) with a test probe that appears near the illusory edge. The task is to decide whether the probe appears inside or outside of the illusory triangle. Assuming an equilateral triangle, and that the illusory edge spans a straight path between the inducers, our results are surprisingly asymmetrical for “inside” and “outside” test probes. While there is no difficulty to judge “outside” targets, probes appearing on the alleged contour, or inside the assumed triangle are very clearly judged to be outside for up to a distance that is about 3% of the illusory contour length. The bent illusory contours seem to be more curved for diagonal than for horizontal or vertical edges. We interpret these results as a new indication for the necessity to couple medialness structure (Aparajeya & Fol Leymarie, 2016) with lateral propagation of contour completion.

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[1P089] Boundary extension and image similarity via convolutional network: expanded views are more similar to the original

**Jiri Lukavsky**

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Boundary extension is a visual memory error, when people tend to report remembering more of an image than was previously shown. According to the Multisource model, people mistake the memories of what was seen with the memories of their expectations about the scene surroundings. Here we explored an alternative account based on image similarity: can we say that either cropped or expanded views are more similar to the original view? In a simulation experiment, we inspected 20050 scenes (401 categories). For each image, we used the 80%-view as an anchor and compared it with corresponding expanded (81-100%) or cropped (79-60%) views. We compared the images using L2 distance of fc7 feature vectors of AlexNet convolution network. We found that the expanded views are more similar to the original: the distances of corresponding cropped views are longer by 10.7% (1.9 - 18.6% depending on the extent). In other words, features extracted by an image classifier differ faster when the photo is cropped compared than when it is expanded. Our findings do not contradict the Multisource model, but they may constitute an additional factor contributing to the boundary extension effect.

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[1P090] Contrast effect on visual spatial summation of different cell categories in cat V1

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Multiple cell classes have been found in the primary visual cortex, but the relationship between cell types and spatial summation has seldom been studied. Parvalbumin-expressing inhibitory interneurons can be distinguished from pyramidal neurons based on their briefer action potential durations. In this study, we classified V1 cells into fast-spiking units (FSUs) and regular-spiking units (RSUs) and then examined spatial summation at high and low contrast. Our results revealed that the excitatory classical receptive field and the suppressive non-classical receptive field expanded at low contrast for both FSUs and RSUs, but the expansion was more marked for the RSUs than for the FSUs. For most V1 neurons, surround suppression varied as the contrast changed from high to low. However, FSUs exhibited no significant difference in the strength of suppression between high and low contrast, although the overall suppression decreased significantly at low contrast for the RSUs. Our results suggest that the modulation of spatial summation by stimulus contrast differs across populations of neurons in the cat primary visual cortex.

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## [1P091] A Retinal Adaptation Model for HDR Image Compression

**Yongjie Li, Xuan Pu, Hui Li, Chaoyi Li**

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The intensities of real scenes are of high dynamic range (HDR). Human visual system can respond for huge luminance range (about 14 log<sub>10</sub> unites), and in particular, photoreceptor cells (i.e., cones and rods) can vary their responsive ranges dynamically to adapt to the available luminance. In contrast, most devices for display are of low dynamic range. Hence, compressing the range of HDR images is necessary for many situations. In this work, we proposed a new visual adaptation model inspired by the physiological process of retinal adaptation. Basically, based on the model proposed by Naka and Rushton in 1996 for simulating the S-potentials in fish, we realized the dark and light adaptation by adaptively varying the semi-saturation (SS) parameter based on an empirical relation between the SS parameter and the local luminance suggested by Xie and Stockham in 1989. Then the outputs of rods and cones are further processed by difference-of-Gaussians shaped bipolar cells to enhance the details. Finally, we designed a sigmoid function as spatial weighting to combine the responses of cone and rod activated bipolar cells. Extensive results on both indoor and outdoor HDR images show that our model can compress HDR images effectively and efficiently.

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## [1P092] Revealing alpha oscillatory activity using Voltage-Sensitive Dye Imaging (VSDI) in Monkey V1

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Alpha oscillations play an important role in sensory processing. In humans, EEG alpha is enhanced in response to random, non-periodic dynamic stimulation (“perceptual echoes”; VanRullen and Macdonald, 2012) or to a static wheel (“flickering wheel illusion”; Sokoliuk and VanRullen, 2013). We used voltage-sensitive dye imaging (Chemla and Chavane, 2010) to investigate at a finer spatial scale whether the same visual patterns could induce an oscillatory response in V1 of two anesthetized monkeys. We observed a 10Hz spectral peak in the cross-correlation between a random, non-periodic dynamic luminance sequence and the corresponding VSD response on each trial, similar to human “perceptual echoes”. However, this reverberation was present in only one of the two monkeys. The same monkey (but not the other) also showed a 10Hz oscillatory response when visually stimulated with a stationary wheel, as in the “flickering wheel illusion”. In conclusion, similarly to well-characterized individual differences between humans, not all monkeys produce sizeable alpha oscillations. But when they occur, these oscillations react in a comparable manner: Alpha can be spatially dissociated from evoked activity, and depends on the spatial frequency of the stimulus. Importantly, these preliminary results provide new insights into the neural basis of alpha in V1.

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## [1P093] Image Reconstruction from Neural Responses: what can we learn from the analytic inverse?

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Low level vision can be understood as a signal transform that relates input stimuli with output neural responses. Advances in neural recording allow gathering thousands of such input-output pairs. In that way, the regression approach allows to model both the encoding or the decoding process using machine learning techniques. The black-box approach has become popular over the last years in visual brain reading to decode visual stimuli from neural recordings [KamitaniNatNeurosci05, KayNature06, MaloECVPSymp16]. The first attempts used plain linear regression, which is inappropriate given the nonlinear nature of the encoding, but the current practice is to use nonlinear techniques such as Support Vector Regression or Kernel Ridge Regression. However, understanding visual information processing goes beyond blind regression: a more explicit description of the transforms is needed. In this work we explore the use of the analytic inverse of classical encoding models (i.e. the conventional filters+nonlinearities [GalánMODVIS-VSS16]) in modeling the decoding process. We show that the analytic inverse is important to improve the decoding performance and to propose novel ways to get the parameters of the forward model in the presence of noise and unknown elements of the model. See results and code here: <http://isp.uv.es/ECVPinversion.html>

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[1P094] Mapping the visual brain areas susceptible to phosphene induction through brain stimulation

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Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation technique whose effects on neural activity can be uncertain. Within the visual cortex, however, phosphenes can be used as a marker of TMS-induced neural activation. Here we sought to identify which portions of the visual cortex are susceptible to TMS-induced phosphenes. We tested 30 participants, finding that seven reported phosphenes reliably. We then systematically mapped out the locations where single pulse TMS induced phosphenes. We applied stimulation at equidistant targets in a 6x8cm grid that was fitted to individual brain surfaces, using MRI data and neuro-navigation. The grid expanded laterally and dorsally from the occipital pole. Stimulator output was adjusted for the underlying scalp-cortex distance to create comparable stimulation effects. We measured the probability of inducing phosphenes and related this to the underlying visual organization as determined from functional MRI measurements. We show that TMS can reliably induce phosphenes in early (V1, V2d and V2v) and dorsal (V3d and V3a) visual areas close to the interhemispheric cleft. However, phosphenes are less likely in more lateral locations. This suggests that early and dorsal visual areas are particularly amenable to TMS to understand the functional roles of these areas in visual perception.

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[1P095] Feedback signals from the local surround are combined with feedforward information in human V1

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Most input to V1 is nonfeedforward, originating from lateral and feedback connections. Using functional magnetic resonance imaging (fMRI) and multivariate pattern analysis (MVPA), Smith & Muckli (2010) showed using natural scene stimuli that nonfeedforward stimulated regions of V1 (i.e. responding to an occluded image quadrant) contain contextual information about the surrounding image, fed back from higher visual areas. We investigated whether feedback signals carry information about the full configuration of the scene (global surround) or information close to the occluded quadrant (local surround). Participants viewed stimuli composed of four Gabors oriented at either 45° or 135°, one in each quadrant. There were four possible global structures: Right (all Gabors at 45°), Left (all 135°), Diamond, and Xshape. Each stimulus was presented in feedback (occluded quadrant) and feedforward (corresponding quadrant visible) conditions. We decoded the stimuli using V1 voxels relating to the quadrant. We could not decode the stimuli in the occluded quadrant. However, decoding was above chance in one of the identical feedforward conditions (the same orientation), but only if there was a difference in the local surround in the two stimuli. This suggests that feedback about the surround combines with feedforward information in the quadrant.

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[1P096] Perceptual Grouping and Feature Based Attention by Firing Coherence Based on Recurrent Connections

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Perceptual grouping is achievable from the use of spiking neuron models (Izhikevich's model or other models) and connection weights depending on distances. Simple three-valued spike-mediated synapses suffice to display the emergence of partial synchrony and make this cognitive task possible. Moreover, feature selectiveness can take place by virtue of a related model which also includes synchronization through discrete lateral couplings and, in addition, incorporates the feature-similarity hypothesis. For simultaneous presentations, the attended feature elicits a higher response while, in the case of sequential single-feature stimuli, repetition of the attended feature also produces an enhancement of the response, displayed by greater coherence and higher spiking rates.

[1P097] Spiking-neuron model for the interaction between visual and motor representations of action in premotor cortex

## **Mohammad Hovaidi Ardestani, Martin A. Giese**

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Action perception and action execution are intrinsically linked in the human brain. Experiments show that concurrent motor execution influences the visual perception of actions. This interaction is mediated by action-selective neurons in premotor and parietal cortex. **METHODS:** Our model is based on two coupled dynamic neural field, one modelling a representation of perceived action patterns (vision field), and one representing associated motor programs (motor field). The fields consist of coupled ensembles of Exponential Integrate-and-Fire neurons. The fields stabilize travelling localized activity peaks that are following the stimulus or propagate autonomously after a go-signal. Both fields are coupled by interaction kernels, resulting in a stabilization of traveling pulses that propagate synchronously in both fields. We used the model to reproduce the result of a psychophysical experiment that tested the detection of point-light stimuli in noise during concurrent motor execution. **RESULTS:** Consistent with the experimental data, we find a facilitation of the detection of visual action patterns by concurrent motor execution if the executed motor pattern is spatio-temporally compatible with the observed pattern, and interference if it is incoherent. **CONCLUSION:** Dynamic neural networks with biophysically realistic neurons can reproduce basic signatures of perception-action coupling in behavioral experiments.

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[1P098] Decoding eye-of-origin signals in and beyond primary visual cortex

**Milena Kaestner<sup>1</sup>, Ryan T. Maloney<sup>1</sup>, Marina Bloj<sup>2</sup>, Julie M. Harris<sup>3</sup>, Alex R. Wade<sup>1</sup>**

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Beyond primary visual cortex (V1), eye-specific information encoded in ocular dominance columns is thought to merge into a single binocular stream. However, recent evidence suggests that eye-of-origin signals must be available after V1, supporting the computation of motion in depth from inter-ocular velocity differences (eg. Czuba, Huk, Cormack & Kohn, 2014). Here, we use 3T fMRI pattern classification to decode how these signals are maintained in and beyond V1. Eye-of-origin stimuli were temporally broadband random fields of Laplacian-of-Gaussian elements (50% contrast). Elements moved (speeds from 0.2-8°/s) either up/down or left/right. We presented stimuli to the left eye, right eye and binocularly. Seven event-related runs consisted of fourteen repeats of each condition (N=7 participants). Retinotopically-defined regions of interest (ROIs) were sub-divided using a functional localiser to identify voxels in and outside the retinotopic extent of our eye-of-origin stimulus. We trained a linear classification algorithm to decode responses to each event within each ROI. In the foveal regions of V1-V3, decoder accuracy was significantly above chance across multiple cross-validation folds, indicating the availability of eye-of-origin information in all these areas. Decoding accuracy in negatively-responding voxels outside the stimulus driven region was similar, suggesting that extraclassical receptive fields also respond selectively to eye-of-origin.

[1P099] Reducing Visually Objectionable Noise in Hyperspectral Renderings

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Most modern render engines use stochastic sampling algorithms, like Monte Carlo, which yield highly realistic images, but suffer from visible noise. A naive solution is to collect more samples for all pixels, but this is computationally extremely costly. We developed a novel image quality metric based on the Jensen-Shannon divergence (JSD), for comparing the normed spectra of different pixels. This metric enables a stopping criterion, which means the sampling for each pixel stops by reaching a certain quality level. The JSD technique has several parameters, which we are determining through psychophysical experiments. The threshold function depends on various factors of the rendering (material, lightning) and the human visual system (contrast sensitivity, masking, etc.). We generated diverse scenes with a wide selection of textured objects and varied lightning. In two different 2AFC tasks subjects were asked to identify which of two images matched a noise-free reference. In the first task we split the scenes into regions based on their luminances, and in the second task by object identity. This allows us to evaluate how well the parameter values generalize across contexts. Our results identify the parameter values required to obtain visually acceptable renderings, enabling substantial gains in rendering speed.

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[1P100] Spatial phase coherence analysis reveals discrete cortical modules within early visual cortex

**Nicolás Gravel<sup>1</sup>, Ben Harvey<sup>2</sup>, Serge O. Dumoulin<sup>3</sup>, Remco Renken<sup>1</sup>, Frans W. Cornelissen<sup>1</sup>**

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Resting-state fMRI is widely used to study brain connectivity. However, interpreting patterns of resting state (RS) fMRI activity remains challenging as they may arise through different neural mechanisms than those triggered by exogenous events. Currently, this limits the use of RS-fMRI for understanding cortical function in health and disease. Here, we establish structural determinants of RS functional connectivity by examining the spatial phase coherence (SPC) of blood-oxygen level dependent (BOLD) signals obtained during 7T fMRI in visual field mapping (VFM) and RS. This data-driven approach exploits spatiotemporal variations in the instantaneous phase of BOLD recordings to establish spatially localized clusters of synchronized activity. We find that SPC decays rapidly as a function of the cortical distance in VFM but not in RS, likely reflecting stimulus-driven spatial selectivity. However, in both VFM and RS data, clustering the strongest 5% of the mean phase coherence matrix identified discrete modules that follow the topographic organization of the visual cortex. These common patterns, in both RS and VFM scans, suggest synchronization clusters share a common –most likely structural- origin.

[1P101] Integrated computational model of salience and semantic similarity on spatial attention

**Ekaterina Gordienko, William Joseph Macinnes**

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Human eye-movements during visual search depend both on geometric (bottom-up) and contextual (top-down) cues. In this study we improve bottom-up salience model (Itti & Koch, 2001) by adding a top-down sub-model. This component uses Latent Dirichlet Allocation (LDA) algorithm which has been suggested to be a model of semantic memory. LDA was trained on a dataset of annotated images (Russell et. Al, 2008), and then used to build a priority map showing the semantics relatedness of the image objects to the target object. The priority map is merged with the saliency map from (Itti & Koch, 2001) resulting in an importance map for an integrated model. We conducted an eye-tracking study where participants searched for “cup” and “painting” on a set of natural indoor images. The results of the experiment show that integrated importance model is significantly ( $p < 0.001$ ) different from the saliency model and is 4% better in predicting human fixations. Yarbus, A. L. (1967). Eye movements during perception of complex objects (pp. 171-211). Springer US. B. C. Russell, A. Torralba, K. P. Murphy, W. T. Freeman, LabelMe: a database and web-based tool for image annotation. International Journal of Computer Vision, pages 157-173, Volume 77, Numbers 1-3, May, 2008

[1P102] A Multi-Task Neurodynamical Model of Lateral Interactions in V1: Visual Saliency of Colour Images

**David Berga, Xavier Otazu**

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Saliency maps are the representation of the most relevant perceived visual cues, determined by attentional mechanisms. We propose a computational mechanism for predicting saliency maps from natural images by modelling some visual processes of the early human visual pathways. Low-level features such as scale, color and orientation selectivity are used to model some V1 receptive fields properties. Additionally, lateral connections present in primary visual cortex are modeled by a firing-rate excitatory-inhibitory recurrent layers architecture. The layers of such model are based on the Li [1] and Penacchio architectures [2], using the same parameters as presented in previous work for brightness [2] and chromatic induction [3]. The resulting saliency maps extracted from the proposed model are compared to other biologically-inspired models of saliency prediction by using eye-fixations from well-known psychophysical experiments performed on public image datasets. Our biologically-plausible model is able to simulate human fixations suggesting that an excitation-inhibition mechanism of lateral connections can simultaneously reproduce several perceptual processes such as brightness induction [2], chromatic induction[3], visual discomfort [4] and visual saliency. [1] Li, Network-Comp Neural, 1999. [2] Penacchio et al., PLOS ONE, 2013. [3] Cerda and Otazu, ECVP, 2016. [4] Penacchio et al, ECVP, 2016.

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### [1P103] Multi-Spatial-Frequency-Channel Processing in Retina

**Jihyun Kim, Marcelo Bertalmio**

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From the times of Shannon, vision scientists have argued that the visual information is processed through multiple spatial frequency (SF) channels each of which has a limited bandwidth. Around the same era, perceptual and physiological studies reported the existence of the excitatory-center-inhibitory-surround receptive field (RF) structure that can be represented in the Difference-of-Gaussian (DOG) form. Blakeslee and McCourt (1997) combined these two notions of evidence, proposed a computational model that is comprised of the multiple sizes of DOF filters (multiscale DOG filtering model), and showed that the proposed model predicts various brightness induction phenomena. From the neurophysiological perspective, the DOG-like RF has been evidenced confirmatively in the retina, although the precise mechanism that forms such RF started to be acknowledged only recently. However, there is no clear understanding on the mechanism by which the multi-SF-channel processing is accomplished in the visual system albeit the evidence that V1 organization is SF sensitive. In the current study, we computationally show that the retinal structure produces the same effect as the multiscale DOF filtering model. The key consideration here is that feedforward/feedback cells in the retinal hierarchy have various sizes of RFs and generate spatial interaction through the feedback system.

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### [1P104] Model selection for prediction of Visually Induced Motion Sickness

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The present study examined the prediction of visually induced motion sickness (VIMS) with psychological and biological information from Artificial Neural Network (ANN) during viewing the VIMS related a visual stimulus. A visual stimulus consisted of a gray scale image for 300-s, before and after a visual motion image for 1200-s. A visual motion image included the first-person viewpoint movies from off-road bike. The training set for ANN was the subjective evaluation of VIMS strength and the input data was the observer's autonomic nerves activity indices estimated from heart rate variability. The VIMS strength was recorded the responses on 5-point scale. During a trial the observers continuously indicated the change in the VIMS strength. To expose an optimal model for the prediction of VIMS strength, we compared three types of ANN, such as Recurrent Neural Network, Time Delay Neural Network, and Time Delay Recurrent Neural Network. Six adult males ( $23.3 \pm 0.7$ ), normal or corrected to normal visual acuity, participated in the experiment. The results showed that the Time Delay Recurrent Neural Network correctly classified with 99.2 % which was the highest among the three types of ANN.

### [1P105] A Model of Competitive Neural Network for Exogenous Visuospatial Orienting

**Drazen Domijan**

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Studies using peripheral cueing showed that abrupt onsets are able to automatically capture attention despite the fact that they are irrelevant for current goals (Theeuwes, 2010). Such stimulus-driven capture of attention poses a strong constraint on computational models of spatial selection because recurrent neural networks with lateral inhibition exhibit dependence on the initial conditions which makes them insensitive to abrupt onsets (Yu, Giese, & Poggio, 2002). In order to explain how sensitivity to abrupt onsets might arise in recurrent neural circuit a new model is proposed. It incorporates dynamics regulation of synaptic transmission by retrograde messengers released from postsynaptic cell to axonal terminals of the presynaptic cells. In this way, a pool of inhibitory interneurons can compute function maximum over its input signals. Computer simulations showed that the proposed model is able to capture transient elevations in the magnitude of input. However, when the strong top-down signals are present, the model becomes insensitive to abrupt onsets consistent with psychophysical findings (Belopolsky & Theeuwes, 2010). Furthermore, the model is able to simulate exogenous cueing in object-centered representation (Theeuwes, Mathot, & Grainger, 2013).

Funding: This work was supported by the Croatian Science Foundation (Grant 4139).

### [1P106] A Multi-Task Neurodynamical Model of Lateral Interactions in V1: Chromatic Induction

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In other works, we show that an enhanced neurodynamical architecture based on Li's model of V1 [1] simultaneously reproduces, with the same set of parameters, several psychophysical experiments of static and dynamic brightness induction [2], visual saliency [3] and visual discomfort [4]. In the present work, we extend this architecture for colour processing in order to reproduce, with the same set of parameters, some chromatic induction psychophysical experiments for both static [5] and dynamic [6] colour stimuli. Our results reproduce subjects' visual perception of static stimuli. In the case of dynamic stimuli, we observed, similarly to psychophysical experiments, that short duration (10 milliseconds) stimuli induce stronger chromatic contrast effects than long duration stimuli (500 milliseconds). All these results show that an excitation-inhibition mechanism of lateral connections can simultaneously reproduce several perceptual processes such as brightness induction, colour induction, visual saliency and visual discomfort. [1] Li, *Network-Comp Neural*, 1999. [2] Penacchio et al., *PLOS ONE*, 2013. [3] Berga and Otazu, *ECVP*, 2016. [4] Penacchio et al., *ECVP*, 2016. [5] Otazu et al., *J Vision*, 2010. [6] Kaneko and Murakami, *J Vision*, 2012. Funding: TIN2013-41751-P

[1P107] Migration through evolution of the bottom-up saliency map from the optic tectum to the primary visual cortex

### **Li Zhaoping**

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Recent data (e.g., Zhaoping 2008, Zhaoping and Zhe 2015) support the hypothesis that the primary visual cortex (V1) in primates creates a saliency map from visual input to guide attention exogenously (Li 1999, 2002). This map can be read out through monosynaptic projections from V1 to the superior colliculus (SC), which can select the most salient location as the target of a gaze shift. Across species, the SC, called optic tectum in lower vertebrate, receives retinal input. Meanwhile, non-mammals lack neocortex, with only a small fraction of their forebrains devoted to visual processing. I propose that evolution leads to a migration of the saliency map from the tectum in lower vertebrates such as fish and birds to V1 in primates. Phylogenetically across vertebrates, including fish, frogs, birds, mice, rats, cats, and primates, this migration is accompanied by an expansion of the forebrain, a migration of visual analysis from the optic tectum to the forebrain (in particular to V1), a smaller percentage of retinal projections to the tectum, and a smaller percentage of retinal ganglion cells tuned to complex features such as motion direction. Effects of lesioning V1 or the tectum are consistent with this hypothesis.

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[1P108] Sensitivity to Weight Changes of Others Depends on Personal Body Size

### **Anne Thaler, Michael N. Geuss, Simone C. Mölbert, Stephan Streuber, Katrin E. Giel, Michael J. Black, Betty J. Mohler**

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Previous research has suggested that own body size estimates are biased towards an average reference body (Cornelissen, Bester, Cairns, Tovée & Cornelissen, 2015). The role of personal body size in body size perception of others is still unclear. In this study, we tested healthy females varying in body mass index (BMI) to investigate whether personal body size influenced accuracy of body size estimation and sensitivity to weight changes of others. We generated four biometric female avatars with BMIs of 15, 25, 35, and 45 and altered the weight of the avatars ( $\pm 5$ ,  $\pm 10$ ,  $\pm 15$ , and  $\pm 20\%$  BMI change) based on a statistical body model. In several psychophysical experiments, we presented the stimuli on a stereoscopic, large-screen immersive display. For each avatar series, participants memorized what the original body looked like and then responded for each of the presented bodies whether it was the same as the one memorized. Our results show that there was no influence of personal BMI on the accuracy of body size estimation of the avatars. Interestingly however, participants were more sensitive to weight changes of an avatar close in BMI to their own, suggesting that own body size influences perception of others' weight.

[1P109] What is a haptic object?

### **Rebecca Lawson, Stefano Cecchetto**

Department of Psychology, University of Liverpool

Despite the importance of objects in perception and cognition it has proven difficult to formally define objects, even for visual stimuli (Feldman, 2003), and this issue has barely been considered in haptics. Given the limited ability of haptics to perceive scenes, and to explore multiple objects simultaneously, objectness could be unimportant for haptics. Also, haptics could rely on vision to specify objects. However, the results of our studies suggest that defining what is an object plays an important role in haptic processing. We compared haptic and visual regularity detection by investigating whether symmetry signals the presence of one object and repetition signals the presence of multiple, similarly-shaped objects. Our results suggest that diverse cues combine to define haptic objects, with some cues (e.g., proximity and contour polarity - concavities and convexities along a contour) also being used by vision, but others (e.g., whether stimulus exploration involves one rather than two hands) being modality-specific. Thus the nature of an object appears to differ for haptics and vision, supporting Feldman's (2003) claim that objects cannot be defined objectively by properties of the external world. Instead, objects appear to be specified relative to the system processing them, and so require a modality-specific definition.

#### [1P110] Visual second-order features and objects categorization

**Daria Alekseeva, Vitaly Babenko, Denis Yavna**

The SFEDU Academy of Psychology and Pedagogy, Southern Federal University

Visual first-order filters extract local features. Second-order filters group them in space. As a result a human visual system extracts the spatially heterogeneous image areas. Modulations of contrast, orientation, or spatial frequency are called the second-order features. The aim of our research is to determine whether this information is useful for object categorization. We created three computer models of the second-order filters that selectively extract the areas with contrast, orientation, or spatial frequency modulation from the input image. This allowed us to compare the value of these second-order features for object categorization. As the initial images we used 63 digital photographs of real-world living and non-living objects that fall into 21 basic categories. The test stimuli were images of these objects that contain areas with the certain modulation of the first-order features only. The subject has to identify clearly an object that was presented on a screen. It was found that the spatial frequency modulations were the most informative in the categorization task.

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#### [1P111] Motion induced distortion of shapes

**Nika Adamian<sup>1</sup>, Patrick Cavanagh<sup>1,2</sup>**

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If an object is flashed on top of a moving texture at the moment the motion reverses direction, a large position shift – flash grab (Cavanagh & Anstis 2013) – is perceived. In this study we show that the motion not only shifts the position but it also distorts the object, displacing some parts of the object more than others. Participants observed a sectorized ring oscillating back and forth while one of two shapes, a “T” or “circle”, was flashed on the ring at the top location, once per cycle. Participants fixated the center of the ring and, for the “T”, shifted the vertical stem until it appeared aligned to the center of the horizontal bar. For the “circle”, participants adjusted its left and right curvature until it appeared circular. The results suggest that the motion displaced horizontal contours (parallel to the motion direction) more than vertical ones. To appear symmetrical, the vertical bar of the “T” needed to be advanced so that an inverted L was presented. To appear as a circle, contour had to be egg-shaped. In other tests, it was found that only outline shapes are distorted, not filled shapes.

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#### [1P112] Optical information for accurate perception of objects with orientation change

**Jing Pan<sup>1</sup>, Ned Bingham<sup>2</sup>, Geoffrey Bingham<sup>3</sup>**

<sup>1</sup>Psychology, Sun Yat-sen University; <sup>2</sup>Cornell University; <sup>3</sup>Indiana University

Identifying tilted objects is harder than identifying upright objects using image structure information. However, motion generates optic flow that calibrates image structure. Calibrated image structure preserves spatial layout despite image distortion. Thus, if the tilting process and the tilting objects are continuously perceptible, then the interaction of optic flow and image structure should allow accurate perception of object locations despite orientation change. We tested

this hypothesis experimentally and found that: (1) when tilting was perceptible, participants identified object locations equally well with or without orientation change; (2) when tilting process was imperceptible, identifying object locations from a tilted scene after orientation change worsened; and (3) when observers did not see but were told about the amount of tilting, identification was worse than with no orientation change. Therefore, combined optic flow and image structure information, not mere knowledge about the tilt, enables accurate perception despite orientation change. Funding: This study is supported by the National Natural Science Foundation of China (Grant #31571116), and by Sun Yat-sen University (Grant #26000-31610114).

[1P113] Speed of color recognition depends on Gestalt representations of cause, consequence, condition, and concession

**Magda L Dumitru<sup>1</sup>, Gitte Joergensen<sup>2</sup>**

<sup>1</sup> University of Liege; <sup>2</sup>University of Connecticut

Fast color recognition allows streamlining thought processes as humans compare objects, imagine events, or hypothesize about past and future experiences. Indeed, recent research on Gestalt reasoning has confirmed that stimuli perceptual properties directly affect the outcome of thinking with logical connectives. Here, we investigated whether connectives expressing cause, consequence, condition, and concession influence the speed of color recognition. We hypothesized that “if”, “therefore”, “because”, and “although” would elicit rich mental representations, each of them with specific spatial and/or temporal properties. Participants’ task was to decide whether the colors of two disks presented onscreen matched a verbal description containing the names of two colors linked by one of the four connectives. Crucially, participants were asked to ignore the connective word and exclusively attend to the color matches. The results of a series of color recognition tasks varying the spatial and temporal properties of binary visual stimuli indicate that participants nevertheless instantly retrieved the meaning of each connective as rich Gestalt simulations. Depending on connective type, spatial, temporal, or both spatial and temporal stimuli properties affected color recognition speed.

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[1P114] Disrupting object identification with iridescence

**Joanna Hall, Karin Kjærsmo, Nick Scott-Samuel, Innes Cuthill, Heather Whitney**

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Variable signals can be much harder for visual systems to interpret than stable ones, and this could slow the process of object identification. Iridescence is defined as a change in hue as visual angle varies (given stable illumination), and is generally considered to be a form of signalling in the natural world. Most iridescent surfaces are also glossy, and the pattern of reflectance may also change with varying visual angle. Under certain conditions, this combination of changing signals could interfere with identification of a target and thus provide protection from visual predators. Experiments using green, artificial flowers presented on a green background showed no difference in the time taken for bumblebees (*Bombus terrestris*) to land on background-matching flowers compared to flowers displaying multilayer iridescence. A significant effect of gloss was found for both background-matching and iridescent conditions, with bumblebees taking longer to land on a second glossy flower compared to a second matte flower. We will present additional data on the effects of iridescence on the human visual system, using participants foraging for iridescent (diffraction grating), coloured or plain beetle-like plastic targets on a background of artificial leaves.

[1P115] Estimation of the individual tendencies in the subjective Kansei evaluation of three-dimensional shapes

**Kazuhito Muto, Sho Hashimoto, Kazuaki Tanaka, Kenji Katahira, Noriko Nagata**

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In recent years, personal fabrication has evolved because of technological innovations such as the 3D printer. To facilitate personal fabrication that reflects the user's personality, it is necessary to quantitatively estimate the needs of each individual user. To accomplish this, we propose a new analytical method for three-mode data, which accounts for the difference between individuals when they evaluate a number of stimuli. In the proposed method, we assume that the principal component score matrix of an individual is determined by the sum of scores of the stimuli and the evaluation tendencies of the individual. Using this method, we analyzed the data obtained via an experiment in which

20 individuals evaluate 120 shapes using 18 pairs of adjectives. Consequently, we visually estimated the type of impression that each individual had for each stimulus. Next, we constructed a recommendation system by using the method of estimating the individual Kansei (human sensibility) tendencies when the participants evaluate specific abstract 3D shapes. This system proposes shapes close to the shape for users based on their evaluation tendencies. We demonstrate this recommendation system to validate the efficiency of the proposed system. Thus, the estimation of the individual Kansei tendencies was validated.

[1P116] Tuning to radial frequency patterns in human visual cortex

**Samuel J Lawrence<sup>1</sup>, Richard Vernon<sup>1</sup>, Bruce Keefe<sup>1</sup>, Andre Gouws<sup>1</sup>, Alex Wade<sup>1</sup>, Declan McKeefry<sup>2</sup>, Antony Morland<sup>1</sup>**

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Radial frequency (RF) patterns are shape stimuli defined by a sinusoidal modulation of a circle's radius. Low frequency RF patterns, with few modulations around the perimeter, are processed by mechanisms which integrate over local information to represent global shape, however the neural locus of these mechanisms in humans is unclear. Using fMRI, we measured tuning to RF in human observers. We presented a series of RF patterns ranging from RF2 (2 modulations) to RF20 patterns (20 modulations). Time series data were modelled by a Gaussian distribution in RF space, where each voxel's tuning to RF was defined by the Gaussian which produced the best fitting model. Tuning to low, globally processed, RFs was localised to lateral occipital cortex in all subjects. To quantify these data we measured the average tuning to RF within visual field maps V1, V2, V3, V4, VO1, VO2, LO1 and LO2. All maps showed a clear preference for high RFs, except for LO2 where the preferred RF was significantly lower. Our data suggest that low RF patterns are selectively processed in lateral occipital cortex, and a preference for low RFs emerges in LO2. LO2 is therefore a likely candidate for early global shape processing in humans.

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[1P117] Exploring curvature representations in LO-1, LO-2 and shape-selective Lateral Occipital Cortex (LO)

**Richard J W Vernon, Samuel Lawrence, Andre Gouws, Bruce Keefe, Antony Morland**

Department of Psychology, University of York, UK

We recently identified a shift from retinotopic representations in V1-V3 to more 'abstract' (perhaps curvature-based) shape-representations in LO. A potential transition between these representations emerged around retinotopically-defined regions LO-1 and LO-2. We explored this transition by manipulating curvature information in shape stimuli (rendered with Gabor elements) for an fMRI block-design experiment. Six conditions were used; two 'full-outline' conditions with varying Gabor element density, a 'curves' condition in which only segments of the shape with maximal curvature change were rendered, the complement of that condition ('not curves'), 'rotated curves' in which the 'curve' segments were rotated 180deg., then finally a 'scrambled' condition with spatially jittered Gabor elements. ANOVAs revealed significant effects of condition in LO-2 and LO, but not LO-1. Planned-comparisons comparing 'curves' to all other conditions revealed unexpected 'not curves' preferences in LO-2 and LO, as well as more predictable 'curves' over 'scrambled' preferences in both ROIs. A full-outline over 'curves' preference only emerged in LO, indicating emerging shape-sensitivity. Surprisingly, these results imply that LO-2 may prefer (non-curved) shape-fragments and these fragments may only be bound into a cohesive whole later in LO.

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[1P118] Perceived rigidity is not enough to explain why shape from specular flow in 3D-rotating objects is difficult

**Dicle N Dovencioglu<sup>1</sup>, Maarten Wijntjes<sup>2</sup>, Ohad Ben-Shahar<sup>3</sup>, Katja Doerschner<sup>4</sup>**

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Surface reflectance and motion characteristics affect the perceived shape of 3D dynamic objects. Results from our

group (Doerschner, 2013; Dovencioglu, 2015) suggest that the perceived local and global shape of specular objects substantially differ from that of matte objects. This is possibly due to the fact that shape from specular flow is somewhat more difficult to solve for the visual system. For example, observers frequently report perceiving non-rigidity when judging the shape of moving specular objects. Here we explored this idea formally. We used low, mid and high amplitude, matte and specular bumpy objects that rotated around either the vertical or viewing axis. Observers compared these test objects to a mixed material (half-specular, half-diffuse) object of the same bumpiness and they picked which object looked more rigid. Here, we found that specular objects were perceived as less rigid for all levels of bumpiness magnitudes, there was no effect of rotation axis on the rigidness judgements. In previous bumpiness judgements, specular objects appeared flatter when rotating in-plane. Current results combined with our previous reports suggest that it is difficult to retrieve shape from specular flow but this cannot be solely explained by perceived rigidness from specular flow.

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[1P119] Different electrophysiological correlates for conscious detection and higher-level consciousness

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Is there a brief moment of low-level awareness during which you see a visual stimulus but you are not yet aware of it as any particular type of object? We studied this question by measuring event-related potentials (ERPs) while the observers performed either a low-level task requiring conscious detection of the presence of the digit stimulus (3, 4, 6, 7), or a higher-level task requiring its conscious identification (higher or greater than 5). Behavioral results showed that if the stimulus was detected, it was not necessarily identified. A posterior electrophysiological signature 200-300 ms (N2) after stimulus-onset was sensitive for conscious detection but not for higher-level conscious identification which correlated with a later wide-spread activity (P3). The results suggest that full awareness evolves during the first half second from the mere phenomenal experience of the object’s presence to a richer representation of the features of the object. The search for the neural mechanisms of consciousness should acknowledge this two-stage nature of conscious perception, where basic visual qualia emerge first and are consequently attached to conceptual knowledge for precise conscious recognition.

Funding: Academy of Finland (project no. 269156)

[1P120] Familiarity effect in ERP study of face and word perception

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Human capacity of face and word recognition is fundamental for social communication. Several studies suggested these stimuli to be processed separately, considering their specific features result in left-lateralization for words and right-lateralization for faces. We studied the process of recognition of words and faces and suggested that EEG patterns would be modulated by stimulus familiarity as well as by its type. We recorded EEG in 29 subjects presented with 80 complex stimuli – words superimposed on face images, - combining familiar and unfamiliar faces and words in equal parts. The general task was to judge stimulus familiarity: in one part of the experiment the instruction was to classify the faces as familiar or unfamiliar (with the words unattended), in another part – to classify the words the same way. The results demonstrated a strong familiarity effect, with unfamiliar stimuli (both faces and words) eliciting significantly more negative response in frontal areas than familiar ones in 200–300 ms time window after stimulus onset (N250). Moreover we found the later effect of instruction (attention to faces or to words) more pronounced over the left-hemisphere electrodes, showing greater response in word-task condition as compared to face-task condition within 300–450 ms time window (N400).

Funding: Financial supported by the Russian Science Foundation (project № 14-18-02135)

[1P121] Object selective areas in the lateral occipital complex preferentially process high spatial frequencies

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The spatial frequency (SF) content of an image plays an important role in its processing and subsequent recognition as low SFs provide coarse and high SFs provide detailed information. Various visual areas respond differently depending

on the SF content of an image. Whether this is also the case for the lateral occipital complex (LOC) – an extra-striate visual area involved in object recognition – is yet unknown. With this present fMRI study we explored SF selectivity in the LOC. The LOC was located using an object localiser and subdivided into the lateral occipital (LO) and the posterior fusiform (pFus) area. Additionally, V1 and V2 were located using visual field mapping. Subsequently, we contrasted responses obtained during the passive viewing of images depicting an object with either intact low or high SF content. Based on an analysis of the data of six observers, we found greater sensitivity for high than for low SFs in the LOC. This difference was absent in both V1 and V2. Hence, we conclude that LOC preferentially processes high SFs. This implies that object recognition mediated by the LOC relies more on the processing of high SFs (carrying detail information) than low SFs (carrying coarse information).

[1P123] Distributed Representations – Interplay between internal and external actions in the Tower of Hanoi task

**Gregor Hardiess, Marcel Dorer, Hanspeter A. Mallot**

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A wide variety of cognitive tasks require processing of information distributed across the internal mind and the external environment. Here, such internal and external actions are two indispensable parts of the representational system of any distributed cognitive task. The Tower of Hanoi (TOH) problem is an appropriate problem-solving task involving internal computations (memorizing task rules, organizing & updating task processes) as well as eye movements to support external (epistemic) actions that serve to simplify the mental workload. By introducing a new version of the TOH, where (i) the strength of the problem (using 4 different path lengths for the solution space) and (ii) the executed eye movements were controlled, we present data concerning varying adaptations in order to rely on internal and/or external (shared) representations in humans. In a within-subject design, 15 participants had to solve 16 different TOH problems in a passive manner. Each problem was illustrated by a picture showing always three differing (color & size) discs placed on three poles at an initial state. Given a certain rule set, participants had to mentally rearrange the discs to reach the goal state. Comparing eye patterns, task performance, and difficulty, we provide results showing individualized adaptations to distributed representations.

[1P124] Quick spatial reorientation after teleportation: ERP evidence

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Spatial orientation is an essential requirement of successful navigation. This means that after any form of disorientation, the organism has to reorient itself as soon as possible. Reorientation is thought to be based on geometric, textural, and available landmark information. In the present study, participants had to collect rewards in the horizontal arms (West and East alleys) of a cross-maze while EEG was recorded. The alleys had different textures, but texture-alley associations varied randomly between participants. Their starting position was also randomly chosen in each trial in either the South or the North alley. This way, they had to reorient themselves in the maze in the beginning of each trial. Event related potentials time-locked to the trial starts showed robust changes at the parieto-occipital electrode sites as early as 100 ms. These results show that reorientation could be based only on textural cues when the environment is familiar, and modulates early visual processing.

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[1P126] Men's visual attention to and perceptions of women's dance movements

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Sexual selection may have shaped male visual sensitivity to characteristics that provide information about female mate quality. Indeed, men judge certain facial and bodily configurations of women to be attractive, possibly because those

configurations signal health and fertility. Most of this evidence derives from the study of women's facial and body photographs. In the current study, we tested the hypothesis that attractive female dancers receive greater visual attention from men than do unattractive dancers. We created a set of virtual female dance characters by applying motion-captured dance movements of women to shape-standardized, featureless, gender-neutral humanoids. Twenty-nine men (aged 20-39 years) viewed pairs of videos, previously categorized as high attractive or low attractive, while their eye gaze was tracked, and provided additional ratings of attractiveness, femininity, and dance movement harmony. High attractive dancers received greater visual attention than did low attractive dancers. In addition, men's visual attention (dwell time and number of fixations) correlated positively with their judgments of attractiveness, femininity, and dance movement harmony. We discuss our findings in the context of the 'beauty captures the mind of the beholder' hypothesis and recent literature on the role of dance movements in human mate selection.

[1P127] Beyond humans: contagious yawning in primates elicited by the visual perception of a non-human agent - an android.

**Ramiro M Joly-Mascheroni<sup>1</sup>, Bettina Forster<sup>1</sup>, Miquel Llorente<sup>2</sup>, Beatriz Calvo-Merino<sup>1</sup>**

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The main function of yawning remains disputed (Wilkinson et al 2011). The contagious aspect of yawning has been demonstrated within species, (e.g. between humans: Provine 1986; chimpanzees, (*Pan troglodytes*) Anderson et al 2004, Campbell & de Waal 2011, budgerigars, (*Melopsittacus undulatus*): Miller et al. 2011). Joly-Mascheroni et al (2008) found that domestic dogs (*Canis lupus familiaris*) catch human yawns, in the first study to explore the contagiousness of yawning across species. This reconfirms there is transference of communicative signals between species. In line with evidence that humans are more susceptible to yawn contagiously from those with whom they are familiar, chimpanzees yawn contagiously in response to videos of yawning in-group but not out-group members. Here we explored the contagiousness of yawning between chimpanzees and an inanimate agent, an android. Results show that, in addition to yawning contagiously when visually perceiving an android yawning, chimpanzees lay down, and displayed a behaviour that resembled a state of drowsiness, suggesting the interpretation of a visually perceived communicative signal produced by an unfamiliar model that was humanlike in appearance, but ultimately an android. Findings warrant further explorations of android action perception and interaction.

[1P128] Conscious and Unconscious Priming Influence on Sense of Agency

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Sense of agency (SoA) is the feeling that we are in control of our own actions and events in the outside world (Chambon, Haggard, 2012). Unconscious compatible priming increases SoA ratings (Wenke et al., 2010; Sidarus et al., 2013). We tested whether conscious priming influence on SoA will be higher than unconscious priming effect because subjects will have more information to make prediction about their actions. Participants responded to left- or rightward arrow targets. The key press elicited appearance of a colored circle that was dependent on compatibility between prime and response. After that participants judged how much control they felt over the circle's color on a scale from one to eight. We conducted two experiments with conscious and unconscious prime trials in blocks or mixed together. In compatible conditions participants had faster and more accurate responses and felt stronger SoA after both unconscious and conscious priming with no difference between them. These results are true only for a block design whereas mixed trials design showed no influence of priming on SoA. We consider this to be an evidence of implicit learning across the sequence of trials and/or different response strategy taken by subjects.

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[1P129] Body and eye movements during interactions with avatars in virtual environments

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In previous studies it has been shown that social interactions with avatars in virtual worlds are ruled by the same social norms as interactions in the real world (Yee et al., 2007). We studied participant's ethnic attitudes during the interaction with avatars of different ethnic appearance. Three virtual scenes were constructed differed in ethnic appearance of avatars. Each scene represented a living room with a group of avatars that had the same or different

ethnic appearances as the participant. Virtual scenes were presented using the CAVE virtual reality system. The participant's task was to walk around each avatar in a group and remember all the details of its appearance. During the execution participant's body and eye movements were recorded. Then participants answered the questions about details of avatar's appearance and filled out questionnaires assessing their presence effect (IPQ) and ethnic attitudes (IAT). The results showed the shorter interpersonal distances and longer eye contact with avatars of the same ethnic appearance. It was also found that questionnaire's scores were in good agreement with behavioral characteristics while performing the memory task.

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[1P130] How is the remembered area of scenes affected by location shift in object-centered and ego-centered coordinates?

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We investigated how size and location of an image are represented in both visual and motor tasks by the use of boundary extension experiment paradigm. In each trial, a part of a stimulus image was presented [11] for 3 sec (observation phase), followed by a mask of 1 sec. Participants reported the size or location of the remembered area and object while viewing the full-size image (test phase). In the test phase, the center of the image was shifted according to different coordinate systems. In the ego-centered-shift condition, the image center was shifted leftward or rightward in ego-centered coordinates while it remained fixed in object-centered coordinates. In the object-centered-shift condition, the image center was shifted leftward or rightward in object-centered coordinates, while it remained fixed in ego-centered coordinates. Results showed that the shift of image center affected the performances similarly in the visual and motor tasks. Specifically, in the object-centered-shift condition, the remembered area shifted toward the image center of the full size image. These findings suggest that the size and location of [12] the remembered scene area is determined according to object-centered coordinates in both the visual and motor systems.

[1P131] Perceiving social intention in motor action

**François Quesque, Yann Coello**

Psychology, University of Lille, France

Is it possible to understand others' intention from the mere perception of their actions ? Through a series of experiments performed in dyads and using motion capture and eye-tracking, we investigated how the social scope of intentions is grounded in the interaction between our motor abilities and the environment. Previous research showed that the kinematics of voluntary movements are influenced by the type of social intention that is endorsed by participants. Our most recent findings (using both explicit and implicit tasks) demonstrated that these typical kinematic variations are processed during social interaction and that they can trigger spontaneous social intention attribution. Interestingly, the ability of participants to access others' mental states from motor action variations is strongly related to their explicit mentalizing performances. All together, these data support the possibility to spontaneously access to others' social intentions from perceptive and motor processes.

[1P132] Angle rounding and finger shrinkage when watching and touching a partially occluded corner

**Walter Gerbino, Giovanni Lecci, Joanna Jarmolowska, Carlo Fantoni**

Department of Life Sciences, University of Trieste

Gerbino et al. (2016) showed that the rounding of 3D amodally completed angles reached by the index finger depends on the temporal length of the reach. When reaching for a partially occluded corner two components are thus intermixed: finger shrinkage and smooth rounding of the visually interpolated angle. Here we disentangle such components by asking participants to use their index finger to touch the visually occluded portion of a tile bounded by rectilinear edges. In the control condition the unoccluded edges of the tile were collinear, supporting a straight interpolation. In the experimental condition the unoccluded edges were orthogonal, supporting the amodal completion of a smooth rounded angle. The experimenter placed the to-be-touched invisible edge in six different positions, according to the method of constant stimuli. Participants reported whether the edge encountered by the fingertip was inside or outside, relative to the perceived interpolation of the visually observed tile edge. Data were consistent with the additive combination of finger shrinkage and angle rounding, both dependent on amodal completion. The

relationship with other visuo-haptic phenomena such as finger shrinkage when touching the invisible inside of a shell (Ekroll et al. 2016) and implicit hand representations (Longo 2015) will be discussed.

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### [1P133] Personality Predictors of Ideomotor Response in a Detection Task

**Jay A Olson, Amir Raz**

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Some people consult Ouija boards or pendulums and interpret their movements as responses from the subconscious. These subtle muscle movements, known as ideomotor responses, can sometimes reflect unconscious knowledge (Gauchou, Rensink, & Fels, 2012). We examined personality predictors of the accuracy of this knowledge in a visual detection task. Eighty participants completed 24 trials of 2 tasks. In the Verbal Task, participants searched an RSVP stream of 24 numbers for a particular letter; the short SOA (33 ms) made detection difficult. In the Pendulum Task, participants did a similar procedure but instead "asked" a hand-held pendulum whether the letter was present; we told them particular motions signified yes and no. Using logistic regression, we predicted detection accuracy across the tasks given several personality measures. The results showed that in the Verbal Task, faith in intuition predicted performance (odds ratio [OR]=1.09); in the Pendulum Task, sensitivity to subtle stimuli (i.e., transliminality; OR=1.15) and need for cognition did (OR=0.93). Detection and bias were both higher in the Verbal Task (57%,  $c=0.17$ ; Pendulum: 53%,  $c=-0.03$ ; all  $p < 0.001$ ). These results suggest that different mechanisms underlie verbal and ideomotor responses, which may help explain why some people can express knowledge through subtle muscle movements.

Funding: BIAL

### [1P134] Visual processes dominate perception and action during social interactions

**Laura Fademrecht, Heinrich H. Bülthoff, Stephan de la Rosa**

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A central question in visual neuroscience concerns the degree to which visual representations of actions are used for action execution. Previously, we have shown that during simultaneous action observation and action execution, visual action recognition relies on visual but not motor processes. This research suggests a primacy of visual processes in social interaction scenarios. Here, we provide further evidence for visual processes dominating perception and action in social interactions. We examined the influence of visual processes on motor control. 16 participants were tested in a 3D virtual environment setup. Participants were visually adapted to an action (fist bump or punch) and subsequently categorized an ambiguous morphed action as either fist bump or punch in three experimental conditions. In the first condition participants responded via key press after having seen the entire test stimulus. In the second, participants responded with carrying out the complementary action after having seen the entire test stimulus. In the third (social interaction condition) participants carried out the complementary action while observing the test stimulus. We found an antagonistic bias of movement trajectories towards the non-adapted action (adaptation aftereffect) only in the social interaction condition. Our results highlight the importance of visual processes in social interactions.

### [1P135] The power of self-reference in action: Prioritized processing of self-relevant stimuli extends from perception to response execution

**Clea E Desebrock, Jie Sui, Charles Spence**

Experimental of Psychology, University of Oxford, UK

Considerable evidence shows that self-related (compared with e.g. other-person-related) stimuli receive prioritised processing which can confer a performance advantage. Sui, He, and Humphreys (2012) have shown that the effect is independent of stimulus familiarity, modulates perceptual as well as higher-level cognitive (e.g. attention and memory) processes, and is supported by a distinct neural circuitry (Sui, Rotshtein, & Humphreys, 2013). However, no studies have investigated whether prioritised-processing of self-relevant stimuli also reflects in response execution. This was tested in the current study where we had participants associate two geometric shapes with two people (self vs. stranger) and then carry out a shape-label matching task. A response box and keyboard recorded button releases (measuring response initiation time from stimulus onset) followed by button depressions 14cm away (measuring movement time from button release to a target button depression), respectively. A speed and sensitivity ( $d'$ ) advantage for execution of self-linked responses was found, suggesting that this self-advantage can permeate response execution and

enhance movement efficiency (further qualified by moderately-high correlations (e.g. -.41) between speed and d'). Implications for traditional models of information processing and translational work are discussed.

[1P136] The role of action in the formation of visual representations of both actors and observers

**Dejan Draschkow, Melissa L.-H. Võ**

Scene Grammar Lab, Goethe University Frankfurt

There is evidence suggesting little use of working memory (WM) in natural tasks, while object-interactions seem to facilitate their long-term memory storage. Here we tested whether interacting with an object modulates WM representations of actors and observers alike. In a real-world paradigm, participants performed an object-sorting task – copying a pattern of object photographs– wearing mobile eye-tracking glasses. Participants either performed the task without interacting with the pattern they should copy (Passive condition), or picked up each photograph of the pattern shortly before copying it (Interactive condition). Moreover, in the “Actor condition”, participants performed the task themselves, whereas in the “Observer condition” they observed another participant performing the task. We measured the sequence in which participants sampled and stored visual information using WM by calculating the frequency of just-in-time fixation – eye-movements allowing subjects to postpone the gathering of task-relevant information until just before it is required. We found that participants use WM to a higher capacity after interacting with an object. Interestingly, we found the same pattern in the “Observer condition”, suggesting that observers use WM to a similar capacity as if actually completing the task. We argue that object handling interacts strongly with WM usage for efficient task completion.

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[1P137] A strategy to improve arithmetical performance in four day-old domestic chicks (*Gallus gallus*)

**Maria Loconsole, Rosa Rugani, Lucia Regolin**

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Previous studies demonstrated that newly hatched domestic chicks reared with identical objects, when presented with objects disappearing one-by-one in separate locations, were able to compute the overall amount of objects present at each location as they successfully inspected the location concealing the larger set in the numerical comparisons 2 vs. 3 and 2 vs. 4. Here, we investigated the upper limits of this ability. Chicks were reared with 7 identical red objects and, on day 4 of life, they were tested with the comparison 3 vs. 4. In Experiment 1, when the objects were presented and hidden one-by-one, chicks could not discriminate among the two locations ( $M=55.000$ ;  $SEM= 2.500$ ;  $p=0.856$ ;  $t(7)=2.000$ ). In Experiment 2, when objects were presented and hidden as chunked into (2+1) vs. (2+2) units, chicks succeeded in discriminating and inspected the location hiding the larger group ( $M=72.000$ ;  $SEM=7.010$ ;  $p=0.014$ ;  $t(7)=3.210$ ), i.e. the four objects. Overall these data suggest that presentation modality significantly affects the performance and confirm that a mechanism such as chunking can improve mathematical performance in an animal model.

[1P138] The time course of image memorability

**Lore Goetschalckx, Johan Wagemans**

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Some images we see stick in mind, while others fade. Recent studies of visual memory have found remarkable levels of consistency for this inter-item variability across observers. This suggests that memorability can be considered an intrinsic image property. Most of these studies quantified the memorability of an image as the proportion of participants recognizing it in a repeat-detection memory task. The retention interval in this task is typically quite short (e.g., 4 min.), although one previous study increased it to 40 min. and found some evidence for the consistency of image memorability over time. The current study sought to further evaluate this consistency with a more traditional visual long-term memory task. Participants studied 342 previously quantified images and completed a first recognition test immediately after. Two additional recognition tests followed one day and one week later. A Latin square design enabled us to quantify the memorability of each image at each retention interval without testing participants for the same image twice. Our memorability scores show levels of consistency across observers in line with those reported in previous research. They correlate strongly with previous quantifications ( $\rho$ 's between .52-.76 at the shortest interval) and appear stable over time ( $\rho$ 's between .52-.69).

[1P139] Is it a bird? Is it a plane? Evidence from cognitive science about detection and identification of objects during scene viewing.

**Javier Ortiz<sup>1</sup>, Bruce Milliken<sup>2</sup>, Juan Lupiáñez<sup>1</sup>**

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Perceiving an object requires the combination of two processes: detection and identification. While the former is often believed to occur first in a bottom-up fashion with little or no influence from previous experiences, the later is assumed to rely heavily on our prior understanding of the world in a sort of top-down manner. However, our work 1) challenges those assumptions showing that both processes can be biased by previous knowledge and 2) explores the updating of the information stored in memory as a function of the two processes. Particularly, we used a change detection task in which we manipulated the semantic congruity of the objects embedded in one of the alternating scenes and later tested memory for them. Throughout several experiments we consistently show that the mismatch between the object and the scene in which it is embedded can improve detection while hurting the identification of the object. Furthermore, our results show that mismatching objects are poorly remembered when compared to congruent ones regardless of the level of identification of the object. We discuss these results in the context of how prior expectancies can indeed impact the detection process and also shape the information that will be later remembered.

[1P140] Numerosity-evoked fMRI activity patterns in human intra-parietal cortex reflect individual differences in behavioral numerical acuity

**Evelyn Eger<sup>1</sup>, Gabriel Lasne<sup>2</sup>, Stanislas Dehaene<sup>3</sup>, Manuela Piazza<sup>4</sup>, Andreas Kleinschmidt<sup>5</sup>**

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The importance of parietal cortex for numerical processing is supported by different methods. Recently, using multivariate decoding on fMRI data we have shown that human intraparietal cortex contains information discriminative between individual numerical magnitudes. However, it remains open in how far this information is relevant for behavior. Here, we measured discrimination of visual numerosities (clouds of simultaneously presented dots) in 12 healthy young adult subjects outside the scanner psychophysically in a delayed numerical comparison task. We then scanned subjects during a similar paradigm and tested for discrimination of activity patterns evoked by the different sample numerosities, in parietal and early visual cortex ROIs, as well as within parietal cortex in the human functional equivalents of macaque areas LIP and VIP. Sample numerosities were decodable in both early visual and intra-parietal cortex with approximately equal accuracy. However, in parietal but not early visual cortex fMRI decoding performance was negatively correlated across subjects with behavioral Weber fractions (subjects with a more precise behavioral discrimination measured prior to scanning showed a better discriminability of numerosity-evoked fMRI activity patterns). These results suggest a crucial role for intra-parietal but not early visual cortex in supporting a numerical representation which is explicitly accessed for behavior.

[1P141] Subordinated function of visual perception in conscious semantic cognitive tasks

**Sergei Artemenkov**

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Conscious problem solving is done mostly on semantic level of understanding using human reasoning, which is relying on available memory capacities of the person. Thus, in cognitive task solution untrained individuals usually should not take into account the results of their situational perception as being invisibly intermediate and subordinated to thinking. Our experiments displayed the truth of this proposal for situational visual semantic information processing. Participants (university students) were given oral cognitive task consisted in semantic problem also presented in text form on the projective screen. They simultaneously or sequentially were shown images or other text including the direct solution of this cognitive task. Regardless of changing conditions and actual presence of visual attention while solving the problem they were starting to look for appropriate notions in their memory or in external computer-aided source and in most cases were not able to see obvious answer in the visual field before them. This effect of perceptual semantic blindness under execution of pure semantic cognitive task shows that distinction between perception and conscious control (internal presence) during cognitive task solution is extraordinarily robust. Subordinated function of visual perception in conscious semantic cognitive tasks conforms to findings of cultural-historical theory of L.S. Vygotsky.

[1P142] The role of categorization in the cognitive process of a person moving in an interior space

**Anna Losonczy, Anett Rago, Levente Gulyás, Klára Sarbak, Attila Kurucz, Andrea Dúll**

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Our group examines the psychological impact of spaces on people moving around. Our goal is to integrate traditional perception concepts into the framework of architecture. Our project called Perceptual Matrix1 studied the interrelationship of basic perceptual elements, and the impact of their specific arrangements on participants' spatial experience in a given space (Bafna et al. 2012). Our results show that different exploration routes influence the observer's attention that result in modified cognitive experience. Here we systematically examined the most important elements of the space which could influence perception such as categorization, localization, attention, motivation and personal involvement. However, it seems that one of the factors, namely categorization has a more significant organizational role. To understand the impact of the original interpretation process on the organization of the matrix, we designed present study where, by manipulating participants' goal in the space and/or the function of different elements we measured participants (architects) attention, memory, and preference for specific elements. Our results show that the previous categorization of a space changes all the cognitive and affective reactions. Furthermore, we revealed the mechanism of a dynamic re-interpretation process which increased participants' involvement and activity in the space.

[1P143] Metacontrast masking applied to lexical stimuli

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Various masking procedures have been used to limit the input of visual information to the cognitive system. Nonetheless, it is still not entirely clear what level of processing is struck by certain types of masking procedures. Here we examine the processing limits regarding masked lexical stimuli. Priming of masked stimuli is one approach to index how far masked stimuli enter into the system. To probe the depth of processing that masked stimuli can reach we employed the lexical decision task. In this task, participants indicate whether a visible letter string is a word or a non-word. The effect of preceding masked word- or non-word-stimuli indicates whether the masked stimuli reach semantic levels of processing. Previous studies with pattern masking reported reduced priming effects with strong masking. These findings indicate that pattern masking limits early levels of processing which could be preserved when metacontrast masking is used. We developed different types of metacontrast masks for word stimuli. Distinct masking functions prove that we can control the input of visual information to the system by the strength of our masks. We present data of recent experiments that examine whether priming effects also decrease when strong masking is used.

[1P144] Individual Perception Style Affects Implicit Memory

**Kyoko Hine**

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Implicit memory broadly affects our behavior, attitude, and preference. However, it is still unclear how individual perception style affects implicit memory. Here, we assessed the effect of individual perception styles (global- or local-style) on the implicit memory. In our study, participants viewed 17 movies of scenery from a car window (the average of movie length was 31 sec) and took an implicit memory test. In the implicit memory test, participants were asked to tell about an associable word to 60 given words (e.g. "coffee" to ). Also, each participant did Navon task (Navon, 1977) for checking each individual perception style, global- or local-style. As a result, local-style participants provided higher occurrence rate of words related to the individual feature presented in the movies than global-style participants. The current study has suggested that individual perception style affects implicit memory.

[1P145] Remembering without really trying

**Volodya Yakovlev, Shaul Hochstein**

ELSC & Life Sciences Institute, Hebrew University

We study familiarity memory without explicitly requesting that observers remember displayed images. Can observers differentiate between recently seen and never seen images? Part 1: Observers were shown a sequence of 1-9 sample images followed by a repetition ('match') of one sample (the 'cue') and responded to the repetition. Sequence length and

cue position were randomized. Stimulus duration and inter-stimulus-interval were 1s. All images were novel; they were shown only once per observer, throughout their sessions, with two exceptions: 1- match images were identical to the cue. 2- In 10% of trials, one sample had been shown on a previous trial. These 'catch' images were not novel, and yet observers were not supposed to respond to them. Each session also had a paired-images task. Observers were shown two images, side by side, one image from the first session part and one novel image. Observers indicated the familiar image. To test memory longevity, we added another paired-images task before each session, using images from previous sessions. Two trends were found: Familiarity memory decayed with time, or intervening images, between first presentation and paired-image test. Familiarity memory was also hampered by number of sessions or images in memory

[1P146] Effects of geometrical shape on the retrieval of spatial location

**Elena Azañón, Metodi Siromahov, Matthew R Longo**

Dept of Psychological Sciences, Birkbeck, University of London, UK

Humans are thought to subdivide space by boundaries. Within these boundaries, memories for spatial locations seem to be weighted by their distance to an assumed centre, producing biases towards this so-called prototype. Previous studies using circular shapes have shown systematic errors towards the centroids of each quadrant, reflecting a subdivision of the shape along the horizontal and vertical meridians in retinal space. However, this seemingly universal division of space might not take place when the intrinsic geometry of the shape facilitates other subdivisions. To test this, participants had to remember and reproduce the location of a dot presented inside different geometrical shapes. We found similar patterns of biases in a square, rectangle and circle: Subjects misplaced dots towards the centroids of each quadrant, as if they were imposing horizontal and vertical divisions. Analyses of cosine similarity between localization errors and predicted errors towards prototypes confirmed this pattern. We did not find any systematic bias when the remembered dots were presented inside a 90-deg. rotated square (rhombus). This clearly speaks against a universal division of space along the horizontal and vertical meridians in retinal space. Instead, humans appear to divide visual space as a function of the shape of surrounding boundaries.

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[1P147] Space-Valence Priming with Subliminal and Supraliminal Words: ERP Investigations

**Shah Khalid**

Institute of Cognitive Science, University of Osnabrück

Using event-related potentials (ERPs) we investigated how non-evaluative semantic processes influence affective semantics and how affective semantics influence non-evaluative semantic processing in the presence and absence of participants awareness. We presented subliminal (masked) and supraliminal (unmasked) prime words prior to visible target words in a space-valence across-category and same-category congruent and incongruent conditions. In addition to reaction times (RTs) we analyzed the N200 and N400 components of ERPs to measure the prime-target congruence effects. We found that the same-category valence primes (for instance, 'happy' or 'sad') and across-category space primes (for instance, 'above' or 'below') influenced valence classification of supraliminal target words as 'positive' or 'negative' (Experiment 1). Also the congruence effects of valence primes and space primes on the classification of space targets into 'above' and 'below' words were found (Experiment 2). Prime visibility measured confirmed that participants were unaware of the masked primes and successfully categorized only the unmasked primes. Together, the data confirmed that both awareness-independent non-evaluative semantic priming influences valence judgments, and affective semantics influence non-evaluative semantic processing.

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### ***Monday August 29th Symposia presentations***

[11S201] NeuroInformation Processing Machines

**Aurel A Lazar**

Electrical Engineering, Columbia University

In recent years substantial amount of progress in formal/rigorous models of neural computing engines, and spike and phase processing machines has been achieved. Key advances in neural encoding with Time Encoding Machines (TEMs) and functional identification of neural circuits with Channel Identification Machines (CIMs) will be reviewed. The Duality between TEMs and CIMs will be discussed. We show that via simple connectivity changes, Spike Processing Machines (SPMs) enable rotations, translations and scaling of the input visual field. SPMs for mixing/demixing of auditory and visual fields will also be demonstrated. Finally, a motion detection algorithm for natural scenes using local phase information will briefly be discussed.

Funding: NSF grant #1544383

[11S202] A fully computable model of stimulus-driven and top-down effects in high-level visual cortex  
**Kendrick Kay<sup>1</sup>, Jason Yeatman<sup>2</sup>**

<sup>1</sup>Center for Magnetic Resonance Research, University of Minnesota, Twin Cities; <sup>2</sup>University of Washington

The ability to read a page of text or recognize a person's face critically depends on category-selective visual regions in ventral temporal cortex (VTC). Using an fMRI experimental paradigm that samples a range of carefully controlled stimuli and cognitive tasks, we have developed a fully computable model of VTC that addresses both bottom-up and top-down effects and quantitatively predicts VTC responses.

[11S203] Neural decisions under perceptual uncertainty

**Janneke F Jehee**

Center for Cognitive Neuroimaging, Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen

Virtually anything we sense, think and do is uncertain. For instance, when driving a car, you often need to determine how close you are to the car in front of you. It is near impossible to estimate this distance with absolute certainty – but it is possible to guess and even to estimate the uncertainty associated with that guess. Accordingly, we reduce speed when driving at night, because we realize perceived distance is more uncertain in the dark than on a sunny, clear day. How do we infer that visual information is less reliable at night? How does the brain represent knowledge of sensory uncertainty? In this talk, I will present recent neuroimaging data combined with novel analysis tools to address these questions. Our results indicate that perceptual uncertainty can reliably be estimated from the human visual cortex on a trial-by-trial basis, and moreover that observers appear to take this uncertainty into account when making perceptual decisions.

[11S204] Modeling and decoding of natural visual cognition

**Shinji Nishimoto**

Center for Information and Neural Networks, National Institute of Information and Communications Technology

One of the goals of studying systems neuroscience is to understand how the brain works under day-to-day, natural conditions. Pursuing such a goal inevitably involves the use of two kinds of high-dimensional data: one of them is dynamic spatiotemporal patterns of perceptual and cognitive experience. The other is spatiotemporal patterns of brain activity that represent those internal experiences. We aim to understand the brain by building predictive models that explain the relationship between these two kinds of high-dimensional patterns. Such models reveal quantitative representations inside the brain, such as space-time visual representations in early visual areas, semantic representations in occipitotemporal areas, and their dynamic warps during cognitive tasks. We have also built brain decoders that can quantify and visualize perceptual experiences from brain activity in humans. As a whole, modeling of the brain provides a general and quantitative foundation for understanding human perception and cognition.

[11S205] Non-linear encoding and linear decoding in the retina

**Olivier Marre<sup>1</sup>, Ulisse Ferrari<sup>1</sup>, Christophe Gardella<sup>1</sup>, Stephane Deny<sup>1</sup>, Thierry Mora<sup>2</sup>**

<sup>1</sup>Physiology, Institut de la Vision, INSERM; <sup>2</sup>Ecole Normale Supérieure, Paris

It is still unclear how the information from different neurons can be combined together to decode the stimulus. We recorded a large population of ganglion cells in a dense patch of salamander while displaying a bar moving diffusively. We show that the bar position can be reconstructed from retinal activity with a high precision using a linear decoder acting on 100+ cells. The classical view would have suggested that the firing rates of the cells form a moving hill of

activity tracking the bar position. Instead, we found that most ganglion cells in the salamander fired sparsely, so that their neural image did not track the bar. Furthermore, ganglion cell activity spanned an area much larger than predicted by their receptive fields, with cells coding for motion far in their surround. Our results show that, while the stimulus was encoded non-linearly by the retinal neurons, it was still possible to decode very well the stimulus from their spiking responses. The retina is therefore a non-linear encoder, but remains linearly decodable. I will discuss new methods to assess if this linear decoding is optimal, or it could be outperformed by non-linear methods.

[11S206] Deep neural networks: a new framework for modeling biological vision and brain information processing

**Nikolaus Kriegeskorte**

Cognition and Brain Sciences Unit, Cambridge University, UK

Recent advances in neural network modeling have enabled major strides in computer vision and other artificial intelligence applications. Human-level visual recognition abilities are coming within reach of artificial systems. Artificial neural networks are inspired by the brain, and their computations could be implemented in biological neurons. Convolutional feedforward networks, which now dominate computer vision, take further inspiration from the architecture of the primate visual hierarchy. However, the current models are designed with engineering goals, not to model brain computations. Nevertheless, initial studies comparing internal representations between these models and primate brains find surprisingly similar representational spaces. With human-level performance no longer out of reach, we are entering an exciting new era, in which we will be able to build biologically faithful feedforward and recurrent computational models of how biological brains perform high-level feats of intelligence, including vision.

Funding: MRC, ERC

[11S301] Lighting as a perceptual grouping problem

**Alan L Gilchrist**

Psychology, Rutgers University, NJ, USA

Maloney and others (Helmholtz, 1866; Boyaci et al, 2003; Bloj et al 2004) have argued that, to compute surface lightness, the visual system must estimate the direction and intensity of the light source. But this becomes computationally implausible in most scenes, which contain multiple light sources, including windows and indirect lighting. Instead it appears that the visual system solves this problem in a much simpler way, by perceptually grouping together surfaces that share the same illumination level. With illumination held constant, luminance variations within such a group arise only from reflectance. This kind of perceptual grouping is distinct from, but a twin of, the traditional idea of grouping. Segmenting an object by grouping its lighted and shadowed halves is just the flip-side of grouping the shadowed half with its shadowed background to segment a framework of illumination. Grouping by illumination requires only a few simple image-based rules (Gilchrist, 2006) involving penumbra, occlusion boundaries, and corners. Ironically, the Helmholtzian approach cannot avoid this segmentation problem given that complex scenes contain adjacent regions of different illumination level and thus different levels of illumination must be taken into account in each of these. Grouping by illumination is simple and consistent with empirical data.

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[11S302] Interactions between illumination, shape and reflectance

**Wendy J Adams**

Psychology, University of Southampton

Recovering shape or reflectance from an object's image is under-constrained: effects of shape, reflectance and illumination are confounded in the image. Priors over the scene variables make this problem tractable. I consider whether illumination priors guide perception, such that: (i) Shape, reflectance and illumination estimates are mutually consistent: When an observer estimates shape or reflectance, or searches for a shape-from-shading target, performance in all three tasks reflects the same estimated illumination (Adams, 2007). In addition, interactions between perceived shape and gloss suggest that the two are jointly estimated (Adams & Elder, 2014). (ii) Illumination priors are modified when the world changes: Observers change their prior over illumination in response to visual-haptic training (Adams, Graf & Ernst, 2004), and can store different context-contingent priors (Adams, Kerrigan & Graf, 2010; Kerrigan & Adams, 2013) (iii) This learning affects estimates of both shape and reflectance: When the illumination prior is

modified via a visual-haptic shape discrimination task, this learning transfers to reflectance judgments of a novel object (Adams, Graf & Ernst, 2004). I suggest that the visual system does, perhaps implicitly, estimate characteristics of the illumination field, that these estimates are influenced by prior experience, and they affect judgments of shape and reflectance.

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[11S303] A contrast-based model of lightness perception

**Marianne Maertens<sup>1</sup>, Robert Shapley<sup>2</sup>, Christiane Wiebel<sup>3</sup>**

<sup>1</sup>Software Engineering and Theoretical Computer Science, Technische Universität Berlin; <sup>2</sup>Center for Neural Science, New York University, New York USA; <sup>3</sup>Technische Universität Berlin

Human observers perceive surface lightness accurately despite variations in viewing conditions. This so called lightness constancy depends on contextual modulation of the sensory input but the underlying mechanisms are not yet understood. We studied lightness constancy in 2d-images of variegated checkerboards shown as perspective projections of 3d-objects. We manipulated the context of a target check by rendering the image under different viewing conditions or by introducing non-coincidental changes in the surround reflectances. Observers' lightness matches in different viewing conditions were accounted for by a contrast-based computation. The contrast-based model predicted characteristic mismatches for context changes due to different surround reflectances. However, such simultaneous contrast effects were smaller than predicted by the model. We tested two model extensions to account for the observed data. In one alternative, the surround term in the contrast equation was extended to include a larger area for normalization. In the other alternative, the reflectance change is mistaken as a change in viewing conditions and the visual system compensated for it accordingly. Both model versions accounted equally well for the data. Crucially, the main currency of both models is contrast, but it remains to be discussed what kind of mechanism could provide for a non-local contrast computation.

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[11S304] Human vision uses a flexible model of lighting variations

**Richard F Murray<sup>1</sup>, John D. Wilder<sup>1,2</sup>, Minjung Kim<sup>1,3</sup>**

<sup>1</sup>Department of Psychology and Centre for Vision Research, York University; <sup>2</sup>University of Toronto; <sup>3</sup>New York University

Does human vision estimate lighting conditions when perceiving 3D shape from image shading? To examine this question, we tested whether people can recover 3D shape when illumination varies spatially in ways that violate any ecologically valid model of lighting. Ostrovsky et al. (2005) showed that people are insensitive to some inconsistencies in lighting. How much inconsistency can we tolerate? We examined depth perception in computer-generated scenes where lighting direction changed from place to place at various rates. We found that people could tolerate highly variable lighting conditions, and that depth perception was mostly unimpaired if lighting was constant over small regions the size of a few surface bumps. Apparently people required lighting consistency only over small regions, and globally consistent scene lighting was unimportant. However, vision cannot be completely insensitive to lighting inconsistency. We have shown that ambiguous shapes are disambiguated by lighting cues on distinct objects more than 3 degrees apart (Morgenstern et al. 2011). Here vision assumes consistent lighting over relatively large regions. We conclude that human vision assumes constant lighting only over small image regions. However, when lighting cues are weak, vision propagates lighting estimates over larger distances, effectively assuming constant lighting over much larger image regions.

Funding: Natural Sciences and Engineering Research Council of Canada

[11S305] The appearance of light

**Sylvia Pont**

Industrial Design Engineering, Perceptual Intelligence Lab, Delft University of Technology, The Netherlands

Materials, shapes, spaces and light sources all affect the resulting light distributions in scenes (so-called “light fields”) and appearance of objects in it. Material, shape, space and light perception are basically confounded. We usually look at scenes, objects and people instead of light sources. Thus, I focus on appearance instead of lamps. We are sensitive to the (physical) light field in the sense that we have expectations of how an object would appear if it were introduced at some arbitrary location in empty space (Koenderink et al., 2007). In our research we demonstrated the feasibility of an

approach using so-called “canonical modes” in the optical structure, components that represent key components in the visual information, for light fields (Pont, 2013) as well as materials (Pont et al., 2012; Zhang et al., 2015). We also demonstrated analogies between such perception-based representations in physics, perception and design, in theory and experiments (Mury et al., 2008; Kartashova, 2015; Pont, 2013, Xia et al., 2014). I will explain this theoretical framework and methods to describe, measure, and visualize light; discuss empirical results of its visual effects on material and shape appearance; and explain applications in scientifically informed design of intelligent lighting systems.

[11S306] Equivalent illumination models and the cues selecting them

**Laurence T Maloney**

Dept. of Psychology, New York University

Light and surface are dual: each time we measure the perceived color of a matte surface in a scene we also obtain an implicit measure of the light impinging in the surface, the equivalent illuminant. Such measurements allow us to estimate an equivalent illumination model (EIM; Brainard & Maloney, 2011, JoV), the subjective analogue of the actual light field present in the scene. If the EIM is consistent with the light field then the subject’s judgments of surface color will be accurate; failures in estimating the EIM will result in failures in surface color estimation and v.v. Two possible routes to modeling surface color perception are (1) to establish the spectral and spatial limitations on possible EIMs and (2) to determine the sources of information (cues) about scene illumination used in selecting an EIM in a particular scene. I will present a model – based on past research – of possible EIMs and the cues that permit selection of particular EIMs in particular scenes.

Funding: NSF 1059166

### ***Monday August 29th Oral presentations***

[11T101] Saccade preparation reshapes sensory tuning

**Marisa Carrasco, Hsin-Hung Li, Antoine Barbot**

Psychology Department and Center for Neural Science, New York University

Human and primates make large rapid eye movements—saccades—to bring behaviorally relevant information into the fovea, where spatial resolution is greatest. Performance at the saccade target location improves before saccade onset. Although this effect called presaccadic enhancement is well documented, it remains unknown whether and how presaccadic modulations change the processing of feature information. Here, we investigated how saccade preparation influences the processing of orientation and spatial frequency using a psychophysical reverse correlation approach. We found that saccade preparation selectively enhanced the gain of high spatial frequency information and narrowed orientation tuning at the upcoming saccade landing position. These modulations were time-locked to saccade onset, peaking right before the eyes moved (-50-0 ms). A control experiment showed that merely deploying covert attention without preparing a saccade did not alter performance within the same temporal interval. The observed presaccadic tuning changes might reflect the presaccadic enhancement and receptive field shifts reported in neurophysiological studies. We propose that saccade preparation may support transsaccadic integration by reshaping the representation of the saccade target to be more fovea-like just before saccade onset. These results illustrate a strong perception-action coupling by revealing that the visual system dynamically reshapes feature selectivity contingent upon eye movements. Funding: US National Institutes of Health grants R01-EY019693 and 427 R01-EY016200 to M.C.

[11T102] Perisaccadic suppression during double-step saccades

**Eckart Zimmermann<sup>1</sup>, Concetta Morrone<sup>2</sup>, Paola Binda<sup>2</sup>**

<sup>1</sup>Institute for Experimental Psychology, Heinrich Heine University Düsseldorf; <sup>2</sup>CNR Pisa

Every time we make a saccade, the image of the external world sweeps across the retina with high-speed motion, yet our perception remains stable and seamless. This is due to a drastic reduction of sensitivity to motion and luminance contrast, which could result from an active suppression mechanism triggered by saccade planning. Here we dissociate the consequences of saccade planning from saccade execution by studying suppression in a double-step saccade paradigm. In this paradigm, two saccade targets are briefly shown before the first saccade, and the second saccade follows with extremely short inter-saccadic intervals (down to 20 ms), suggesting that both saccades are pre-planned in

parallel. We probe perisaccadic suppression by asking subjects to report the contrast polarity of a grating, shown for one monitor frame parallel to the saccade path and of 0.1 c/deg. Sensitivity is suppressed during the first saccade, but suppression is weaker during the second saccade, in trials with short but not with long inter-saccadic intervals. Changes in suppression magnitude cannot be explained by variations in saccade dynamics. The results suggest that perisaccadic suppression is controlled by an active extra-retinal mechanism, linked to saccade planning, not saccade execution.

[11T103] Modeling attention and saccade programming in real-world contexts

**Gregory Zelinsky<sup>1</sup>, Hossein Adeli<sup>1</sup>, Françoise Vitu<sup>2</sup>**

<sup>1</sup>Department of Psychology, Stony Brook University; <sup>2</sup>CNRS Aix-Marseille Université

Models of scene viewing and visual search largely ignore the neural basis of saccade programming. Conversely, models of saccade programming are closely tied to neural mechanisms but cannot be applied to common objects and scenes. We introduce MASC, a computational Model of Attention in the Superior Colliculus (SC). MASC combines methods from computer vision for predicting fixations in visually-complex environments with neural constraints known to exist in the SC, a mid-brain structure implicated in saccade targeting. We evaluated MASC against human fixation behavior in a free-viewing task (n=15, MIT dataset of 1000 realistic scenes) and two search tasks, exemplar search (n=15, target cued by picture preview) and categorical search (n=15, target cued by category name). We show that MASC predicted saccade landing positions and amplitudes in the free-viewing task, and the summed saccade distance and the proportion of trials in which the target was the first-fixated object in both the exemplar and categorical search tasks, a breadth achieved by no other existing model. Moreover, it did this as well or better when compared to more specialized state-of-the-art competing models. We conclude that MASC's predictive success stems from its inclusion of neural principles and constraints from the SC in its design.

Funding: This work was supported by a SUNY Brain Network of Excellence grant to GZ.

[11T104] Counter compression: the cause of 'reverse' pre-saccadic perceptual distortion

**Tamara L Watson<sup>1</sup>, Markus Lappe<sup>2</sup>**

<sup>1</sup>School of Social Sciences and Psychology, Western Sydney University; <sup>2</sup>Westfälische Wilhelms Universität Münster

Perceived compression of visual stimuli towards a saccade target is well established. An earlier shift in the direction of the initial fixation point has also been shown. To establish the cause of the 'reverse' pre-saccadic perceptual distortion, five participants completed four versions of a saccade task. Participants made 1) reflexive horizontal saccades, 2) overlap saccades, 3) overlap saccades with immediate return saccade, 4) no saccades with target stimuli masked at various ISIs. After the cue to saccade, a bar stimulus was briefly presented within the saccade trajectory. Participants indicated the bar's location using a mouse cursor. In all conditions involving a saccade, pre-saccadic compression was preceded by compression toward the initial fixation. In contrast, stimuli masked at fixation were not compressed. This suggests the two opposing compression effects are related to the act of executing an eye movement. They are also not caused by the requirement to make two sequential saccades ending at the initial fixation location and are not caused by continuous presence of the fixation markers. We propose that this effect is related to increased attentional weight given to the initial fixation point as part of the motor plan to execute a cued saccade.

[11T105] Oculomotor learning with slowly fluctuating disturbances of visual feedback

**Florian Ostendorf**

Dept. of Neurology, Charité - Universitätsmedizin Berlin

Visuo-motor learning is often assessed experimentally by inducing a sudden, step-like change in the mapping of visual feedback and corresponding motor action. In everyday life, alterations of visuomotor mapping may rather fluctuate on slower time scales. We assessed oculomotor learning in a classical saccade adaptation paradigm (STEP) with a constant intrasaccadic backward step of the saccade target. A second condition (WALK) probed performance in a new regime that varied perturbation size and direction gradually, according to a random walk dynamic. To assess learning in both conditions, we fit a state equation to individual data, where saccade amplitude of a given trial is determined by (i) the prediction error encountered on the previous trial, weighted by a learning rate  $K$ , and (ii) the current state estimate of the visuomotor mapping, weighted by a retention factor  $A$ . Results (n=6) demonstrate that saccade amplitude fluctuations clearly track random walk dynamics. Model fits indicate higher learning rates for WALK versus STEP condition ( $P = .014$ ). A second experiment (n=8) probed learning with random walk perturbations either with or without a random noise component added. Ideal observer analysis suggests that subjects exhibited highly efficient

learning in face of the added random noise.

Funding: n/a

#### [11T106] Vergence Eye Movements to Unbalanced Dichoptic Visual Stimuli

**Guido Maiello<sup>1</sup>, Agostino Gibaldi<sup>2</sup>, Silvio Sabatini<sup>2</sup>, Peter Bex<sup>3</sup>**

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Our binocular interaction with the 3 dimensional world uses retinal disparities for the perception of stereoscopic depth and to drive short-latency vergence eye movements, which are opposite rotations of the eyes that redirect both foveae onto a visual target. Out of computational efficiency, stereopsis and vergence likely share V1 resources where disparities are first encoded. When exposed to unbalanced dichoptic visual stimuli, the visual system suppresses one eye's input from conscious perception. These interocular suppressive mechanisms originate in V1 and hinder depth perception. It is unclear whether vergence is similarly affected by interocular suppression. If vergence were affected, this could suggest that vergence and stereopsis share computational resources where suppression occurs, or that perceptual processing of disparity information feeds back into the oculomotor planning system. We asked human observers to perform a vergence task with dichoptic "dead-leaves" stimuli at  $\pm 2^\circ$  disparity. The interocular contrast and luminance of the stimuli was systematically varied to elicit binocular suppression and degraded depth perception. Observers reliably executed vergence eye movements to these unbalanced dichoptic stimuli, however, the vergence response decreased as the dichoptic imbalance increased. Perceptual processing might thus play a neglected role in planning of eye movements in depth.

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#### [11T107] Visuomotor Behavior of Dominant and Non-Dominant Eye in 3D Visual Exploration

**Agostino Gibaldi, Andrea Canessa, Silvio P. Sabatini**

DIBRIS, University of Genova

Saccades are fast ballistic eye movements that redirect the fovea of the eyes onto the object of interest. When exploring the three-dimensional environment, different amplitudes are necessary to make the eyes land on the target at the same time, thus requiring an effective processing of the visual information from both eyes. We asked 30 human observers, with normal or corrected-to-normal vision and stereopsis, to perform a visual exploration of natural images, while binocularly recording their eye movements. Different stimulations were used: 2D image of a natural scene, presented equal to both eyes, and 3D image of the same scene, either with its actual texture, or with pink-noise texture coherent to the disparity of the scene. Kinematic performances with significant differences were measured between the two eyes, depending on the visual information presented. While the dominant eye is almost unaffected by the presence of depth information, the non-dominant one shows a decreased peak velocity, particularly on pink-noise images, where object texture is removed. Our results suggest how this asymmetry in the saccadic motor control can be interpreted as a significant role of monocular visual processing in the neural mechanism underlying the generation of the binocular coordination of saccadic movement.

#### [11T108] Inflexible eye movements to faces with changes in front end sensory processing

**Miguel P Eckstein, Yuliy Tsank**

Psychological and Brain Sciences, University of California, Santa Barbara

Humans can program their eye movements optimally to maximize the acquisition of visual information in a variety of tasks from search and reading to face recognition. Human eye movements also adapt to changes in the sensory system such as central visual loss (scotoma) due to macular degeneration. Yet, the tasks often evaluated simply require uncovering a small stimulus with the central scotoma. Here, we explore the possible effects of central vision loss in the optimal eye movements during a more complex face identification utilizing a gaze contingent simulated scotoma. We show that a newly proposed foveated ideal observer with a central scotoma correctly predicts that the human optimal (accuracy maximizing) point of fixation to identify faces shifts from just below the eyes (without the scotoma) to the tip of the nose (with the scotoma). Yet, surprisingly even after 4000 trials, humans do not change their initial fixations to faces to adapt to the simulated scotoma but do compensate their eye movements in simpler tasks such as object following and search. Our findings suggest task-specificity in the learning of oculomotor plans in response to changes

in front end sensory processing and illustrate the entrenched nature of eye movements to faces.

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[12T101] Different serial dependencies for the perception of stable and changeable facial attributes

**David Alais<sup>1</sup>, Jessica Taubert<sup>1</sup>, David Burr<sup>2</sup>**

<sup>1</sup>School of Psychology, University of Sydney; <sup>2</sup>University of Florence

Face perception involves detecting and discriminating attributes that may be either stable (e.g., gender, identity) or variable (e.g., expression). This is a challenge for the perceptual system as it may improve signal-to-noise ratio of stable attributes by integrating successive images yet needs to differentiate between images to be sensitive to changeable attributes. To test whether integration or differentiation dominates, we examined serial dependencies in random sequences of faces drawn from a 5x5 two-dimensional gender/expression face space that varied from male to female on one dimension and from happy to sad on the other. Subjects made two responses on each trial: male or female, and happy or sad. We found very strong and consistent positive serial dependencies for gender, with the previous stimulus accounting for over 30% of the current response. However, the serial dependency for expression was consistently negative, on average -20%, consistent with adaptation aftereffects. These results show that both processes can operate at the same time, on the same stimuli, depending on the attribute being judged. The results point to a sophisticated and flexible mechanism for optimizing use of past information, either integrating or differentiating, depending on whether the attribute is a stable or variable one.

[12T102] Single-blink adaptation of gaze direction to correct for oculomotor errors

**Gerrit Maus<sup>1</sup>, Thérèse Collins<sup>2</sup>**

<sup>1</sup>Division of Psychology, Nanyang Technological University; <sup>2</sup>Université Paris Descartes

When a fixation target is displaced repeatedly during eye blinks, the oculomotor system adapts: when a target is moved laterally by a fixed step size during repeated eye blinks, the initial gaze direction after each eye blink becomes biased towards the new target positions, without the subject noticing. Previously reported for repeated identical displacements, here we show that this adaptation of gaze can also occur for random target steps and is evident after just one blink. Observers were instructed to fixate a target dot on the screen. We detected eye blinks in real-time and used them to trigger random target jumps left or right (between 0.1 and 1.0 degrees). We recorded the first gaze direction after each eye blink, and observers reported the perceived direction of each jump. The change in gaze direction from one blink to the next correlated with the retinal position of the target after the previous blink. This correlation was reduced, when observers perceived the previous jump accurately. This is evidence for a fast-acting adaptive mechanism: when visual changes during blinks are not perceived as object motion, the oculomotor system tries to compensate for previously experienced errors due to oculomotor noise.

[12T103] Transparency cues determine afterimage filling-in

**Jeroen J van Boxtel**

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Recently, Lier et al (2009, *Current Biology*) showed a striking example of how boundaries influence perception. They created afterimages with a star-shaped stimulus consisting of red and green points and a gray center. When they outlined the afterimage created by the red (or green) points, the central patch was filled-in with the colors of the outlined points, even though the center had not received a colored stimulus. It was suggested that the central area was actively filled-in with the color of the points. However, the central patch represents a transparent overlay of two differently colored stars. Could transparency cues instead determine the filling-in of the central patch. In 3 experiments we show that (1) making the star's points all the same color – preserving luminance differences, but removing the transparent percept – removes perceptual filling-in; (2) rendering the luminance of the central patch inconsistent with transparency rules prevents perceptual filling-in; (3) perceptual ratings of transparency of the afterimage inducer correlated with the amount of filling in of the afterimage. Therefore, transparency-induced scission – breaking the scene into different depth layers – determines whether a boundary induces filling-in, and it thus plays an essential role in determining conscious visual perception.

[12T104] Changes in visibility as a function of spatial frequency and microsaccade occurrence  
**Susana Martinez-Conde<sup>1</sup>, Francisco Costela<sup>2</sup>, Michael McCamy<sup>3</sup>, Mary Coffelt<sup>4</sup>, Jorge Otero-Millan<sup>5</sup>, Stephen Macknik<sup>1</sup>**

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Fixational eye movements, including microsaccades, drift, and tremor, shift our eye position during ocular fixation, producing retinal motion that is thought to help visibility by counteracting neural adaptation to unchanging visual stimulation. Yet, how each eye movement type influences this process is still debated. Here we asked how the visibility of targets of various SFs changed over time, in relationship with concurrent microsaccade production. Human participants continuously reported on changes in target visibility, allowing us to time-lock ongoing changes in microsaccade parameters to perceptual transitions in visibility, which occurred at multiple and variable times during each trial. Microsaccades restored/improved the visibility of low SF targets more efficiently than that of high SF targets. Yet, microsaccade rates rose before periods of increased visibility, and dropped before periods of diminished visibility, for all target SFs tested, indicating that microsaccades are beneficial to target visibility across a wide range of SFs. Because microsaccades rarely preceded transitions to diminished visibility for any SF, our data also denote that visual stimuli seldom fade or become harder to see in the presence of microsaccades. These combined results support the proposal that neural transients created by microsaccades are beneficial to vision, across a broad variety of SFs. Funding: This study was supported by a challenge grant from Research to Prevent Blindness Inc. to the Department of Ophthalmology at SUNY Downstate, the Empire Innovation Program (Awards to SLM and SMC), the Barrow Neurological Foundation (Awards to SLM and SMC) a

[12T105] Adaptation of face gender, expression, and head direction from random-noise adaptation images: A surprising prediction of Li and Atick's efficient binocular coding theory

**Keith May, Li Zhaoping**

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We present a novel face adaptation paradigm that follows from Li and Atick's (1994) theory of efficient binocular encoding. In this theory, the inputs to the two eyes are combined using separately adaptable binocular summation and differencing channels. We designed a dichoptic test stimulus for which the summation channel sees one face image, and the differencing channel sees a different face image. The pairs of faces seen by the two channels were male/female, happy/sad, or turned slightly to the left/right. The face perceived by the observer depended on the relative sensitivities of the two channels. We manipulated channel sensitivity by selective adaptation with images that were low-pass filtered white noise. In correlated adaptation, each eye received the same adaptation image, which selectively adapted the summation channel; in anticorrelated adaptation, the adaptor contrast was reversed between the eyes, selectively adapting the differencing channel. After adaptation, we presented the dichoptic test stimulus, and found that the observer perceived the summation channel's face image most often after anticorrelated adaptation, and perceived the differencing channel's face image most often after correlated adaptation. For male/female and left/right judgements, perception was generally biased towards the summation channel; for happy/sad judgements, there was little or no bias. Funding: This work was supported by a grant to Li Zhaoping from the Gatsby Charitable Foundation and ESRC grant ES/K006509/1 to Li Zhaoping.

[12T106] The Neural Encoding of Bodies along the Dimensions of Fat and Muscle

**Kevin R Brooks, Daniel Sturman, Jonathan Mond, Richard Stevenson, Ian Stephen**

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Following decades of research connecting unrealistic "ideal" bodies in the media with widespread body dissatisfaction, perceptual research has begun to focus on visual adaptation as a potential mechanism. These experiments have used simple image manipulations to alter body size, demonstrating aftereffects of overestimation and underestimation following adaptation to images of decreased and increased size respectively. However, studies to date have focussed on body size per se even though this depends on both fat and muscle mass, which have very different relationships with health, and are prioritised differently by each gender. The current study investigated the neural mechanisms by examining whether adaptation occurs independently along the body dimensions of fat and muscle. Participants adjusted images of bodies using a two-dimensional manipulation tool to represent their perception of an average body before

and after adaptation to low fat, high fat, low muscle or high muscle bodies. Aftereffects were along the adapted body dimension, indicating dissociable neural populations encoding adiposity and muscularity, and a relocation of norms in multidimensional body space. These results may have implications regarding exposure to unrealistic images of bodies in the media and the development of eating disorders and related manifestations of body image disturbance, such as muscle dysmorphia.

[12T201] Gist perception in adolescents with and without ASD: Ultra-rapid categorization of meaningful real-life scenes

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Previous research has suggested the presence of a reduced preference to report and spontaneously interpret the global properties of a scene picture in adults with Autism Spectrum Disorder (ASD). Contrary to what is seen in typically developing (TD) participants, gist perception in ASD seems to occur mostly in a more explicit manner with focused attention. The current study used a set of non-social and social ultra-rapid categorization tasks to investigate gist perception in adolescents with and without ASD. When we instructed the participants to rapidly identify briefly presented object or scene information, we found that adolescents with ASD performed worse than TD participants. These findings complemented our previous study on ultra-rapid categorization in adults with or without ASD, in which no group-level differences in gist perception were observed. When categorization specifically entailed the fast processing of socially salient information, both adolescents and adults with ASD performed worse than TD participants. The combination of these results suggests an age-dependent improvement in general categorization ability but more long-lasting difficulties in rapid social categorization in individuals with ASD. We suggest that the poorer general performance of adolescents with ASD results from a less efficient rapid feedforward processing of global semantic structure.

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[12T202] Dorsal stream deficits following perinatal brain injury: reduced global motion sensitivity correlated with specific components of visual attention in the ecab (early child attention battery)

**Janette Atkinson<sup>1</sup>, Oliver Braddick<sup>2</sup>, Christine Montague-Johnson<sup>2</sup>, Morag Andrew<sup>2</sup>, Jeremy Parr<sup>3</sup>, Peter Sullivan<sup>2</sup>**

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We previously reported a cluster of deficits including global motion and visual attention, found across many developmental and visual disorders, which can be considered as ‘dorsal stream vulnerability’. In a cohort of 31 children (aged 4-6, mean 4.9 years), followed from infancy with perinatal brain injury (PBI) identified on MRI, we show (a) significant correlation between deficits in motion coherence sensitivity and visual attention (subtests in Early Childhood Attention Battery for specific components of attention) which go beyond any general cognitive disability (mean mental age 4.6). Standard scores, scaled to mental age, (expected value=10) were particularly low on visual search, sustained attention, and counterpointing (executive function) (mean = 5.7, 5.5, and 6.2 respectively) and lower for global motion (8.1) than form (8.8). Chronological age standard scores showed highly significant correlations between motion sensitivity and the ECAB search and flanker tests; (b) deficits on the ECAB flanker test correlated with infant attention deficits (measured using the Fixation Shift Paradigm on these children). Our results show specific attention deficits correlated with global motion deficits, following PBI. The neural basis of these associations may relate to structural variations in parietal lobe, which we found to correlate with global motion sensitivity (Atkinson, ECVP 2014).

[12T203] Development of shape from shading perception

**Ayelet Sapir, Giovanni d'Avossa**

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When judging the 3D shape of a shaded image, observers generally assume that the light source is placed above and to

the left of the stimulus. This leftward bias has been attributed to hemispheric lateralization or experiential factors related to learning and habitual scanning direction. In the current study, we tested children age 4-12 year old in a shape from shading task. Children were asked to judge the relative depth of the central hexagon surrounded by six shaded hexagons. Additionally, we tested their ability to process stimuli globally, reading proficiency and visual scanning direction. We found that most 5-year-old participants did not judge 3D shape consistently. Among older children (age 7 and above), those who could consistently perceive 3D shape, the assumed light source direction showed a left bias, of a magnitude similar to the one shown by young adults. None of the ancillary measures correlated with either the sensitivity to shading or the assumed light source direction. This result suggests that innate factors are more important than experiential ones in determining the direction of the assumed light source.

[12T204] Normative values for a speed-acuity test to determine delays in visual processing speed

**Annemiek Barsingerhorn, Nienke Boonstra, Jeroen Goossens**

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Measurement of visual acuity is standard practice during ophthalmic examination, but visual processing speed is never tested. However, there are children who display symptoms of slowed visual perception. At present there are no clinical tests available which allow simultaneous testing of visual acuity and processing speed to quantify these symptoms. Our goal was to develop such a test and to establish normative values for children between 5 and 12 years old. Seventy-one children with normal vision ( $8.7 \pm 2.0$  years) performed the speed-acuity test. The test consists of 2x90 trials in which children had to indicate, as fast and accurate as possible, on which side the opening of a Landolt-C was located. Nine sizes of the optotype were used, ranging from below their acuity threshold to at least 0.9 LogMAR above threshold. The results revealed that children become faster as they grow older. Additionally, children get slower as optotype size decreases, even if the optotype size is still well above threshold. Decision-making models, such as drift-diffusion models can be used to explain the effect of optotype size on reaction time. The normative values of the speed-acuity test allow assessment of visual processing speed in clinical populations.

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[12T205] Development of visual information sampling in road traffic situations

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Each year 270000 pedestrians die of road traffic and millions are injured (WHO, 2011). Despite children being largely over-represented in casualties, little is known about the perceptual processes used by children for judgments typically made as a pedestrian. In the present study, we addressed two crucial questions: 1- In road-crossing situations, are children more influenced than adults by specific social and visual saliency features, 2- how does this influence change with age? We recorded the eye-movements of more than 100 children from 5 to 14 years-old and 30 adults while they were watching road-traffic videos on screen and performing a road-crossing decision task. Linear-mixed models showed a strong age effect on crossing decisions and clustering techniques isolated 5-9 years-old children as more likely to cross the road in short gaps. Young children also showed difficulties in inhibiting reflexive orientation responses towards traffic irrelevant distractors. Statistical mapping of eye-movements identified the social and visual saliency features leading to the strongest orientation responses. Our data offer a novel fine-grained description of the visuo-spatial processes of children's engaged in road-traffic situations. These findings have a profound impact on the understanding of the visual system and road safety issues.

[12T206] Colour discrimination ellipses of infants aged 4-6 months

**Jenny M Bosten, Alice Skelton, Anna Franklin**

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Human colour discrimination ellipses are typically elongated in a blue-yellow direction, meaning that colour discrimination is worse for colours that vary in blueness or yellowness than for colours that vary orthogonally. It has been proposed that this chromatic tuning of colour sensitivity may reflect the colour statistics of natural scenes: it is along the blue-yellow axis there is most chromatic variance (Bosten, Beer and MacLeod, JOV, 2015, 15:5). The colour mechanisms of individuals may become tuned to represent the ranges of chromaticities encountered in the environment

along each colour axis. A critical test of the tuning hypothesis is the discrimination performance of infants, whose visual systems may not yet have calibrated to the chromatic content of natural scenes. Using the same eye-tracking method for adults and for infants, we measured detection of coloured targets as a function of saturation in eight colour directions. Preliminary results indicate that the colour discrimination ellipses of infants aged 4-6 months are not elongated in a blue-yellow direction like those of adults. Our findings are tentatively in favour of the idea that colour performance becomes tuned to chromatic statistics during ontogenetic development.

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[12T301] Viewpoint and identity-invariant categorisation of the six basic expressions

**Milena Dzhelyova, Bruno Rossion**

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Humans are particularly adept at detecting changes of facial expressions under different conditions of lighting or viewpoint, independently of the individuals, displaying these expressions. To characterize this fundamental brain process, we recorded EEG during fast periodic visual stimulation (FPVS) coupled with electroencephalography (EEG). Neutral faces were presented at a rate of 6 Hz (F) for 1 min changing viewpoint (0; 45° to the left and right, experiment 1) or identity (experiment 2) at every stimulation cycle. Every five stimuli, faces briefly changed expression into one of the six basic emotions (in different stimulation sequences). Thus the 1.2 Hz (F/5) response and its harmonics in the EEG spectrum objectively indexed 1) the detection of a facial expression change and 2) the generalisation of this expression across viewpoints (expt. 1) or across different identities (expt. 2). This high signal-to-noise ratio (SNR) response focused on occipito-temporal sites, but its magnitude varied among the facial expressions, with more subtle expressions like sadness and fear leading to weaker responses. A complementary time domain analysis showed that the automatic facial expression change categorisation occurs very quickly (shortly after 100ms) but is prolonged (several hundred ms after the presentation of the expressive face).

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[12T302] What causes the other-race effect? Evidence from classification images

**William Simpson, Christopher Longmore, Grace Anderson, Sylvia Terbeck**

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In the other-race effect, participants can better recognize faces from their own race compared to those from another race. Several phenomena point to this effect being due to people's inability to process other-race faces with the holistic mechanism they use when recognizing own-race faces. One meaning of "holistic" is that the processing of the stimulus is nonlinear. Our observers decided if a very low contrast face had been presented or not. According to signal detection theory, the ideal way to perform this task is to cross-correlate the stimulus with a template of the signal, which is a linear process. Using the classification image technique, we find that observers can form a good template of same-race faces, but not other-race faces.

[12T303] Dynamic reweighting of facial form and motion cues during face recognition

**Katharina Dobs, Leila Reddy**

Université Paul Sabatier, CNRS-CerCo

The integration of multiple sensory cues pertaining to the same object is essential for precise and accurate perception. An optimal strategy is to weight these cues proportional to their reliability. Moreover, as reliability of sensory information may rapidly change, the perceptual weight assigned to each cue must also change dynamically. Recent studies showed that human observers apply this principle when integrating low-level unisensory and multisensory signals, but evidence for high-level perception remains scarce. Here we asked if human observers dynamically reweight high-level visual cues during face recognition. We therefore had subjects (n=6) identify one of two previously learned synthetic facial identities using form and motion, and varied form reliability (i.e., by making faces "older") on a trial-to-trial level. For each subject, we fitted psychometric functions to the proportion of identity choices in each condition. As predicted by optimal cue integration, the empirical combined variance did not differ from the optimal combined variance ( $p > 0.2$ , t-test). Importantly, the reduced form reliability ( $p < 0.01$ ) led to a reweighting of the form cue ( $p < 0.01$ ). Our data thus suggest that humans not only integrate but also dynamically reweight high-level visual

cues, such as facial form and motion, to yield a coherent percept of a facial identity.

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[12T304] Wobble-wobble: motion and shape indicate softness of deformable materials

**Vivian C Paulun, Filipp Schmidt, Jan Jaap R. van Assen, Roland W. Fleming**

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The behavior of non-rigid materials, like jelly, is determined by their physical properties and the external force applied. Which visual cues do we use to infer an object's softness from its behavior? We computer-simulated cubes of varying softness exposed to different types of an external force: (1) a rigid cylinder pushing downwards into the cube to various amounts (shape change, but little motion), (2) a cylinder quickly retracting from the cube (same initial shapes, differences in motion). Thus, either shape- or motion-related cues to stiffness were dominant in the animations.

Observers rated how soft/hard the cubes appeared. In the first scene, ratings were based mainly on the magnitude of the perturbations rather than the intrinsic material properties of the cube, i.e. observers assumed a constant force moving the cylinder. In the second scene, with motion being the dominant cue, perceived softness depended strongly on the amplitude and frequency of the cube's motion, which varied with its stiffness. Generally, cues related to curvature, and frequency and damping of oscillations dominated the judgments and outweighed the influence of the material's optical appearance. Our results suggest a rich internal representation of the properties and behavior of non-rigid materials.

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[12T305] An episodic face space model for representing faces

**Tobias M Schneider, Claus-Christian Carbon**

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It is commonly accepted that (facial) prototypes can be seen as averages of all face exemplars of a person experienced so far. In the sense of such average models, the most influential theoretical framework of mental face representations postulates a so-called "face space" with the centroid representing the respective prototype. Still, there is hardly any knowledge about the genesis of such a face-space and the dynamics of changes over time due to visual update and memory and retrieval effects. Frequency, familiarity, as well as experience and elaboration factors to specific facial instances, are not explicitly modelled in the classical face space concept. We propose a more complex, more precise model of facial prototypes which suggests a weighted average model of facial prototypes, demonstrating the advantage of episodic prototypes which represent characteristic time spans of a human life with ongoing facial changes due to ageing and environmental factors. This leads to a more economic model, especially for referring to the recognition of current facial depictions. In three experiments we demonstrate the decisive superiority of episodic prototypes compared to typical exhaustive prototypes.

[12T306] Identifying shape features underlying liquid perception

**Jan Jaap R van Assen<sup>1</sup>, Pascal Barla<sup>2</sup>, Roland W. Fleming<sup>1</sup>**

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Liquids are highly mutable. External forces and intrinsic properties cause liquids to adopt a very wide range of different shapes. Previous work has shown that despite this large spectrum of liquid shapes we are curiously good at estimating liquids' intrinsic properties (e.g., viscosity). In this study we try to identify 3D shape features that are common across different instances of a liquid. We conducted two experiments using simulated pouring liquids. (1) Observers matched eight variations of pouring liquids at seven different viscosities to a more precise standard viscosity scale. We find that observers show a high degree of constancy in matching viscosity across the different variations. (2) Observers rated twenty shape features (e.g., clumping, folding, and spread) for 32 different viscosities at 6 different time periods. We then tested the extent to which each of the computational shape measures predicted the perceptual shape- and viscosity judgments. We find that cues related to curvature, periodic movements, and spread predict many but not all of the human performance.

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### [13T101] Multiple Modality Dependent Priors in Human Time Perception

**Darren Rhodes, Warrick Roseboom, Anil Seth**

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In temporal reproduction tasks, humans bias their actions such that reproduced intervals are more similar to the mean of previous intervals. These effects have typically been interpreted as indicating the operation of a single temporal prior for duration judgements. Here, we show that humans can form multiple, modality contingent priors, and that these priors affect perceptual reports of timing. We presented participants with sequences of four auditory tones or visual flashes; the first three events separated by a regular temporal interval with the last event jittered around this interval. Participants reported whether the final event was early or late relative to expectation. In a trial block, intervals between successive auditory tones were, on average, shorter than for visual stimuli, or vice versa. The data suggest that participants' responses were biased such that they were attracted towards the mean interval, contingent on presentation modality, with experience of short auditory and long visual intervals biasing reports of auditory timing to be shorter and visual timing longer (or the reverse). These results are easily described by a Bayesian model of the influence of recent experience on temporal perception and demonstrate that humans can acquire and maintain multiple modality contingent priors for time perception.

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### [13T102] Individual temporal integration window durations correlate with resting state alpha

**Jan Drewes, Weina Zhu, Evelyn Muschter, David Melcher**

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Temporal integration and segregation are key elements of visual perception. When two visual events happen in rapid succession, they may not be separable to the visual system and are thus processed as one event. With longer temporal intervals between events, the probability for the events to be temporally segregated increases. Given suitable timing, identical paired-stimulus presentations may result in different outcomes (segregation or integration) on a trial-by-trial basis. We presented two stimuli in rapid succession at different ISIs (33, 66, 100 and 400ms) while recording MEG. The first stimulus was presented at near-threshold intensity, while the second stimulus was presented at above-threshold intensity (dual pulse paradigm). Subjects reported the number of stimuli seen. Behaviorally, subjects differed in their ability to correctly discriminate the two pulses, with some needing a much longer ISI in order to detect both stimuli. Performance was reflected in the evoked responses to the two stimulus pulses. In addition, we found a significant correlation between duration of the temporal integration window of our subjects and their measured resting state alpha frequency. These results provide evidence for a close link between the speed at which information is integrated and the resting rate of neural oscillations in the brain.

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### [13T103] Pupil hazard rates predict perceived gaze durations

**Nicola Binetti<sup>1</sup>, Charlotte Harrison<sup>1</sup>, Isabelle Mareschal<sup>2,3</sup>, Alan Johnston<sup>3</sup>**

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Several studies have shown that gaze direction processing is embedded in dedicated neuronal circuitry. However, given the inherently dynamic nature of gaze behaviours we also require an understanding of gaze duration processing. Time is processed throughout a distributed brain network and operates by means of endogenous signals which index subjective duration. Cortical arousal has been frequently linked to time: arousing stimuli lead to lengthened durations. While this has been typically framed in terms of arousal affecting a timekeeping mechanism, here we chose arousal as a candidate for an endogenous timing signal. In order to disentangle differences in arousal from differences in sensory content, we directly evaluated across identical stimuli, how differences in arousal contribute to differences in perceived time. Participants were asked to compare the duration of gaze shifts performed sequentially by two face stimuli. While performing this task we recorded pupil responses, a proxy of cortical arousal. We observed that gaze shifts perceived as "longer" were associated with greater increases in pupil diameter. This was not replicated when timing equivalent Gabor shifts, indicating the effect is gaze specific. These results demonstrate that endogenous arousal signals are

exploited by a face processing system to encode gaze shift durations.  
Funding: Leverhulme Trust

[13T104] Right hemisphere dominance in temporal attention: a TMS study

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Right posterior parietal cortex (rPPC) shows an advantage over the left (lPPC) for spatio-temporal computations. Patients with right parietal lesion show impaired temporal attention across the entire visual field (Battelli et al., 2008). Moreover, right parietal patients show non-spatially lateralized deficits (Husain et al., 1997). Here, the role of the rPPC in events discrimination across time was investigated using an offline TMS. 10 healthy participants were administered a simultaneity-judgment task and asked to discriminate whether two flickering dots among four (two in the left and two in the right visual field presented simultaneously) were flickering in- or out-of-phase. We used a staircase procedure to measure their phase discrimination threshold in both visual fields. We compared performance at baseline, and after 20min 1Hz stimulation. We stimulated the left, right PPC and V1 in three separate counterbalanced sessions. Results showed that TMS caused a significant reduction of the phase discrimination threshold in both the left and right visual field after stimulation over the rPPC, while it had no effect over the lPPC or EVA. In conclusion, our data casually linked the inhibition of the right PPC with a decreased performance in the simultaneity judgment task, closely mimicking right parietal patients' performance.

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[13T105] Dynamic changes in cortical effective connectivity underlie transsaccadic integration in humans

**Henry Railo, Jarno Tuominen, Valtteri Kaasinen, Henri Pesonen**

Psychology, University of Turku

Due to saccadic eye movements the retinal image is abruptly displaced 2-4 times a second, yet we experience a stable and continuous stream of vision. It is known that saccades modulate neural processing in various local brain areas, but the question of how saccades influence neural communication between different areas in the thalamo-cortical system has remained unanswered. By combining transcranial magnetic stimulation with electroencephalography we show that saccades are accompanied by dynamic changes in causal communication between different brain areas in humans. These changes are anticipatory; they begin before the actual eye movement. Compared to fixation, communication between posterior cortical areas is first briefly enhanced during saccades, but subsequently peri-saccadic information does not ignite sustained activity in fronto-parietal cortices. This suggests that the brain constructs a stable and continuous stream of conscious vision from discrete fixations by restricting the access of peri-saccadic visual information to sustained processing in fronto-parietal cortices.

[13T106] Spatial but not temporal bisection of sound sources elicit early occipital cortex responses in human

**Claudio Campus<sup>1</sup>, Giulio Sandini<sup>1</sup>, Maria Concetta Morrone<sup>2</sup>, Monica Gori<sup>1</sup>**

U-VIP, Fondazione Istituto Italiano di Tecnologia; Università di Pisa, Italy

It is not clear to date whether early visual cortical areas mediate the perception of audio signal in naïve sighted people. Only responses of extrastriate areas during auditory tests have been reported in blind and sighted and only after long term or transiently induced neural plasticity. Here we show a peculiar response of occipital cortex (early P100, 70-100 ms) to sound that it is strongly modulated by the task assigned to the subject. In two different set of experiments 16 sighted individuals performed a spatial and a temporal bisection judgment on the same three tone sequences, while recording ERPs. The P100 response amplitude to sound, usually barely measurable, increased by more than 10 folds during the spatial bisection task. This response amplification was specific for the spatial and not temporal task, for the second sound and surprisingly for the physical and perceived position of the stimulus in the two hemisphere. We suggest that this early occipital processing of sound is linked to the construction of an audio spatial map that is projected on the retinotopic map used by visual cortex.

[13T201] Feature-based attention reduces the critical spacing of visual crowding

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Visual object recognition is severely impaired in clutter, a phenomenon known as crowding. Spatial attention reduces crowding and supposedly the spatial extent over which flankers interfere with target processing (the critical spacing) is defined by the resolution of spatial attention. Thus, spatial attention might play a special and perhaps unique role in crowding, as other forms of attentional selection (e.g. feature-based attention) have no specific spatial resolution. If, however, attentional effects on crowding are due to general attentional mechanism (e.g. signal gain enhancement), then other forms of attentional selection should affect crowding similarly. We tested this hypothesis by investigating the effect of feature-based attention on crowding using a dual task paradigm. Participants performed a primary task at fixation where they responded to motion in one of two sets of colored dots. A peripheral crowding task was simultaneously presented, where the target had the same color as the attended or the unattended dots in the central task. Feature-based attention improved performance in the crowding task and reduced the critical spacing equally or even more than previously reported effects of spatial attention. This finding challenges purely spatial accounts of attention in crowding and suggests close links between attentional mechanisms and crowding.

[13T202] Crowding, spatial complexity and the W-shape of serial position functions for identification of letters and symbols

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Some researchers assume that different categories of items (such as letters vs. symbols) are differentially affected by crowding, allegedly as a result of different levels of familiarity. It has notably been shown that the classic W-shape of letter-in-word identification performance disappears when symbols are used instead of letters. With a 5-item string, this is due to outer symbols (first and fifth positions) having a very low performance compared to outer letters. One problematic aspect in many studies of this type is an insufficient control of the difference in spatial complexity between distinct categories. To avoid this problem, we created 9 symbols that were matched with 9 consonants (one-to-one correspondence) based on perimeter and area. Twenty adult skilled readers had to identify a letter (or symbol) within a 100 ms string of 5 letters (or symbols) centered at fixation (category was blocked). A post-cue indicated the target position (from 1 to 5). Each string was a random sample (without replacement) drawn from the 9-item set. Results show that the W-shape of the identification curve is maintained with symbols, thus arguing against specialized crowding mechanisms that would have evolved to optimize visual processing of letter strings (vs. symbol strings).

[13T203] Concordant effects of letter similarity in crowding and visual search

**Daniel R Coates<sup>1</sup>, Johan Wagemans<sup>1</sup>, Bilge Sayim<sup>2</sup>**

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The role of item similarity in visual search is well established. Analogous effects have been observed in crowding, such as worsened performance when flankers resemble targets. However, visual search and crowding are usually studied with different tasks, and it remains unclear to what extent they share common mechanisms. Here, we used a single task combining aspects of visual search and crowding. A foveally-centered ring of eight Sloan letters was briefly presented, comprising 7 identical letters and a single oddball target letter. Subjects indicated the target location. In the crowding condition, additional letter rings were presented inside and outside of the target ring. Error matrices constructed from target and distractor letters resembled crowded letter confusion matrices. In particular, errors revealed featural similarity (e.g., confusions between "V,K,X,Z" from oblique features), in contrast to isolated letter confusion matrices that typically reflect letter envelopes. As in previous crowding experiments, additional homogeneous flankers weakened crowding strength by enhancing grouping amongst flankers. Preattentive grouping of proto-object shapes (here letters) is a fundamental component of visual processing. Our task allows the study of grouping effects and error characteristics with a variety of methodological advantages. The similarities of crowding and search errors reveal clues about their underlying mechanisms.

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[13T204] How best to unify crowding?

**Matthew Pachai, Adrien Doerig, Michael Herzog**

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Crowding refers to the detrimental effect of nearby elements on target perception. Recently, Harrison and Bex (Curr Biol, 2015) modeled performance in a novel orientation crowding paradigm where observers reported the orientation of a Landolt C presented alone or surrounded by a flanking C. They found that crowding decreased as flanker radius increased, and their model fit these results well. A key prediction of their model is that flankers with each radius, if presented simultaneously, will additively deteriorate performance. However, evidence from other paradigms suggests that presenting several flankers can actually improve performance, if configured to group separately from the target (e.g., Manassi et al, J Vis 2012). Here, we show a similar grouping effect in the orientation crowding paradigm. We tested observers in three conditions: no flanker, one flanker, or five aligned flankers. All of our observers experienced less crowding with five aligned flankers than one flanker, and our reproduction of Harrison and Bex's model indeed produced the opposite result. Although Harrison and Bex's model provides a powerful framework to explain some crowding phenomena, a truly unifying model must also account for such grouping effects, as they are likely ubiquitous in everyday environments.

Funding: Swiss National Science Foundation (SNF)

[13T205] Flanker stimuli suppress target processing in visual cortex beyond the range of behavioural interference

**Leli Soo, Ramakrishna Chakravarthi, Plamen Antonov, Søren K. Andersen**

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Crowding is a phenomenon in which peripheral object recognition is impaired by the close proximity of irrelevant stimuli. Currently, the neural processes underlying object recognition and its failure in crowding are not well understood. Is the breakdown of object recognition seen in crowding due to a reduction in cortical processing of the target in the presence of distracters? To answer this question, we assessed cortical processing of a target object as a function of flanker presence and distance to the target while participants performed a target orientation discrimination task. Flankers and targets flickered at different frequencies to elicit Steady-State Visual Evoked potentials (SSVEPs), which allow for the assessment of cortical processing of each of multiple concurrently presented stimuli. Target identification accuracy and target elicited SSVEP amplitudes decreased when flankers approached the target. However, SSVEP amplitudes elicited by the target suffered the largest drop by the mere presence of flankers at the farthest flanker distance, although there was no corresponding drop in behavioural performance. We conclude that target-flanker interference in visual cortex occurs over large distances, but that behavioural performance is only affected once it reaches a certain strength.

Funding: EASTBIO BBSRC

[13T206] Crowding effects in real 3D

**Lisa V Eberhardt, Anke Huckauf**

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The phenomenon of impaired stimulus recognition in periphery when targets are surrounded by flanking stimuli is referred to as crowding. In virtual 3D there is evidence that perceiving a target in front of the flankers reduces crowding relative to perceiving it behind (Astle et al., 2014, Journal of Vision). We studied depth differences of target and flankers in real 3D using a semi-transparent mirror. A fixation cross was positioned at a depth of 190cm. Targets were presented at three degrees of eccentricity, either at, in front of, or behind the fixation plane. Flankers were presented either in the same or in different depths planes as the target. When presenting the target at the fixation plane crowding is unaffected by the depth of the flankers. But, presenting the flankers at the fixation plane resulted in a reduced crowding effect when targets were presented in another depth, either in front of, or behind the flankers, compared to the target in the same depth plane as the flankers. Defocus blur might account for the observed effect. However, since all stimuli were presented within the depth of field, other mechanisms of peripheral object recognition have to be identified.

[13T301] Object selective influence of fixated luminance on brightness perception in the periphery of the

visual field

**Matteo Toscani, Matteo Valsecchi, Karl Gegenfurtner**

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Despite poor resolution and distortions in peripheral viewing, the visual scene appears uniform. Possibly, peripheral appearance is extrapolated based on foveal information. Here we investigate whether the brightness of shaded objects at peripherally viewed locations is influenced by the foveal content. We rendered a matte cylinder in a gray room. Observers were asked to adjust the luminance of a matching disk to match a peripherally viewed target area on the cylinder's surface. A gaze-contingent display forced the observer to fixate specific locations on the object. Six observers fixated dark and bright points on the cylinder surface. Fixation of the light points lead to 16% brighter matches compared to fixating the dark points. Ten observers also fixated additional points with the same luminance outside of the cylinder on the scene's background. Fixating the brighter point of the cylinder again led to a significant increase in the brightness matches whereas fixated brightness had no effect outside of the object. Results indicate that our visual system uses the brightness of the foveally viewed surface area to estimate the brightness of areas in the periphery, and that this mechanism is selectively applied within an object's boundary.

[13T302] A novel paradigm for studying the relationship between luminance perception and contrast perception.

**David Kane, Marcelo Bertalmio**

Information and Communication Technologies, Universitat Pompeu Fabra, Barcelona

We present a novel paradigm that allows us to investigate luminance perception and contrast perception using near-identical stimulus configurations. In both experiments subjects view two 10 circles upon a uniform surround. In the contrast experiment the circles are white noise and have different mean luminances. The subject indicates which has more contrast and the point-of-subjective equality (PSE) is estimated. For the luminance experiment, the two circles are uniform and the task is to indicate which has the higher luminance. Sensitivity is then computed across the full luminance range of the monitor. Both experiments are evaluated using different background luminance levels. The sensitivity functions exhibit Whittle's 'crispening' effect (1992) whereby subjects are more sensitive around the background luminance level. However, the 'crispening' effect is reduced by the introduction of a hue-difference between the background and the test circles, or abolished by the introduction of a small annulus. We find that the data in the contrast experiment can only be predicted by taking into account the sensitivity functions prior to the computation of contrast over space. This indicates that contrast models must include a sophisticated, adaptive luminance nonlinearity that can account for the degree of 'crispening'.

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[13T303] Lightness perception in real and simulated scenes

**Ana Radonjić, David Brainard**

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The use of simulated stimuli is pervasive in vision research. However, the extent to which measures of object color and lightness in simulated scenes match those obtained in real illuminated scenes is not well understood. We measured the lightness of targets embedded in contrast-inducing backgrounds in real illuminated scenes and in well-matched graphics simulations. In Experiment 1, the stimuli were flat, matte, single-panel displays, each consisting of a different target-background combination, and presented in a dark surrounding context. Here, target lightnesses and the size of the contrast effects were essentially identical across real and simulated scenes. In Experiment 2, the scenes included a larger contextual background and the stimuli consisted of two panels meeting at right angle. One panel was covered with a black-and-white checkerboard, while the other featured the same target-background combinations we used in Experiment 1. Here, contrast effects were larger in real scenes with targets on dark contrast-inducing backgrounds appearing significantly lighter. Furthermore, these targets appeared darker in simulated scenes from Experiment 2 compared with Experiment 1, while across-experiment differences between real scenes were small. This work places limits on the degree to which current simulations capture lightness perception for real scenes, and motivates further investigation.

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[13T304] Brightness illusions as (unconditionally imposed) signal alterations by the outer retinal network

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Many published theories and computational models are rather ad hoc approaches in order to account for a set of brightness/lightness illusions, but frequently fall short of offering insights about any convincing benefits for visual signal processing (e.g. noise suppression, energy saving, etc.). It is also often ignored that visual input to the cortex is significantly processed by the retina in terms of luminance (outer retina) and pattern adaptation (inner retina). Here I present a computational approach to information processing in the outer retina. My proposal is that the horizontal-bipolar network implements spatio-temporal dynamic normalization based on nonlinear diffusion. This mechanism acts locally: It reduces the dynamic range of a visual scene, and reduces (local) color casts. In its present state, the dynamic normalization network predicts that White's effect, simultaneous contrast, the Benary cross, and grating induction, are all imposed by local luminance adaptation in the outer retina. The network also reduces the dynamic range of real-world images, while at the same time enhancing their contrast. In this way, detail in over- and underexposed regions is revealed. At least theoretically, the model should also be capable of explaining an even bigger range of brightness/lightness phenomena, including lightness anchoring and color constancy.

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[13T305] The effect of color on perceived luminance contrast and luminance on perceived color contrast

**Kathy T Mullen, Yeon Jin Kim**

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The study of interactions between color and luminance contrast is fundamental to a complete understanding of visual processing. Here we investigate how color contrast affects the perception of luminance contrast and vice versa. We used suprathreshold RG color and luminance contrast Gabors overlaid to form a cross-oriented plaid. This arrangement was chosen to reveal interactions mediated by contrast normalization. The perception of the color contrast and luminance contrast components in the plaid were measured separately using a method of constant stimuli. We determined a PSE between a color-only test stimulus and the plaid color contrast, and between a luminance-only test stimulus and the plaid luminance contrast. Binocular, monocular and dichoptic viewing conditions were used for different spatial frequencies (0.375-1.5 cpd, 2Hz) and base contrasts. Results show that luminance contrast enhances perceived color contrast in the plaid by an average of 44% under binocular and monocular conditions. Effects are consistent across spatial frequency and over a range of component contrasts. Conversely, color contrast has no effect on perceived luminance contrast under any viewing condition. In conclusion, we find asymmetric effects in contrast normalization: while perceived luminance contrast is unaffected by color contrast, luminance contrast enhances perceived color contrast.

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[13T306] Inferring light characteristics in spaces with multiple light zones

**Tatiana Kartashova, Huib de Ridder, Susan te Pas, Sylvia Pont**

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Light zones are spatial groupings of lighting variables (intensity, direction, etc.) significant to the space- and form-giving characteristics of light (Madsen, 2007). Previously, Kartashova et al. (2015) found that for paintings in which more than one light zone was present the light inferences showed striking individual differences. We investigated this matter further to study if the light inferences are influenced by the orientation of the zones relatively to the picture plane. We created a scene with two light zones, contrasting mainly in light direction, in the a) left and right (condition LR) and b) front and back parts (condition FB) of a space. A grid of locations across the scene was tested using probes (white matte spheres). The observers' task was to set the light on the probe (one per trial) as if it belonged to the scene. For condition LR the settings were highly consistent over observers and rather different in direction between the two zones. Contrarily, for condition FB we found high inter-observer settings variability, suggesting that observers estimated the relative sizes of the zones differently. We will further investigate the relation of these findings with space perception.

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## ***Tuesday August 30th Poster presentations***

[2P001] Does surprise enhancement or repetition suppression explain visual mismatch negativity?

**Catarina Amado, Gyula Kovács**

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A long tradition of electrophysiological studies, using oddball sequences, showed that the neural responses to a given stimulus differ when their presentation occurs frequently as compared to rare, infrequent presentations. This difference, originally described in acoustic perception, can also be detected in the visual modality and is termed as visual mismatch negativity (vMMN). A large number of studies detected the reduction of the neuronal response after the repetition of a given stimulus (repetition suppression - RS) and it was suggested that RS is the major mechanism of MMN. However, human studies have proposed that a surprise-related response enhancement for the deviant stimuli might also underlie vMMN. Therefore, the aim of the current study was to disentangle which neural mechanism explains vMMN better: the surprise for the presentation of rare deviants or the RS related to the frequent presentation of the standards. We tested the neural mechanisms of vMMN for different stimulus categories (faces, chairs, real and false characters). We found significant vMMN for every stimulus category. The neural mechanisms behind vMMN were found to be category dependent: for faces and chairs it was largely driven by RS, whereas for real and false characters it was mainly due to surprise-related changes.

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[2P002] Spatial factors underlying curvature detection

**Marie Morita, Takao Sato**

Graduate school of Letters, Ritsumeikan University

Gheorghiu & Kingdom (2007) examined the contribution of spatial factors of curvature including, shape-frequency (cycle number of periodic curvature), shape-amplitude, and local curvature to the amount of shape-aftereffect after prolonged exposures, and concluded that local curvature is the most important factor. On the other hand, Tyler (1973) measured the curvature detection threshold and obtained results that suggest shape-frequency tuning. In this study, we tried to elucidate the relationship between curvature detection threshold and the three spatial features examined by Gheorghiu & Kingdom (2007). The results indicated that the detection threshold was not systematically related neither shape-frequency nor local curvature, but could be related to shape-amplitude. That is, the shape-amplitude can be the determining feature of curvature detection. If so, the mechanisms underlying curvature detection and vernier acuity possibly share some sub-processes. We examined this possibility by using curvature stimuli consisting of dots in which dots were allocated at the peaks and zero-crossings of the original curvature. It was found that the dot-displacement threshold is three times larger than that for real curvy lines. The results may be explained by the difference in either visibility of the stimulus or some integration effect that exist between lines and dots.

[2P003] Modelling Chromatic Adaptation using Unique Hues

**Tushar Chauhan, Sophie Wuerger**

Experimental Psychology, University of Liverpool

This analysis evaluates the performance of three chromatic adaptation models: channel-wise gain (diagonal), cross-channel gain (linear) and cross-channel gain with origin recalibration (affine) using a large unique hues dataset (Xiao et al., 2011) collected in three different ambient illumination conditions – dark, simulated daylight and cool white fluorescent. The models are optimised in three colour spaces – the cone excitation space, the differential cone excitation space, and the cone-contrast based DKL opponency space. The small-sample Akaike criterion AICc (an information theoretic measure which takes the trade-off between model accuracy and the number of free parameters into account) is used to evaluate the models and the diagonal Von Kries model in the cone excitation space is found to perform best. Model performance on three perceptual metrics is also evaluated – the colour difference, the hue-angle difference, and the angle between fitted unique hue planes. The model with the highest number of parameters, i.e. the Affine model, is found to perform the best on all the metrics. The diagonal and linear models show similar performances across colour spaces, corroborating their theoretical equivalence implied by diagonalisation models such as spectral sharpening. These models also show a deviation from strict unimodality on luminance-dependent metrics.

[2P004] Vergence is limited by adaptation

**Elizabeth Fast<sup>1</sup>, Linus Holm<sup>2</sup>, Linda McLoon<sup>1</sup>, Stephen Engel<sup>1</sup>**

<sup>1</sup>Psychology, University of Minnesota; <sup>2</sup>Umeå University, Sweden

What limits the range of possible vergence movements? Vergence is driven by a fusion-based mechanism operating from a baseline provided by an adaptable tonic mechanism. We hypothesized that fusion breaks when the tonic mechanism doesn't fully adapt. Eight subjects viewed stimuli through a stereoscope, while we recorded eye position. The disparity presented to both eyes began at  $4\Delta$ , and was held for 5 minutes while the tonic mechanism adapted. The disparity increased by  $1\Delta$  every 5 minutes until fusion broke. Throughout the experiment, the right eye image was removed for 5s every 30s. With only monocular stimulation, the eyes drifted towards baseline, producing a phoria measurable as right eye movement. As subjects neared fusional limits, their phorias increased ( $p = 0.02$ ), suggesting subjects were less able to adapt. In a second session, the image moved without pause, and we measured fusional limits without adaptation. Fusion broke at smaller disparities ( $p < 0.01$ ), confirming the role of adaptation in setting limits. Our results support the hypothesis that fusion is limited by adaptation of the tonic component. When the tonic component cannot "keep up" with stimulus demands, fusion eventually breaks. When subjects are given more time to adapt, their fusional limits expand.

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[2P005] An adaptable, context-dependent object size representation in human parietal cortex

**Stephanie Kristensen<sup>1</sup>, Alessio Fracasso<sup>2</sup>, Serge Dumoulin<sup>3</sup>, Jorge Almeida<sup>1</sup>, Ben Harvey<sup>1</sup>**

<sup>1</sup>Faculty of psychology, University of Coimbra; <sup>2</sup>Utrecht University; <sup>3</sup>Spinoza Center for Neuroimaging Amsterdam

Humans and animals rely on accurate object size perception to guide behavior. Object size is judged from visual input, but an object's size on the retina differs from its real world size: retinal size decreases with distance. An adaptable system could compensate for this variable relationship using the context of sizes in which an object is seen. We recently described topographic object size maps in the human parietal cortex. Here we ask whether these object size representations adapt to the range of presented object sizes. Using ultra-high-field (7T) functional MRI and population receptive field modeling, we compare neural object size selectivity derived from responses to small ( $0.05$ - $1.4^\circ$  diameter) and large objects sizes ( $0.1$ - $2.8^\circ$ ). Object size preferences and tuning widths within the object size map change significantly between these conditions, but less than would be predicted from the change in presented object sizes. Therefore, the neural representation of object size adapts to the context of recently viewed sizes, but is not entirely relative. It may be constrained by early visual cortex's representation of retinal space. This context-dependent object size representation may use visual adaptation mechanisms to derive real world object sizes, and complement the retinal space representation in early visual cortex.

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[2P006] Effect of orthogonal adaptation on the perceived velocity of multidirectional random dot stimuli at different speeds

**Nikos Gekas, Pascal Mamassian**

Département d'études cognitives, Ecole Normale Supérieure

Motion adaptation generates strong aftereffects in the opposite direction. Here, we investigated the effect of orthogonal adaptation on perceived velocity across different speeds. Human observers adapted to a broadband grating, moving upwards at  $6^\circ/s$ . Then, a test stimulus was presented, which consisted of random dots moving at directions following a gaussian distribution centered at the orthogonal direction to adaptation (leftwards or rightwards). Participants manually matched the velocity of unidirectional dots arranged in a ring around the adaptation area with the perceived velocity of the test stimulus. Due to the aperture problem, the ambiguity of the adaptor's velocity should produce an asymmetry in the adaptation of velocity channels: faster speeds should be adapted for directions away from upwards but not slower speeds. To test this prediction, test stimuli were presented at speeds both faster and slower than the adapting speed. Our results showed a strong effect of repulsion away from the presented velocity (downwards and slower). The effect on speed was stronger at the adapting speed and weaker elsewhere, consistent with a non-directional adaptation (Stocker and Simoncelli, 2009). In contrast, the effect on direction was uniform across speeds. We present a computational model that can explain this discrepancy.

[2P007] Visual similarity modulates visual size contrast

**Nicola Bruno, Oga Daneyko, Gioacchino Garofalo, Lucia Riggio**

Dipartimento di Neuroscienze, Università di Parma, Italy

Perception is relational: object properties are perceived in comparison with their spatiotemporal context rather than absolutely. This principle predicts well known contrast effects: For instance, the same sphere will feel smaller after feeling a larger sphere and larger after feeling a smaller sphere (the Uznadze effect). In a series of experiments, we used a visual version of the Uznadze effect to test whether contrast effects can be modulated by higher-level factors, such as the similarity between the contrasting inducer stimulus and the contrasted induced stimulus. Our results suggest that the answer is positive for some dimensions of similarity, but not all. In particular, we report that size contrast is weaker for inducer-inducing pairs having the same shape but different colors, in comparison to the same color; for pairs having the same color, but different shape in comparison to the same shape; but that size contrast is unaffected by dissimilarity in orientation of gratings embedded in similar shapes. These findings complement related work in haptics (Kappers & Tiest, 2014) in suggesting that relational determination in perception can recruit high-level factors.

[2P008] Adaptation to eyeglasses with fully-corrected lenses: Assessment of wearing feeling and depth distortion

**Yasuaki Tamada<sup>1</sup>, Takumi Ono<sup>1</sup>, Ryuto Fujie<sup>2</sup>, Hiroshi Kaneko<sup>2</sup>, Masayuki Sato<sup>1</sup>**

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Eyeglasses slightly distort visual images on retinae of the both eyes and binocular differences between these image distortions cause a three-dimensional distortion in perceived space. Full correction for refractive error of the eye with glasses enables higher visual acuity, however, slightly weak correction is usually chosen because image distortions often degrade the wearing feeling of the glasses. The purpose of this study was to examine how the wearing feeling of the fully-corrected glasses is improved along long-term wearing. Three undergraduate students participated in the experiments. First they wore glasses with ordinary weakly-corrected lenses for 3-5 weeks. Replacement to the fully fully-corrected lenses introduced binocular size differences of the retinal image. For participant A and B, binocular vertical size ratio increased by approximately 0.01 and for participant C, both horizontal and vertical size ratio increased by approximately 0.02. The wearing feeling of the glasses was improved within a week for participant A and B but not for C. A tiny depth distortion was experienced immediately after replacement of lenses and this distortion did not disappear at least for three weeks. These results suggest that wearing feeling of the glasses can be improved in spite of continuous apparent depth distortion.

[2P009] Temporal Expectations and Stimulus Repetition: An Event-Related Potential Study

**Daniel Feuerriegel<sup>1</sup>, Scott Coussens<sup>1</sup>, Owen Churches<sup>2</sup>, Hannah Keage<sup>1</sup>**

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Repeatedly presenting a stimulus leads to changes in response magnitude and stimulus selectivity of cortical neurons. Predictive coding models have been proposed to account for these effects, emphasising the role of top-down and lateral feedback in suppressing neuronal activity signals. One prediction of these models is that the magnitude of repetition effects will be larger when the timing of stimuli can be predicted. We recorded event-related potentials (ERPs) from 18 participants and assessed whether the magnitude of ERP repetition effects are influenced by temporal expectations. In each trial participants were presented with an adapter face, followed by an inter-stimulus interval (500ms or 1000ms), and a test face, which was either the same or a different face identity to the adapter. The probability a test face after the 500ms ISI was cued by the adapter face gender. Mass univariate ERP analyses revealed several repetition effects between 150-600ms. Earlier ERP repetition effects were larger for test stimuli after unexpected ISIs, whereas later repetition effects were larger for test stimuli after expected ISIs. These results suggest that the relationship between stimulus repetition and temporal expectations is qualitatively different over time, supporting two-stage models in which repetition effects precede expectation-related effects on neuronal activity.

[2P010] The time course of visual adaptation is adaptable

**Sarah Maddison, Neil Roach, Ben Webb**

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The visual system adapts over time to the statistical regularities of the environment. Perceptual aftereffects induced by exposure to consistent visual input have a characteristic time course of build-up and decay. Recent work suggests that these dynamics reflect the combined effect of multiple mechanisms operating at distinct timescales (Bao & Engel, 2012). Here we ask whether the contribution of these adapting mechanisms is fixed or matched to the temporal regularities of recent visual input. We measured the build-up and decay of the tilt aftereffect by asking observers to reproduce the orientation of a tilted Gabor ( $\pm 18\text{-}22^\circ$  from vertical) before, during and after adaptation to a vertically oriented Gabor. In separate conditions, observers were pre-exposed to segments of a popular TV show that were either unaltered or temporally filtered (9th order low- or high-pass Butterworth filter, 0.8Hz cut-off). Following exposure to low-pass filtered episodes, the tilt aftereffect grew more slowly and reached a smaller peak magnitude compared to the unaltered and high-pass conditions. These differences are consistent with selective changes to the gain of adapting mechanisms operating at different timescales. Our results suggest a form of meta-plasticity in which adaptation is itself an adaptable property of the visual system.

[2P011] Attention and the Motion Aftereffect

**Laura Bartlett, Wendy Adams, Erich Graf**

Psychology, University of Southampton, UK

Attention has been shown to modulate the motion aftereffect (MAE) (e.g. Chaudhuri, 1990; Rees, Frith & Lavie, 1997; Taya, Adams, Graf & Lavie, 2009). If, during adaptation, attention is diverted to a centrally presented, demanding task, subsequent MAEs are reduced. However, recent studies have failed to replicate this effect, and have attributed previous findings to response bias (Morgan, 2011, 2012, 2013). To reconcile these inconsistencies, we adapted a paradigm designed to eliminate response bias (Morgan, 2013) while also exploring the time course of MAE accumulation. Random dot motion stimuli were presented above and below a central stream of letters. After each brief adaptation period, participants reported the relative speed of two test stimuli. Each trial consisted of 24 adaptation-test cycles, allowing estimation of the accumulating MAE. On attention-focussed trials, participants detected speed changes in the adaptation stimulus. On attention-diverted trials, they detected white vowels within the letter stream. The attention-focussed condition resulted in larger MAEs than the attention-diverted condition; the MAE saturated quickly in both conditions. Thus, in agreement with our previous work, the MAE is modulated by attention (Taya et. al, 2009; Bartlett, Adams & Graf, 2015) and this does not appear to be attributable to response bias.

[2P012] Effects of attention on form perception and form-motion integration from static and dynamic Glass patterns

**Andrea Pavan, Matthew Foxwell, George Mather**

School of Psychology, University of Lincoln

In the current study, we explored the effects of attentional modulation on form perception and form-motion integration using high-density static and dynamic Glass patterns (GPs). We used three different GP configurations (translational, circular and radial). Participants performed three conditions: (i) a no-adaptation condition in which they judge which side of a vertically divided test GP displayed the highest coherence, (ii) an adaptation non-distracted condition in which the test GP was preceded by an adaptation period of 30 or 10 seconds to a 100% coherent GP, and (iii) an attention-distracted condition in which participants performed a demanding RSVP task during the adaptation period. The rationale was that if attention play a role in extracting the global form from local oriented dipoles, then diverting attention away from the adapter coherence thresholds should be increased. The results show a statistically significant attention-related reduction of 3.3% for static GPs. On the other hand, this attentional modulation was not found for dynamic GPs. These results suggest that attentional resources are needed for the spatial summation of local orientation signals in high-density static GPs. However, the motion information in dynamic GPs may aid the extraction of global form, surpassing the need for attentional resources.

[2P013] Sharpening static spatial vision by adapting to flicker

**Derek Arnold<sup>1</sup>, Jeremy D. Williams<sup>1</sup>, Natasha E. Phipps<sup>1</sup>, Melvyn A. Goodale<sup>2</sup>**

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Visual adaptation is one of the most popular means of elucidating what types of computation underlie a given sensory experience. Recently we examined the acuity of human spatial vision, first by having people perform spatial alignment decisions in an unadapted baseline, and after adapting to flicker. We found that flicker adaptation improves the acuity

of spatial vision. We attributed this to the deleterious impact flicker adaptation has on the responsiveness of magnocellular mechanisms, which are important for encoding information about movement, but can have poor spatial resolution. We assessed this proposition by measuring contrast sensitivity functions at baseline, and after flicker adaptation. Flicker adaptation selectively reduced sensitivity to low spatial frequencies, biasing coding toward higher spatial frequencies. Finally we examined the spatial frequency tuning of face perception after flicker adaptation. This shifted the tuning of face perception to higher spatial frequencies. Overall, our data reveal that mechanisms with high temporal but poor spatial resolution usually contribute to form perception, but this influence can be transiently reduced by flicker adaptation.

[2P014] Proactive control mechanisms in visual search

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Visual search tasks help unravelling cognitive processes for selecting target stimuli among distractors. However, whether any proactive control mechanisms guide selection during parallel search remains unresolved. Here, we combined a covert visual search task with the Distraction Context Manipulation (DCM) paradigm, a method for studying proactive control mechanisms (Marini et al., 2013, *Journal of Experimental Psychology: General*). Accordingly, blocks were of three types: Pure blocks (100% distractor-absent trials) and two types of Mixed blocks (33% distractor-absent and 66% distractor-present trials each). The two types of Mixed blocks differed in that the Parallel Search Mixed block included single-feature distractors, while the Serial Search Mixed block included feature-conjunction distractors. In all block types, participants' task was to indicate if a target (horizontally bisected black/gray disk) was present or absent on each trial. In the DCM paradigm, the comparison of distractor-absent trials of Mixed versus Pure blocks helps detecting proactive control mechanisms. Increases of detection sensitivity and slowing-down of reaction time (RT) were observed when distractors were expected, yet not presented (distractor-absent trials of Mixed versus Pure blocks). Thus, expectation of distractors recruited a proactive process that improved detection sensitivity and entailed a RT cost both in parallel and serial search tasks.

[2P015] Negative emotional valence intensity modulates visual search performance

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Negative stimuli (e.g., angry face) are considered to be processed with higher priority. This priority is related to the rapid shifts of attention. However, the relationship between the processing superiority and negative emotional valence intensity has not been clarified. In my previous research, I examined the relationship between negative emotional valence intensity and visual target detection performance. In results, emotional valence intensity did not affect the detection performance. On the other hand, the effects on the attentional shift speed have not been investigated yet. Therefore, I researched the effects of emotional valence intensity on visual search performance. In the experiment, target was three types: neutral, high, or low negative emotional valence angry faces. The results indicated that the response time of high negative emotional valence angry faces were shorter than other two categories faces. Therefore, emotional valence intensity affects the attentional shift speed, not the target detection accuracy. These results suggested that the speed of target detection is related to the intensity of aroused emotional valence.

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[2P016] Modyfing detectibility map for formal models of visual search

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When searching for a target, human performance is limited by how detectability of the target varies across the visual field (e.g., Najemnik & Geisler, 2005). This spatial map of detectability ( $d'$ -map) can be measured in a three-step procedure: (1) measure psychometric function in the fovea to find how foveal detectability ( $d'$ ) varies with target contrast, (2) then measure how detectability falls off from the fovea in the four cardinal directions given a fixed contrast of the target, and (3) interpolate the results to the rest of the visual field. In current experiments, we are measuring the effects of artificial scotomas on human search performance. To model the effects of vision loss on search performance it is necessary to estimate affected observer's  $d'$ -map. Here, we describe a formal method for estimating the detectability map for targets in  $1/f$  noise, for an arbitrary modification of visual field (artificial scotoma).

By exploiting the linear relationship between target threshold power and background power, and by measuring  $d'$  map in a uniform background and in noise with fixed RMS contrast, we can determine the precise relationship between original and modified  $d'$ -map. These modified maps can be used in formal models of search, including ideal-searcher models.

[2P017] Temporal attention aids the selection of targets in a visual search task: An ERP study

**Bettina Rolke, Verena Carola Seibold**

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Temporal attention, i.e., the possibility to anticipate the occurrence of a stimulus at a given time, has been shown to improve visual perceptual processing. In this study, we investigated whether and how temporal attention interacts with spatial attention and feature-based selection of visual stimuli. To monitor the influence of the three different attentional mechanisms from early perceptual processing until the motor response, we measured event-related potentials (ERPs). Our participants performed a visual search task, in which a colored singleton was presented amongst a set of homogenous distractors. Participants were asked to respond only to target singletons of a particular color and only if they were presented at a to-be-attended spatial position. We manipulated temporal attention by means of an explicit temporal cue that either validly or invalidly announced the occurrence of the search display. Besides independent effects of attentional mechanisms, we obtained interactive effects between temporal attention, spatial attention, and feature-based selection on ERPs linked to perceptual processing. Taken together, the results show that temporal attention induced by explicit cues boosts the effects of spatial attention and aids feature-based target selection.

Funding: The study was supported by the German Research Foundation (DFG)

[2P018] Search Advantage by Color Repetition Priming and Distracter Preview

**Sophie Lukes, Malte Persike, Günter Meinhardt**

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Recently, Meinhardt & Persike (2015, JoV) reported that random changes of target and distracter features across trials disrupts the preview benefit (PB) in a classical color-letter conjunction search task (Watson & Humphreys, 1997), while repeating same target and distracter features (repetition priming, RP) maintains the PB. In single feature search the PB did not depend on trial-by-trial feature variation. This suggests that task load interferes with resource spending for spatial marking, while RP facilitates conjunction search by adding a redundant segmentation cue (color). In various experiments we varied task load (near efficient, inefficient, strongly inefficient) and measured the effects of distracter preview and repetition priming. Independent of task load, RP did not or only marginally improve search rates in single feature search, and did also not affect the PB. In conjunction search, however, baseline search rates were nearly halved by RP. RP improved the PB in easier tasks, but not or just marginally in difficult tasks. The results indicate that RP enables observers to use color as a segmentation cue in conjunction search. However, there are no or minor synergy effects of color and temporal asynchrony when task demands are high.

[2P019] Active Ignoring by Color Repetition Priming

**Günter Meinhardt, Sophie Lukes, Malte Persike**

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Recently, Meinhardt & Persike (2015, JoV) found that repetition priming (fixed target and distracter features) enhances the preview benefit (PB) in color/shape conjunction search, but not in near efficient single feature search. To resolve a potential confound with search efficiency we used a search task that demanded to mirror local elements, rendering feature and conjunction search highly inefficient (baseline search rates  $> 180$  ms/item). In the preview condition, half of the distracters were presented 2 seconds before the remainder items completed the search array. For randomly changing target and distracter features we found that conjunction search was less efficient, but had a larger PB than feature search. With repetition priming conjunction search was much more efficient than feature search. Slope ratios indicted that repetition priming enabled the observers to ignore nearly all items of the non-target color in conjunction search, even without preview. Distracter preview did only modestly improve search efficiency further. These findings show that observers are able to prioritize one item class over the other just by color grouping, and without using distracter position foreknowledge or temporal asynchrony of old and new items. Thus, active ignoring of distracters is enabled by color repetition priming.

[2P020] Human foraging in dynamic versus static displays.

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In a previous series of experiments using both hand and eye movements, we explored how human participants “foraged” through static displays containing multiple target categories (Kristjánsson, Jóhannesson & Thornton, 2014; Jóhannesson, Thornton, Smith, Chetverikov & Kristjánsson, 2016). We found that when demands on attention were increased, foraging patterns tended to shift from random category selection to exhaustive category selection. Such shifts appeared to be more pronounced when participants foraged with their fingers than with their eyes alone. In the current work we created displays containing identical target and distractor categories that could either be in motion or at rest. In separate blocks, participants selected target items using different modalities, specifically: a) mouse b) touchscreen c) eye tracker or d) infrared hand tracker. Selected targets were always cancelled via a common button press response. Across modality, random category selection was much less pronounced in moving than in static displays. This was true for both high and low attentional load conditions. Furthermore, initial results suggest that in this context the main impact of selection modality is to influence foraging speed rather than foraging strategy.

[2P021] Visual search asymmetry between photographs and illustrations of animals and man-made objects

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From a biological viewpoint, animate objects have a special and important meaning for humans. The present study examined how visual reality of animate objects modulate visual search efficiency by using the search asymmetry paradigm. Visual stimuli were photographs and illustrations of animals (e.g., dog or turtle). A search display consisted of 3, 6, or 12 stimuli. The participants were asked to answer whether a photograph (photograph-search task) or an illustration (illustration-search task) was present in the search display as quickly as possible (blocked design). In the target present trials, one of the stimuli was a photograph (an illustration) and the others were illustrations (photographs) in the photograph-search (illustration-search) task. In the target absent trials, all stimuli were illustrations (photographs) in the photograph-search (illustration-search) task. The results demonstrated that searching a photograph among illustrations was more efficient than searching an illustration among photographs. However, this search asymmetry was not observed when the stimuli were photographs and illustrations of man-made objects (e.g., car or clock). These results imply that the photographs of animals would be salient to human visual system and hence humans may have the specific mechanisms to detect and process a realistic animate objects.

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[2P022] Forcing strategy change: Time limited visual foraging reveals template switches

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During difficult foraging tasks, such as when targets differ from distractors by a conjunction of two features, humans do not switch between target categories, while they switch freely in easier feature-based foraging tasks. This is in line with research on animal behavior, but the question remains whether this reflects that humans cannot switch between target categories, without sacrifices in speed or accuracy, or simply choose not to, possibly due to added difficulty of switching between target categories. Our participants performed time-limited (5, 10, 15 s) or unlimited foraging on iPads where they tapped as many stimuli, from two target categories, as they could before the time ran out while avoiding items from two distractor categories. With time limits participants were able to switch more frequently between target types during conjunction foraging than they do when there is a longer time limit or no time limit. Furthermore, switch-costs were smaller with shorter time limits, even with constant set-size. This suggests that although people do not generally switch between target categories in conjunction foraging, they are able to do so when the task demands such switches. We discuss the implications of such rapid switching for recent theories of working memory and attention.

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[2P023] Collinear search impairment is luminance contrast invariant

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Collinear search impairment (CSI) is a phenomenon opposite to the well-documented attentional capture (AC). In CSI, a task-irrelevant collinear structure impairs target search in a visual display, while in AC, salient and task-irrelevant basic features (e.g. color, orientation) enhance target detection. The mechanism of CSI was suggested to be monocular and does not require consciousness, converging to the belief that it may be processed at early visual site, possibly in V1. All these observations, however, were made when the search elements were high contrast (i.e. supra-threshold). Here we examined CSI under various luminance contrast levels. Nine participants showed that, regardless of the luminance contrast levels of visual search display, targets displayed on the collinear structure (snake) were consistently slower than those displayed on the non-collinear (ladder) structure. The result differs from that in collinear flanker effect in which collinearity facilitates target detection at low contrasts and impairs it at high contrasts, suggesting different mechanisms underlying these two phenomena. Furthermore, contrast invariance implies that CSI, unlike suggested in previous reports, is not subserved by an early vision mechanism. Instead, certain higher-level of visual processing is involved. We conclude that reverse-hierarchy model is necessary to account for this counter-intuitive phenomenon.

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### [2P024] Individual Differences in Change Blindness

**Nora Andermane**

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The phenomenon of change blindness (CB) reveals that people are generally quite poor at detecting unexpected visual changes. However, it is not entirely clear whether there are stable individual differences in CB and whether these can be predicted by other cognitive and perceptual abilities. The present research administered a battery of ten perceptual and cognitive measures to identify the strongest predictors of CB. Strong, significant correlations emerged between attentional capture by irrelevant distractors, perceptual alternation rate when viewing ambiguous bistable stimuli, and CB performance. Greater perceptual instability and lower attentional capture was associated with superior ability to detect visual changes, suggesting a common underlying mechanism of updating visual predictions. Within the predictive coding framework, individual differences in perceptual alternation rate have been argued to reflect variability in reliance on bottom-up prediction error. Our findings demonstrate that in more ecologically valid settings greater reliance on prediction error may also be associated with an enhanced ability to notice novel visual changes.

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### [2P025] Relationship between the stereoscopic feeling and weave structure of carbon fiber woven fabric

**Tomoko Awazitani, Aki Kondo, Sachiko Sukigara**

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Woven fabric is made from the arrangement of interlaced yarns. This weave structure consists of repeated unit and generates the concave-convex surface. When the light incidents into the fabric, we sometimes feel the stereoscopic shape and aesthetic even the fabric is placed as flattened. Objective of this study is to find how the weave unit influences the impression of fabric stereoscopic and weave design pattern. Samples used were seven carbon fiber woven fabrics changing the arrangement of interlaced yarns. Carbon yarn showed a different light reflection between along and perpendicular direction of fiber axis. The distribution of light reflection from the fabric was measured by a gonio-spectrophotometer color measurement system. "Weave factor: WF" was used to characterize weave structure. Thirty students looked the flat fabrics, then made ranking from the strong order of "stereoscopic". Relationship between the subjective values of "stereoscopic" and WF showed the positive correlation. Fabric with larger WF have more concave-convex surface, thus the contrast of light and shade are seen clearly. It was also found that a larger repeated unit area of weave pattern contributed the stereoscopic impression, because of the larger area of shadow in the fabric surface.

### [2P026] What Defeats Binocular Stereo?

## **Kokichi Sugihara**

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Binocular stereo gives a strong cue for interpreting retinal images as 3D shapes, particularly when we see objects in short distances. However, there are some cases, such as reverspective and ambiguous cylinders, in which binocular stereo does not work well to extract 3D shapes of objects even though the objects are viewed in short distances. What makes binocular stereo useless in those illusions? One of answers might be that in those illusory objects the lines that look parallel are really parallel or aligned in a radial manner in the 3D space. We observe this characteristic in many examples. In Patrick Hughes reverspective, lines are drawn in partly planar surfaces and hence they are actually aligned in a radial manner. In anomalous solids that realize pictures of impossible objects, illusion becomes stable if the edges that look parallel are actually parallel. In crater illusion generated by 3D surfaces illuminated from below, mutually parallel edges remain parallel because the surface is not physically deformed. This characteristic suggests that the human binocular stereo is more sensitive to nonparallel lines than metric inconsistency obtained by triangulation. We discuss this point using small and large 3D models of impossible objects.

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[2P027] Stereoscopic viewing induces changes in the accommodation-vergence cross-coupling

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The adaptability of the vergence accommodation, quantified using the convergence-accommodation to convergence (CA/C) ratio, is still a subject of debate. The present study sought to investigate its adaptability using a stereoscopic viewing exposure. Stereoscopic displays challenge the neural cross-coupling between accommodation and vergence by inducing a constant accommodative demand and a varying vergence demand. Stereoscopic viewing calls for a decrease in the cross-coupling through the CA/C ratio, helping the accommodative system to remain in focus by reducing vergence accommodation. Cross-coupling (CA/C and AC/A) and tonic components of vergence and accommodation were assessed in twelve participants before and after a 20-min exposure to stereoscopic viewing. During stimulation, vergence demand oscillated from 1 to 3 MA along a virtual sagittal line in sinusoidal movements, while accommodative demand was fixed at 1.5 D. Results showed a decreased CA/C ratio (-10.36%, DF=10, t=2.835 and p-value=0.018), with no change in the AC/A and tonic components. These findings demonstrate that the CA/C can exhibit adaptive adjustments and have important implications in stereoscopic environments, where the accommodation vergence conflict is a source of discomfort and fatigue. However, the small decline in CA/C associated with no change in the tonic components, suggests that the adaptive process is partial.

[2P028] Apparent depth in glass, bronze, and nickel mirrors: Color effects

**Atsuki Higashiyama, Seiichi Tsuinashi**

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The world seen in mirror is not an exact copy of directly observed world. In particular, distances to targets in glass mirror are judged to be smaller than they are (Higashiyama, Yokoyama, and Shimono, 2001; Higashiyama and Shimono, 2004). In this study, we investigated how the apparent distance to targets and the apparent depth between targets vary by mirror material. The properties of light reflected by mirror depend on mirror material: Bronze and nickel mirrors make the reflected scene darker and more reddish than glass mirror. In Experiment 1, 20 observers judged apparent distance and depth for targets reflected by glass, bronze, and nickel mirrors under normal light. The metal mirrors made apparent distance and depth larger than the glass mirror. To investigate the effects of luminance and color on apparent depth separately, in Experiment 2, white targets were illuminated with white, red, and blue light in darkness and 15 observers viewed them through ND filters of 50 and 12.5 % in transmission. When seen with the 50-% transmission filter, targets illuminated with red light was judged to be larger in depth than that illuminated with blue light. We suggest that red illumination enlarges apparent depth.

[2P029] Reaction times to changes in binocular correlation are consistent with the fusional hysteresis effect

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Stereoscopic fusion of random dot stereograms is resistant to changes in disparity that are greater than disparities that can be fused otherwise, a phenomenon called fusional hysteresis. Here we studied if a similar effect can be observed for transitions between binocularly correlated and disordered states when binocular disparities are not present. To this end, simple reaction times (RTs) were measured to checkerboard patterned dynamic random dot correlogram (DRDC) targets (i.e., correlated (C), anti-correlated (A) and uncorrelated (U)) that appeared from homogenous C, A or U background. Altogether, the following background-target combinations were studied: AC, CA, UC, CU, AU and UA. Firstly, RTs for A-targets were shorter than for U-targets, even though both were non-correlated stimuli. Thus, A- and U-states are processed differently. Interestingly however, AU or UA changes could not be seen by any subject. Secondly, subjects gave faster responses to C-targets from a non-correlated (A, U) background than to the opposite direction of changes (CU, CA). This result is consistent with the fusional hysteresis effect. Our data suggest that binocular correlation is the most persistent and anti-correlation is the least persistent neuronal state in the visual cortex. Funding: Supported by grants OTKA K108747 and the Hungarian Brain Research Program KTIA\_13\_NAP-A-I/11.

[2P030] Effect of the field of view on accommodation stimulated with a volumetric badal optometer

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A volumetric 3D virtual reality system can, theoretically, represent appropriate focus cues (i.e., accommodation and retinal blur). In practice, it depends on the number of focal planes displayed by the system, which are limited by current technology components. It is also important to consider the trade-off between the field of view and the optical image quality of these systems. Both concepts have an important impact on accommodation, which in turn can have an impact on depth perception. The purpose of this study was to investigate the effects of different FOV on accommodation stimulated with a volumetric Badal optometer and to compare these results with the natural viewing condition. Accommodation was objectively measured with the PowerRef II at 0.17, 2.00 and 5.00 D of accommodation stimulation (AS) on 30 young healthy patients. For both Badal targets and real free space targets (natural-viewing condition), at each AS, the FOV was discretely changed from 10° to 25° (5°-step). The volumetric system comprised the fixation plane and two fix planes at 0.17 D and 5.00D. The results showed that agreement between both stimulation methods decreased for smaller FOV. However, differences were not clinically relevant.

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[2P031] A geodesic on a piecewise smooth surface and a piecewise smooth curve as a geodesic on a surface

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Recovering 3D information from a 2D line-drawing is an ill-posed problem. The visual system uses a priori constraints to make this problem well-posed. It has been suggested that a curve on the surface of a 3D object is perceived as a geodesic and this geodesic induces the 3D perception of the surface. Geodesics on a surface are defined as curves that are locally the shortest. Any pair of neighboring points on the surface is connected by a geodesic with the shortest length. The role of geodesics in visual perception has been studied with surfaces that are twice-differentiable everywhere, but contours in a line-drawing often represent sharp non-differentiable parts of a surface (e.g. angular edges and pointed apices). In this study, we generalize the concept of geodesics to surfaces and curves that are only piecewise smooth. We discuss the validity of using geodesics as a constraint for recovering a 3D shape from a 2D image on the basis of this generalized concept.

[2P032] Convergent Stereo-Cameras affect Distance and Depth Perception

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The design of stereograms requires a correct configuration of the left and right cameras. Two options are available: convergent or parallel cameras. The literature has so far identified that convergent cameras can distort the layout of the

visual scene. They introduce vertical parallax and modify the horizontal disparity in the scene. Though vertical disparity has a well-known effect on depth perception, there is no evidence that the combination of these distortions can affect perceived depth or distance. To study the effect of convergent cameras, we asked observers to judge the distance or the depth of a cylinder displayed in front of a large fronto-parallel surface (60 degrees). Stimuli were texture-mapped with random-dots and displayed using OpenGL to compare convergent and parallel cameras. A series of experiments showed that the convergent method tends to compress visual space because the cylinder distance was underestimated as compared to the one in the parallel configuration. The removal of vertical parallax lessened the effect on perceived distance, suggesting that the vertical distortion introduced by convergent cameras was mainly responsible for the effect. Overall, these results indicate that convergent cameras can affect perceived distance and depth in stereograms and support the use of parallel stereo-cameras.

[2P033] Eye movements during perception of 3D scenes using hologram and stereo image stimuli

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Recent advances in three-dimensional (3D) digital holographic displays attempt to combine multiple display devices to improve the field of view, stereo parallax, and motion parallax. There is interest in understanding what requirements the visual system, eye movement behaviour, and the visual perception process place on such future displays. However, 3D digital holographic displays of sufficient quality are not yet available. We propose that the visual properties of traditional glass plate holograms can act as an ideal digital holographic display. By studying binocular eye movements during viewing of real-world scenes captured in glass plate holograms, we can determine which technical compromises have the least impact on 3D perception with future digital holographic displays. We studied how five participants move their eyes when viewing particular features at different depths in holograms, and how the eye movement patterns differ from viewing conventional stereo image stimuli. We found that the convergence variation between eyes, and participants' perception of depth, was greater when viewing a 3D scene using hologram stimuli compared with equivalent stereo or 2D stimuli. We conclude that for holographic displays, one should not neglect the inherent properties of multiple accommodation, monocular parallax, and monocular cues such as blur, perspective, and occlusion.

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[2P034] Comparing stereotests: the TNO test overestimates stereoacuity

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Tests of stereoacuity may use either contour or cyclopean stereograms like random dot stereograms (RDS). In contour stereograms, disparity is defined by monocularly visible contours. In RDS, objects are defined by disparity only. Second, tests can either use polarising or anaglyph glasses. The aim of the current study is to compare stereoacuity thresholds measured with these tests. In total, 117 children aged 4 to 16 completed at least two of the following 4 stereotests: two paper-based clinical tests using different 3D technology (Randot Circles: contours, polarising glasses; and TNO: RDS, anaglyph glasses) and computer-based versions of these presented on a polarising 3D monitor. Average stereothreshold estimates were 37arcsec in the Randot Circles, 35arcsec in the computer-based contour test, 89arcsec in the TNO, and 32arcsec in the computer-based RDS. No significant differences in mean stereothreshold were found between the Randot Circles and the computer-based contour test ( $p=.17$ ) or between the computer-based contour test and the computer-based RDS ( $p=.77$ ). However, significant differences were found between TNO and Randot Circles ( $p<0.001$ ) and between TNO and the computer-based RDS ( $p=.03$ ). Bland-Altman plots pointed in similar directions. We conclude that TNO overestimates stereothresholds, possibly due to its use of anaglyph (red/green) glasses.

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[2P035] Eye Fixation during static multi-object attention in 3D: Evidence for perspective scaling of attention?

## **Dhanraj Vishwanath, Giedre Zlatkute**

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Objects or regions selected by attention are the spatial input for natural eye-movement guidance. Recently we reported that fixation is directed to the centroid of discrete spatial foci at target locations during multi-focal attention. Together with findings on saccadic localization, this suggests that the eye is directed to a location providing globally optimal attentional resolution of task-relevant regions of space. Previously we found that saccades directed at single 3D objects are shifted away from the centroid of the 2D retinal projection toward the projected location of the 3D centroid. A natural bias in eye position to the 3D centroid, for saccades and fixation, would imply that attentional resolution is not distributed simply on the basis of the retinal image, but is modulated by perceived 3D scene structure. Observers attended to multiple targets organized in either a 2D or 3D configuration to detect a brief visual transient. We found evidence for a shift in fixation toward the projected 3D centroid, i.e., closer to the farther (and protectively smaller) elements. Similar shifts were not observed for 2D stimuli that matched the projective 3D size variation. These results may be indicative of a denser (higher) attentional resolution for regions more distant in depth.

[2P036] Interaction among binocular disparity, motion parallax, and relative size cues for perceiving large depth

### **Yuta Ozawa, Tamada Yasuaki, Sato Masayuki**

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To examine the interaction among binocular disparity, motion parallax, and relative size cues for perceiving large depth, we quantified the apparent depth from these cues using a matching method. Eighty Gaussian blobs were presented on a 65-inch display and distributed randomly in a virtual three-dimensional space in front of or beyond the display. The viewing distance was 80 cm and simulated depth ranged from -40 cm to 25 m from the display (corresponding binocular disparities were -4.7 deg and +4.5 deg). When only one of these cues was given, apparent depth was very tiny. When the depth was specified by both binocular disparity and motion parallax, perceived depth was so small again. However, adding relative size cue to binocular disparity and/or motion parallax expanded apparent depth much. These results suggest that the interaction between relative size cue and binocular disparity or motion parallax plays a major role for perceiving large depth

[2P037] Vergence dynamics in stereoscopic displays are related to fusional reserves

### **Anne-Emmanuelle Priot, Cyril Vienne, Bertrand Saussard, Justin Plantier, Pascaline Neveu**

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Vergence movements are driven by two conflicting stimuli in stereoscopic displays: varying binocular disparity related to the simulated object distance and constant focal cues determined by display distance. This conflict may alter vergence response dynamics (Vienne et al. 2014). We studied how stereoscopic viewing affects the dynamic characteristics of horizontal symmetric vergence, with regards to individual measures of fusional reserves which are performed in focal/vergence conflicts conditions. Vergence movements in response to step disparity-changes were recorded in twelve participants using a binocular eyetracker. Crossed and uncrossed disparities (absolute amplitude ranging from 0.75° to 1.5°) were presented on a stereoscope (image plane at 0.4 m). Latency, time-to-peak velocity, time constant, response duration, amplitude/gain and main sequence were analyzed. Overall, we found significant correlations between individual fusional reserves and dynamic parameters, towards faster dynamics for larger reserves. Shibata et al. (2011) have shown a relation between fusional reserves (or similar) and subjective visual discomfort in stereoscopic displays. We here further showed a relation between fusional reserves and dynamic parameters of vergence response.

[2P038] Representation of visual distance in the brain

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Receptive fields in early visual regions are generally tied to retinal locations. Therefore, a read-out of the firing rates of cells in early visual areas provides an explicit representation of the retinal locations of visual stimuli. However, information about the visual distance (visual angle) between two stimuli is only present implicitly in such a read-out.

Nonetheless, we readily perceive the visual distances between stimuli, and furthermore a large body of literature indicates that the visual control of action is achieved by control heuristics that are applied directly to visual angles. We hypothesize that the explicit representation of a small number of currently attended or task-relevant visual angles occurs in a brain area corresponding to sub-region 5 of the human Superior Parietal Lobule (SPL5). A number of previous brain imaging studies have associated this region with an implausibly diverse range of highly specific functions, suggesting that it actually performs a more basic and ubiquitous function such as visual distance representation. However, it has also been proposed that SPL5 supports shifting or division of the focus of spatial attention. Here we present fMRI data that falsifies the attention-shifting/division account of SPL5, but which is consistent with the visual distance account.

[2P039] The motion/pursuit law's limit on depth from motion parallax

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The visual perception of depth from motion parallax relies on the integration of retinal image motion and extra-retinal pursuit eye movement signals. For the dynamic geometry of motion parallax in a rigid environment, the motion/pursuit law indicates that the retinal image velocity of objects beyond fixation never exceeds the pursuit eye movement velocity. That is, a motion/pursuit ratio (M/PR) greater than 1 represents an unrealistic parameter combination, but is often produced in computer-generated motion parallax displays. To study perceived depth in such conditions, observers were asked to report perceived depth-sign of random-dot motion parallax stimuli depicting dihedral angles with the vertex pointed towards or away. The peak M/PR of each stimulus varied between 6 and -6. Observers correctly reported the depth sign of all stimuli nearer than the fixation point with negative M/PRs. However, observers reported the correct depth-sign of stimuli farther than the fixation point only when the M/PR was less than 1. Observers reported seeing the opposite (wrong) stimulus depth for M/PRs greater than 1. The visual system has difficulty representing rigid objects with unrealistic stimulus parameters, and appears to reverse the depth sign in an attempt to represent the motion parallax stimulus.

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[2P040] Binocular summation in Pinna illusion

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In Pinna illusion, an observer perceives an illusory rotational motion on a ring of rhombuses in the absence of real physical motion in the stimuli. We investigated whether there is an effect of binocular summation in Pinna illusion. Three conditions were tested: (a) Binocular viewing: the same traditional Pinna-Brelstaff figures with 16 rhombuses in a ring were presented to both eyes; (b) dichoptic viewing: two interleaving Pinna-Brelstaff figures, each contained half number of the rhombuses, were each presented to one eye; or (c) reduced pattern: the same Pinna-Brelstaff figure with only 8 rhombuses in the ring were presented to both eyes. The diameter of the stimuli was alternatively increased and decreased at the speed 11.97deg/s to elicit the Pinna illusion. The strength of illusion was measured by adjusting the velocity of a physical rotation in the opposite direction from the illusory motion to eliminate the effect. The perceived strength of the illusory motion was about 0.018 rps for both binocular and dichoptic conditions, which were significantly greater than that in the reduced condition (0.016 rps). With same number of elements for each eye, the stronger illusion in the dichoptic than the reduced condition suggests a binocular summation of illusory motion.

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[2P041] Separate recalibration of perception of distance and object size in virtual environment

**Shigeaki Nishina**

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Distances are commonly underestimated in immersive virtual information on the environment. In this study, the perception of distances and perception of object sizes are investigated in the same virtual space using a head-mounted display with head-motion tracking. The virtual scene was a non-textured rectangular room. Perceived distances to presented markers were measured by a blind throwing method. A pole-like object, horizontally floating in space, was

then presented, and its perceptual size was measured by the participant's comparing it with the physical pole in their hands. Although throwing is thought to be a weak interaction with the environment, the perceived distances gradually became closer to the correct distances. The perceived object sizes also became closer to the correct lengths, but the rates of the recalibration were substantially different. Results indicate perception of distances and perception of object sizes are not very tightly connected in virtual reality although they share the same 3-dimensional environment. Funding information

[2P042] Gaze strategies in peripheral motion detection: On the superiority of fixations over smooth pursuit eye movements (SPEM)

**André Klostermann, Christian Vater, Ernst-Joachim Hossner**

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Peripheral-motion-change-detection performance was examined by contrasting a fixation with a SPEM condition. To that end, participants were confronted with a visual display consisting of 15 white squares and 1 red square circulating with 6°/s (tracking condition) and stopping in-between (fixation condition). The instruction was to visually follow the red square and to press a button as soon as a white square begins to move. The to-be-detected white square movements varied in eccentricity and speed. A Vicon-integrated eye-tracking system was used for controlling gaze behaviour. Response times (ms) and missed detections (%) were measured as dependent variables. Results in Experiment 1 show faster motion-change detection in fixation vs. tracking condition (401 ms vs. 809 ms) and increased response times as a function of eccentricity in the tracking condition only (4°: 570 ms; 8°: 737 ms; 16°: 1121 ms). Moreover, missed detections were revealed at 16° eccentricity in the tracking condition only. Experiment 2 controlled for foveal load as possible confounder by replacing the red square with a virtual centre evoked by 4 red squares. The same results were obtained as in Experiment 1. In sum, it could be shown that SPEM impair the ability to detect peripheral motion changes.

[2P043] Novelty modulates oculomotor learning

**Annegret Meermeier, Svenja Gremmler, Markus Lappe**

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Saccadic adaptation aims at keeping saccades accurate to enable precise foveation of objects. It is believed to be a rather low level adjustment, responding chiefly to direction and magnitude of post-saccadic position error. However, recent studies have shown that image content can modify saccade kinematics and adaptation. Targets that carry positive intrinsic value are for example socially relevant stimuli like images of humans. Saccadic adaptation towards human figures in comparison to noise is more complete when time constraint exist. In the present experiment, we show that saccadic adaptation is also susceptible to the novelty of a stimulus. In a scanning adaptation paradigm, 20 subjects underwent two sessions of forward adaptation to one position at which always the same human picture was displayed versus a position at which a new human figure was presented in every trial. Saccadic adaptation was more complete to the novel target position. Furthermore exponential fitting revealed a significantly increased starting point of adaptation curves, maybe indicating a specific reaction of the system to the higher informational value of the novel stimuli, increased salience or higher associated reward.

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[2P044] Modeling the effect of dynamic contingencies on anticipatory eye movements

**Jean-Bernard Damasse, Anna Montagnini, Laurent U Perrinet**

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In a simple visual tracking task, we manipulated across blocks the probability for the target to move in one direction (Right) or another (Left). Three probability conditions were implemented (50%, 75% and 90% of rightward trials) and the pseudo-random sequence of trials was the same for all subjects (N=18). The probability bias for target direction resulted in a robust anticipatory smooth pursuit (aSP) toward the expected direction and we found a linear effect of probability on aSP velocity across the three probability conditions. As Maus and collaborators (2015) recently proposed a model of aSP-velocity as a function of the mean target speed across the recent trial-history, we implemented an agent that generates aSP in function of the binned target direction of recent trials. We challenged this model by comparing its predictions to the observed aSP changes associated to specific trial-sequences (tested across

many subjects). Moreover, in a Bayesian model framework, we analyzed long-term versus short-term effect of trial history on prior actualization (as probed by aSP). As a further development of our agent sensitive to dynamic contingencies of the environment, we aim to extend our model to mimic the observed sensitivity of aSP to reward contingencies (Damasse et al. 2015).

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[2P045] Voluntary tracking the moving clouds : Effects of speed variability on human smooth pursuit

**Kiana Mansour Pour, Laurent Perrinet, Guillaume Masson, Anna Montagnini**

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We have previously investigated the human ocular following responses to a novel class of broadband random-texture stimuli, the Motion Clouds which have naturalistic spatiotemporal frequency spectrum (Sanz-Leon et al. 2011). Motion clouds allow manipulating the proportion of signal and noise and the detailed input distributions along a spatiotemporal continuum. In particular, we showed that reflexive tracking precision increases with the spatial and temporal frequency bandwidth for a given mean speed (Simoncini et al. 2012). Here, we extended this approach to voluntary tracking in order to investigate the effects of speed bandwidth (i.e. the variability of local speed around the mean value) on the different phases of smooth pursuit eye movements with Motion Clouds. Subjects were asked to track a large (either full-field or 5°-diameter patch) moving cloud stimulus, presented with three mean speed (5, 10 and 20°/s) and different speed bandwidths. We show that lower speed variability resulted in stronger initial eye acceleration. Pursuit gain during the steady-state phase was also dependent upon image speed variability. This study probes how global motion speed is estimated by the visual system and how the precision of voluntary pursuit eye movements depends upon the variability of the motion input.

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[2P046] Spatial frequency selectivity of microsaccadic suppression

**Chris Scholes, Neil W Roach, Paul V McGraw**

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During a voluntary saccade the visual scene is swept across the retina at high velocity, yet we remain unaware of this motion. This is thought to reflect a reduction in contrast sensitivity around the time of the eye movement, due to changes in the spatiotemporal profile of visual input and/or an active extra-retinal suppressive mechanism. Here we asked how contrast sensitivity is affected by microsaccades, small involuntary eye movements that occur when subjects attempt to fixate. Subjects performed a contrast detection task (single interval, orthogonal orientation discrimination judgement) while their eye position was simultaneously recorded with an Eyelink-1000 infrared eye-tracker. Trials were sorted according to the timing of the nearest microsaccade, detected using a velocity-based algorithm.

Psychometric functions, constructed using trials in close temporal proximity to a microsaccade, revealed a small but significant increase in detection thresholds. In contrast to previous findings with large volitional saccades, this effect was consistent across a wide range of spatial frequencies (0.33 to 5 c/deg). Our results suggest that suppression of contrast sensitivity is a ubiquitous feature of ballistic eye movements, irrespective of magnitude or volition. However, there may be important differences in the spatial frequency selectivity of microsaccadic and saccadic suppression.

[2P047] Information uptake around the time of saccades

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Visual perception can be described as an alternation between fixations and saccadic eye movements and it is assumed that no or only little information is gathered during saccades. Here, we investigated the time course of information uptake around the time of saccades. Participants foveated a peripherally appearing Gabor patch. Its orientation was either horizontal with only one deviation for 25 ms per trial (probe experiment, deviations of 8 or 12°) or it was corrupted by normally distributed orientation noise every 25 ms throughout the trial (reverse correlation experiment, SD = 6°). In both experiments, participants indicated whether the orientation deviated clockwise or counterclockwise from horizontal. Reverse correlation results show that information gathering can be maintained until saccade onset, decreases to zero during the saccade and is restored directly after saccade offset. As shown by simulations, this information gathering is not different from a binary process that switches between “on” during fixation and “off”

during saccades. Probe experiment results show that sensitivity to orientation changes decreases before saccade onset and increases for 75 ms after saccade offset independently of deviation magnitude. Altogether, this dissociation between information uptake and sensitivity might point to a modulation in the weighting of information around saccades.

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[2P048] Visual attention saccadic models: taking into account global scene context and temporal aspects of gaze behaviour

**Antoine Coutrot, Olivier Le Meur**

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Over the last 20 years, nearly 100 different saliency models have been proposed across a broad range of scientific communities. However, they remain quite limited when applied to natural scene exploration. Indeed, the vast majority of these models ignore two critical components of visual perception: (1) the global context of the visual scene, and (2) the sequential and time-varying aspects of overt attention. Here, we demonstrate that saccadic models allow overcoming these limitations. Saccadic models aim to predict the visual scanpath itself, i.e. the series of fixations and saccades an observer would perform to sample the visual environment. We trained our saccadic model with eye-tracking data from 6 datasets featuring different categories of visual content (static natural scenes, static webpages, dynamic landscapes and conversational videos). We show that, for a given visual category, our saccadic model tuned with the corresponding eye-tracking data outperforms well-established saliency models blind to visual scene semantic category. Moreover, our model provides scanpaths in close agreement with human behavior. This approach opens new avenues to tailor visual attention models for specific classes of visual stimuli or observer profiles.

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[2P049] Fluctuations in both accommodation and fixational eye movements: effect of distance and peripheral cues

**Josselin Gautier**

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Accommodative fluctuations and microsaccades are driven by multiple endogenous and exogenous factors (stimuli, task, cognitive load). We question their temporal covariation in regards to the distance to the stimuli and the presence of peripheral cues. Fixational eye movements and accommodative fluctuations were recorded simultaneously on respectively the left and right eye of participants. A PowerRef-II recording at 25 Hz was synchronized to an Eyelink-1000-Plus sampling at 1000Hz. The stimuli were displayed monocularly on the right eye whose accommodation response was measured. Six subjects were asked to fixate during 10 sec a Maltese cross at 0D and 5D, in 4 scenarios involving this stimulus presented within a real world scene, on a printed image of this scene with or without blur and on the same cross but with a white background. Each scenario leads to very distinctive fluctuations of accommodation, consistently for all subjects. The real viewed scene brings the lowest fluctuations of accommodations and in turn to the lowest microsaccade amplitudes, rates and eye stabilities (BCEA). The sharp picture, then its blurred version and finally the stimulus without peripheral cues each increase by successive steps the fluctuations in accommodation and interestingly all characteristics of fixational eye stability.

[2P050] Transsaccadic feature prediction is location specific

**Arvid Herwig, Katharina Weiß, Werner X. Schneider**

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With each saccade, internal object representations change their retinal position and spatial resolution. Recently, we suggested that the visual system deals with these saccade induced changes by predicting visual features across saccades (Herwig & Schneider, 2014, JEP:G). Such predictions are assumed to be based on transsaccadic associations of peripheral and foveal input. In the present study, we tested whether feature prediction is bound to the saccade target location and/or the previous learning location. In an acquisition phase one out of two objects systematically changed its spatial frequency during saccades. In the following test phase, participants had to judge the frequency of briefly presented peripheral target objects (PTO). Saccades were either directed at a PTO or at another neutral object presented at the same eccentricity. Moreover, PTOs could be presented either at the previous learning location or at obliquely

displaced locations. Spatial frequency was perceived as lower (higher) if objects previously changed from high (low) in the periphery to low (high) in the fovea indicating transsaccadic feature prediction. Importantly, this pattern was seen only at the previous learning location suggesting that feature prediction is bound to the previous learning location but not to the saccade target location.

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[2P051] The blindspot is remapped before eye movements

**Daniel T Smith, Mark Avery**

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Eye-movements produce snapshots of visual information that need to be integrated across saccades to produce the illusion of perceptual stability. This integration is hypothesised to involve the pre-saccadic generation of a forward model of the expected state of the world which is then compared with post-saccadic sensory and proprioceptive feedback. This feedback allows the observer to discriminate between the changes in retinal input that arise from the movement of the eye and those that arise from changes to objects in the environment. Here, we examine the extent to which forward models account for the location of the blindspot. Participants viewed stimuli monocularly and made vertical eye-movements. Between the onset of saccade target (ST) and saccade execution a discrimination target (DT) was briefly presented at one of 4 locations; within the blindspot, contralateral to the blindspot, in post-saccadic location of the blindspot and contralateral to the post-saccadic location of the blindspot. There was a significant perceptual impairment at the post-saccadic location of the blindspot relative to the contralateral post-saccadic location of the blindspot and the post-saccadic location of the blindspot in a no-saccade control condition. These data suggest that the blindspot is represented in forward models of eye-movements.

[2P052] Stimulus characteristics and presentation time do not influence saccadic inhibition of foveal and peripheral presented distractors in visual fixations

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Saccadic inhibition describes the fixation prolongation due to the sudden onset of irrelevant stimuli, caused by reduced saccadic activity after the visual change. It was proposed that saccadic inhibition reflects processing time of the presented distractor stimuli. Recently, we used saccadic inhibition to analyze the sequence and interaction of information processes within fixations (Schulz & Pannasch, 2015, presented at ECVP). Our results suggested that foveally and peripherally presented distractor information is processed in parallel but independent of each other. In the current experiment, we examined the relationship between fixation durations and saccadic inhibition. Therefore, foveal and peripheral distractors appeared on non-manipulated and blurred stimuli (the latter being known for longer fixation durations) and the distractors were shown either early or late in the trial (the latter being known for longer fixation durations). We found larger fixation prolongation, stronger magnitude and higher inhibition duration for foveally compared to peripherally presented distractors. Additionally, we replicated longer fixation durations for blurred stimuli and late in time. However, saccadic inhibition did not differ with respect to stimulus characteristics and presentation time. We discuss how these results challenge the proposition that saccadic inhibition reflects processing time of the presented distractor stimuli.

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[2P053] Disentangling fixation duration and saccadic planning using gaze dependent guided viewing

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Free-viewing implies a continuous decision process whether to further exploit and process information at the current fixation location or to initiate a saccade and further explore the scene. Here, we isolate these two opposing driving forces and identify a set of relevant factors. In this guided viewing task subjects fixate single 3° apertures of an image (“bubble”). After a varying duration (forced fixation time) the fixated bubble disappeared and one to five new bubbles emerged at different locations. Subjects selected one of these by a saccade. By repeating this procedure, the whole image was explored. We modeled the resulting saccadic reaction times (SRT) from bubble offset to saccade onset

using a Linear-Mixed-Model. The saccadic reaction time decreased exponentially as a function of forced fixation time and increased with the number of targets: short fixation durations elicit longer SRTs. Additionally, factors are spatial bias, stimulus salience and absolute saccade angle. The exponential decay of the SRT suggests, that sampling and processing of the current stimulus is exhausted for long fixation durations, biasing for faster exploration. We further discuss the monotonic increase with number of bubbles and compare the other factors to the free-viewing literature. Funding: SPP 1665, H2020 socSMCs #641321

#### [2P054] Trans-saccadic integration and visual masking

**Alexander C Schütz**

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Peripheral information is used to choose objects of interest, which are then foveated to benefit from high-acuity foveal information. Recently, it has been shown that peripheral and foveal feature information is integrated optimally across saccadic eye movements (Ganmor et al., 2015; Wolf & Schütz, 2015). Here we used a masking-paradigm to study the representation of peripheral and foveal information. We presented noisy Gabor stimuli with varying orientations in the periphery. Observers were asked to saccade to the Gabor and to report its orientation. In one third of trials each, foveal contrast was reduced to zero to measure peripheral discrimination; foveal orientation was identical to peripheral orientation; foveal orientation was rotated by 10 deg relative to peripheral orientation. In addition, in one half of trials the foveal stimulus was followed by a noise mask without orientation information. Response precision was best with foveal stimuli. When there was an offset between peripheral and foveal orientation, average responses were strongly biased towards the foveal orientation. A mask after the foveal stimulus reduced response precision, but did not affect the bias towards foveal orientation. This dissociation between response precision and bias suggests that the mask deteriorated the integrated representation of peripheral and foveal information.

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#### [2P055] Smooth-Pursuit Eye – Gaze interface tracking: “Open – loop” versus “Closed – loop” Tracking Accuracy.

**Michael Wagner, Tomer Elbaum, Assaf Botzer**

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Introduction: In “Gaze Interface”, users’ eyes serve as an input device for computer interaction. For instance, pursuing a moving aircraft to initiate communication with it in an air traffic control task. Cursors in such tasks may provide corrective eye-movement feedback, when trying to stay-on a moving target (i.e., closed-loop-tracking). However, people may conceivably look at the cursor instead of at the moving-away target and this may reduce tracking accuracy. No such problem exists without cursor, yet here, corrective feedback is absent (i.e., open-loop-tracking). We compared “closed-loop” and “open-loop” tracking for tracking accuracy. Materials and Methods: 27 participants. Within-subject-design tracking task (48-trials, 45sec. each). Target size: 2.5°. Eye-Tracker: Eyelink 1000. (Sampling rate 250Hz). Variables: Target maneuvering profile: straight /curved lines (2). Velocity (1.7°/sec. 3.1°/sec. 4.5°/sec.) (3). Cursor: with /without (2). Input eye: dominant/ non-dominant eye (2). Experimental half: (2). Results: Target-to-cursor center distance served as tracking accuracy measure. We used Linear Mixed Model for statistical analysis. We found that cursor reduced accuracy by approximately 25%. This reduction was statistically significant. Conclusions: Cursors may draw users' attention away from the target. This possible effect should be further investigated to support decisions whether or not to use cursors in smooth-pursuit gaze interfaces.

#### [2P056] Interaction between pursuit and saccades for speed judgements

**Alexander Goettker, Karl Gegenfurtner**

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In the real world we typically make an initial saccade to moving objects before pursuing them, and the two types of eye movements work together to keep track of the target. We investigated if the execution of saccades during pursuit initiation has an influence on speed judgements. We used a step-ramp paradigm with varying step-sizes, leading to backwards saccades, forward saccades, or pure smooth pursuit trials. At the end of each trial, the observers had to indicate the speed of the stimulus, by comparing it to a memorized standard speed (11 deg/s). We fitted psychometric functions for the three different types of trials separately. The PSE of the psychometric function is an estimate of the

perceived speed of the comparison stimuli and its slope indicates speed discrimination threshold. We found that perceived speed was significantly lower by about 10% in trials with a backward saccade than in trials with catch-up saccades. Smooth trials led to an intermediate perceived speed. Overall, it seems that moving stimuli are perceived as slower when the eyes have to “wait”, and faster when the eyes lag it. Stimulus speed seems at least partly be determined relative to position and the speed of the eye.

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[2P057] Static cues for mirror-glass discrimination explored by gaze distribution

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Although kinetic cues contribute to the perceptual discrimination between mirror and glass materials (Tamura et al., VSS2016), it is still possible to distinguish them with relatively high accuracy even when an object remains stationary under natural illumination. To investigate what kind of static cues are used for mirror-glass discrimination, we measured eye movements of observers (N=7) during the task using a high-speed eye tracking system. 3D objects rendered by computer graphics under the natural light field (Debevec, 1998) were used in the experiment. Stimuli were presented on a computer screen for 3000ms while the 3D object was just motionless or was rotating around the horizontal axis. Observers were asked to judge the object material (mirror or glass) in a 2AFC paradigm. From obtained gaze data, we found that observers were looking at the upper region above the centroids of the objects in both. We compared the luminance distribution between mirror and glass materials and found that there exists a notable difference at the upper region of the objects: brighter at upper region for mirror; brighter at lower region for glass. This suggests that observers may try to characterize the material of the object using the spatial luminance distribution.

[2P058] Perceptual localization versus oculomotor behaviour

**Eva R Joosten, Thérèse Collins**

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Every saccade changes the retinal location of visual objects, but we perceive the world as stable. In this experiment, we used classification images (CI) to compare perception and oculomotor behaviour in a target displacement paradigm. A white square ( $2^\circ \times 2^\circ$ ,  $10^\circ$  eccentricity) was embedded in a matrix with white noise segments of  $0.5^\circ$  by  $0.5^\circ$ . Participants fixated at screen centre and indicated whether the target appeared to the left or right (pre-saccadic peripheral task). After their decision, participants looked at the target. During their saccade, the noise matrix refreshed and the target stepped  $2^\circ$  to the left or right. Participants judged the direction of the step (post-saccadic foveal task). We compared saccade landing positions with classification images of the peripheral and foveal tasks. While the CI for peripheral perceptual localization was roughly symmetric around the actual target position, saccade landing positions undershot the target. In contrast, the CI for the foveal task matched corrective saccade landing positions. Furthermore, the extent of the foveal CI matched that of the first saccade landing positions, suggesting that sensitivity to trans-saccadic changes depends on saccade accuracy. Further research is currently carried out with respect to the relationship between perceptual and saccadic response patterns.

[2P059] The saccadic global effect with sub-threshold stimuli

**Sabrina Ait Amiri, Delphine Massendari, Françoise Vitu, Thérèse Collins**

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When human observers saccade to a visual target, the presence of a nearby irrelevant distractor deviates saccade landing positions, a phenomenon known as the global effect (GE). The GE is thought to arise from integration between neural representations of target and distractor within the retinotopically organized motor map of the superior colliculus. The strength of the GE is proportional to the relative intensities or contrasts of the target and distractor. In the present experiment we asked if the GE occurred for sub-threshold stimuli, and if sub-threshold gradations evoked proportional GEs. Subjects completed a pre-test in which contrast sensitivity to the distractor was measured. Two noise patches were superimposed on a noisy background. The outer object had a fixed contrast and the inner object's contrast varied. Subjects had to saccade to the outer object and report if one or two objects had been present. In the test phase, subjects made saccades to the outer target in the presence of a distractor that varied proportionally to threshold. We thus quantified the GE for distractor above and below threshold. Results show that sub-threshold distractors continued to exert a GE similarly to above threshold distractors, suggesting that unperceived stimuli can nevertheless influence

saccade programming.

[2P060] Eye movements during gaze-contingent spatial-frequency filtering of real-world scenes: Effects of filter location, cutoff, and size

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Visual attention and gaze control depend on the interaction of central and peripheral processing. The central and peripheral visual field are differentially sensitive to parts of the spatial-frequency spectrum. We investigated in two experiments how the selective attenuation of spatial frequencies in central or peripheral vision affects eye-movement behavior during scene viewing. To this end, gaze-contingent low-pass or high-pass filters with varying filter cutoffs (i.e., filter levels) or filter sizes were applied. Fixation durations increased most with central high-pass and peripheral low-pass filtering. Increasing filter size prolonged fixations with peripheral but not with central filtering, and increasing filter level prolonged fixations with low-pass but not with high-pass filtering. Thus, fixation durations did not necessarily prolong with increasing processing difficulty. Saccade amplitudes largely adapted to processing difficulty. They increased with central and decreased with peripheral filtering; the effects strengthened with increasing filter level and size. Furthermore, a trade-off between saccadic selection and saccade timing occurred, since saccade amplitudes were modulated when fixation durations were unaffected by filtering. We conclude that interactions of perception and gaze control are highly sensitive to experimental manipulations of input images as long as the residual information can still be accessed for gaze control.

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[2P061] The pursuit of covert attention in change blindness

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How does attention operate when participants suffer from change blindness? We studied the distribution of attention in “flicker” change detection task with gaze position monitored by SMI RED-m tracker. Matrices 5x5 of blue and brown squares and diamonds (2.5°) with white pictures served as stimuli. When probes – grey dots (0.2° of v.a. with eccentricity of 0.5-6.5° relative to gaze position) – appeared participants had to respond to them as quickly as possible. In 2/3 of trials probes appeared when the gaze focused on the target (“target probes”). We expected a dissociation of overt and covert attention during change blindness (probes that appeared more than 5 seconds before target was found): gradients of RT with increasing eccentricity of target probes would be shallower compared to distractor probes. The results confirmed our hypothesis. Unexpectedly, gradients for target probes presented in the absence of change blindness were shallow as well. Additionally, we tested whether gradients of RT and accuracy will be the same (Handy, Kingstone, & Mangun, 1996) or different (Muller & Findlay, 1987). Our data provides evidence in favour of the latter point of view although taking into account possible strategies of the target search that can result in change blindness.

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[2P062] Statistics of microsaccades indicate early frequency effects during visual word recognition

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Word frequency is among the most important determinants in the bottom-up processing hierarchy of visual word recognition. Using EEG (Dambacher et al., 2006) and MEG (Assadollahi & Pulvermüller, 2003) early frequency effects were reported only about 150 ms after word presentation, which can be interpreted as an early signature of lexical access. Eye-movements during reading are believed to support only indirect evidence about the time-line of word processing, since fixation durations are affected by a range of processes as well as by more than one word (Engbert et al., 2005). Here we show that microsaccades (the largest component of miniature eye movements during fixation) are modulated by word frequency. In an oddball-type paradigm, we present series of eight words including seven high-frequency and one low-frequency word. We collected binocular eye-position data from 5760 word-

presentation epochs for each of three subjects. We found that microsaccade rates during the reading of high- or low-frequency words begin to diverge well before 200 ms. Furthermore, we found an interaction of word frequency with word length. Thus, our results are in good agreement with early EEG/MEG studies. We conclude that microsaccades provide a new tool for the investigation of the time-line of visual word processing.

[2P063] Temporal Dynamics of Microsaccades and Saccades: Stochasticity or Rhythmicity?

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Purpose: The rhythmicity of neural activity and behavior is thought by many to be the basis of brain functioning. Specifically, sensory organs are thought to sample the environment rhythmically, thereby providing the neural system with periodic input. Saccades and microsaccades were previously hypothesized to constitute the basis mechanism for such a rhythmic visual exploration system. We examined this hypothesis by exploring the temporal dynamics and dependencies between saccadic events. Method: We recorded saccades and microsaccades in four different experimental procedures, including steady fixation and ecologic free-view. These data were analyzed using novel methods from spike-train analysis and then used to validate a mathematical model. Results: We find only first-order interdependencies between saccades, i.e. each saccade depended on the preceding saccade alone and not on the rest of the saccadic-train. The first-order features are enough to fully explain the observed saccadic rhythmicity. Furthermore, we find that the observed rhythmicity of saccades is rare (among observers) and is always short-lived. Therefore, it is incompatible with a sustained oscillatory process. Conclusion: These findings suggest that saccades are a self-generating process, not driven by a base-oscillation. These statistical properties of saccades make them a stochastic rather than a rhythmic exploration system.

Funding: The study is funded by the ISF grant 1427/14

[2P064] Combination of motion and luminance defined edges:a cross-orientation masking study

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Segmentation of visual scenes and object recognition begins with the task of edge detection. Although edges of different attributes (luminance, color, motion and texture) exist in the physical world, it is not entirely understood yet how and at which stage of visual processing they combine. In this cross-orientation masking study, we asked if adding an orthogonal motion edge could increase threshold for detecting a luminance contrast edge and vice versa. In a 2AFC task, a pair of two superimposing random dot motion stimuli was shown; one was uniformly black dots which could contain a motion edge. The other one was randomly moving grey dots with a luminance defined contrast edge. First, threshold for detecting each vertical edge (motion or luminance) was measured separately. In the second experiment a horizontal edge of a different attribute was added. There was no significant elevation of threshold in the presence of the cross-oriented mask. These preliminary results suggest that motion and luminance edge detection might be independent in early stages of visual processing.

[2P065] Visual dominance for darks increases with low light and optical blur

**Carmen Pons, Reece Mazade, Jianzhong Jin, Mitchell Dul, Qasim Zaidi, Jose-Manuel Alonso**

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Humans are more accurate at processing dark than light features in visual scenes, an asymmetry that was recently proposed to originate from differences in the luminance response function between ON and OFF visual-pathways. Here we provide support for this neuronal mechanism by demonstrating specific predictions on how dark/light asymmetries change with stimulus conditions. First, we demonstrate that humans see high spatial frequencies better with dark than light grating-bars but the differences are reduced on bright backgrounds and completely extinguished under low light. Second, we show that, although low light eliminates dark/light asymmetries in grating-bar acuity, it enhances the asymmetries for visual salience, making lights less visible than darks (and we show the same effect for optical blur). Third, we demonstrate that, although grating-bar resolution is higher for darks, visual resolution for small dots is higher for lights, a difference that reverses with bright backgrounds. Finally, we show that all these results can be explained by a computational model that increases ON luminance-response saturation when background luminance is reduced. These results could lead to a better understanding of how low light and optical blur affect visual diseases such as myopia through under-stimulation of the ON pathway.

[2P066] The Glare Effect Test (GET): a tool to assess brightness or discomfort glare?

**Alessio Facchin, Roberta Daini, Daniele Zavagno**

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The Glare Effect is an illusion in which a white region appears self-luminous when surrounded by linearly decreasing luminance ramps (R). The Glare Effect Test (GET) was constructed as a paper test to easily measure luminosity thresholds within such illusion in different age groups with the following hypotheses: (i) GET can actually measure a perceptual process that changes along the lifespan; (ii) given that older adults present more symptoms of discomfort glare, they should show a lower threshold compared to young adults. Two groups of adults were recruited: young (20-30 years old) and senior (60-75 years old). Participants were assessed with GET and a battery of visual tests: acuity, contrast sensitivity, BHT, Ishihara, and the Navon effect. GET comprised 101 cards in which R changed gradually from solid black (card 0) to full black-to-white ramp (card 100). Subjects were required to classify cards on the basis of those two reference cards. PSEs show no correlation with the other visual tests, revealing a divergent validity. A significant difference between the groups “young” and “senior” was found: contrary to our expectations, luminosity thresholds for “senior” were higher than those for “young”, suggesting a non linear relationship between luminosity perception and discomfort glare.

[2P067] Pupillary responses to perceived brightness require visual awareness

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It is well-established that pupil diameter primarily reflects overall illumination. Yet, a growing body of evidence suggests that it is also modulated by extra-retinal information, including attention, contextual processing, and imagery. For example, Binda, Pereverzeva, and Murray (2013) recently reported stronger pupillary constrictions for photographs of the sun compared with their phase-scrambled versions, indicating that pupil size depends on context –not just luminance. Here, we asked whether conscious appraisal of these stimuli is necessary for the pupillary constriction to occur. The pupil diameter of 21 participants was measured while photographs of the sun and phase-scrambled images of matched luminance were shown to the left eye. A stream of Mondrian patterns was displayed to the right eye, which produced continuous flash suppression (CFS), i.e. rendered the sun and phase-scrambled images invisible on a proportion of trials. Results revealed that when participants were aware of the sun pictures (i.e. when CFS failed) their pupils constricted relative to the phase-scrambled versions, replicating Binda et al. (2013). However, no pupil modulation was found when the pictures were successfully suppressed from awareness. These results show that pupil size is a sensitive and accessible index of visual perception, which can precisely track the contents of consciousness.

[2P068] Canonical Material and Illumination Confounds

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MatMix 1.0, a novel material probe (Zhang et al. VSS2015; Zhang et al. SPIE2015), was adjusted to MixIM 1.0 (Mixing Illumination and Material) and implemented in matching experiments to quantify visual perception of canonical material modes and lighting modes (Zhang et al. VSS2016). We found material and light dependent perceptual interactions. To explicitly test these interactions, we designed a 4AFC task as a validation experiment. In each trial, observers were shown a pair of images and four options: “same materials same lightings”, “same materials different lightings”, “different materials same lightings” and “different materials different lightings”. All 78 combinations of 12 photographs were included, which were taken from bird shaped objects covered by four canonical material modes (matte, velvety, specular and glittery) and illuminated under three canonical lighting modes (so-called ambient, focus and brilliance light). By interpreting the probing results of previous experiments, we could predict the observers’ results for the 4AFC task. Results from pilot studies showed that the task was doable but that there were many material-illumination confounds, in accordance with our predictions. Overall, the observers seem to be better at categorizing materials that were different than lightings that were different.

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[2P069] Quantifying the simultaneous contrast for gloss and luminance

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Interactions between the luminance and the gloss on a surface are commonplace. Darker surfaces are perceived glossier than lighter surfaces and darker backgrounds can enhance perceived lightness of surfaces. We used Maximum Likelihood Conjoint Measurements (MLCM) that can simultaneously quantify the strength of those influences (Knoblauch & Maloney, 2012). Stimuli consisted of 25 rendered surfaces (5 luminances  $\times$  5 glosses). In two separate 2AFC tasks, participants indicated which of two surfaces was glossier or lighter. The MLCM analysis consists in assigning perceptual scale values to each luminance and gloss level and modeling the contribution of both features onto perceived gloss. We found that darker surfaces increase perceived gloss by approximately 20%. In two follow-up experiments, we added a constant glossy mid-grey patch at the centre of the surfaces, and participants had to judge either the lightness or the gloss of the centre. We found that a glossy background reduces slightly perceived lightness of the centre and simultaneously strongly enhances its perceived gloss. We also found that lighter backgrounds reduce perceived gloss and perceived lightness. Overall, conjoint measurement is a powerful tool to better understand the degree of contextual effects in gloss and lightness perception.

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[2P070] The effect of luminance gradient induced luminosity and darkness in static and dynamic patterns on pupil diameter

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Luminance gradients can determine strong brightness illusions, which, depending on how gradients are organized around a target area (T), may result in brightness enhancement (e.g. glare effect) or brightness depression (i.e. ‘darkness enhancement’). The effects of such illusions on the eye pupil’s response were studied in an experiment with static and dynamic patterns (similar to the standard ‘glare effect’ pattern) by employing a remote eye-tracking device. Control stimuli were patterns in which luminance gradients were rotated 180° with respect to T, determining peripheral brightness effects external to T. Factors were thus Luminosity (bright, dark), Effect (central, peripheral) and Pattern (static, dynamic). Results show a main effect of Luminosity and Pattern, and a significant interaction Luminosity  $\times$  Effect for both static and dynamic patterns. Summarizing, central bright patterns determined smaller pupils whilst central dark patterns determined larger pupils; the effects for dynamic stimuli were twofold those for static stimuli. Results confirm findings from previous studies with static patterns, while showing that the effect of illusory brightness patterns on pupil diameter extends to illusory darkness patterns and is enhanced by dynamic stimuli.

[2P071] Anchoring theory outmatches ODOG in tests of four lightness illusions

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Anchoring Theory considers perceptual grouping a critical factor in lightness perception. According to the theory, manipulating grouping factors can alter target surface lightness. Blakeslee and McCourt’s ODOG model, on the other hand, emphasizes retinotopic relations among surfaces with no explicit role for grouping effects. We tested ODOG against Anchoring Theory for several illusion variations (Reverse Contrast, Dungeon Illusion, Benary Cross, and Benussi-Koffka illusion) in which targets can group with competing frames of reference. We manipulated proximity, good continuation, articulation, and other grouping factors to affect the grouping of the targets. Where published data were unavailable, we asked observers (separate groups of 10) to match the lightness of targets by adjusting a variable gray patch on a computer screen. The psychophysical data were compared with Anchoring Theory predictions and with ODOG outputs derived by running each variation through the ODOG program. We found that grouping exerts a strong effect on surface lightness (main effects for articulation, good continuation, and common orientation were all significant,  $p$ .values  $< 0.05$ ) and that the empirical data are generally consistent with Anchoring Theory predictions but not consistent with ODOG predictions, both in magnitude and direction.

[2P072] The threat bias for fearful expressions is evident in apparent contrast

## **Abigail L Webb, Paul B Hibbard**

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Fearful face stimuli elicit attentional biases during visual processing (Bannerman et al., 2012) and gain preferential access to awareness under conditions of visual suppression (Yang et al., 2007). This threat bias depends in part on the low-level visual properties of faces, and can occur even under conditions where observers are unable to correctly identify the emotion portrayed (Gray et al., 2013). Typically, these studies use stimuli that are matched for their physical, RMS contrast. Using images that were spatially filtered to contain high, low or broad spatial frequency information, we assessed whether different facial expressions that are matched for physical contrast differ in their apparent contrast. Observers were presented with stimuli depicting a neutral, angry, disgusted, happy or fearful expression, and adjusted the contrast until it matched that of a neutral standard. For broadband stimuli, fearful faces had a higher apparent contrast than neutral faces. This effect was also present in faces filtered to contain only high spatial frequency information, but not for faces containing low frequency information. These findings demonstrate that fearful faces are perceived with higher apparent contrast, when matched for physical contrast, and that this effect is confined to high spatial frequency information.

Funding: ESRC Studentship

[2P073] Proposal for a glare risk scale along a specific route in daylight hours

### **Vincent Boucher**

OUEST, CEREMA

Glare phenomenon can appear in daylight under certain specific conditions related to the sun's position with respect to the driver's line of sight. Day-time driving conditions have rarely been studied, even though a large number of works have been dedicated to night-time glare and interior environment. We are interested here to simulate the day-time visual adaptation and establish a methodology for assessing disability glare in driving conditions when the sun's light reflects on the roadway. Using High Dynamic Range (HDR) acquired onboard a vehicle, we use a known visual adaptation model to compute a retina-like response signal and to suggest a scale of glare risk along a route.

[2P074] Visual impression of the fabric while rotating

### **Megumi Yoshikawa<sup>1</sup>, Aki Kondo<sup>1</sup>, Chiaki Umebayashi<sup>2</sup>, Toshinori Harada<sup>2</sup>, Sachiko Sukigara<sup>1</sup>**

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Visual impressions of clothing are not always the same, may be changed by the reflection of light from the fabric surface and viewing angle. In the present study, we examined the relationship between light reflectance from fabric surface and visual evaluations of fabric lightness and also high-grade feel. Light reflectance distribution (CIELAB L\*) was measured by using a gonio-spectrophotometric measurement system while the fabrics were rotating under the constant condition of 45/-60 illumination/viewing angles. The visual feel of 6 cotton/polyester blended fabrics was judged using the Scheffe-Nakaya's paired comparison method. Participants observed fabric pairs at the 45/-60 angle while rotating them freely to change the light reflection and rated the difference of "Light-dark change" and "High-grade feel" of each fabric pair on a  $\pm 3$ -point scale. The results showed that the change in L\* is positively correlated with the evaluations of "Light-dark change" and "High-grade feel". Additionally, comparing the fabrics having same structure and color, the more clear lightness change was observed for the fabric made from finer yarns. These findings suggest that the yarn count is a factor influencing the lightness of fabrics, and the changes in lightness while rotating had an effect on the high-grade feeling of fabrics.

[2P075] "Glowing gray" does exist: the influence of luminance ramps on whiteness perception.

### **Yuki Kobayashi, Soyogu Matsushita, Kazunori Morikawa**

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A white patch surrounded by luminance ramps is perceived as if it is glowing. Zavagno and Caputo (2005) employed the method of adjustment and demonstrated that this phenomenon is observed even when the luminance of the central patch is lower than that of subjective white, indicating the perception of "glowing gray." However, in their experiments, the luminance threshold for white was measured with uniformly colored surroundings. Therefore, there still remains the question whether subjective white with luminance ramps is at higher luminance than glowing objects.

In this study, we used the stimulus with ramps for measuring subjective white as well, and examined the luminance threshold for white and luminosity. The result indicated that the threshold for luminosity was lower than that for white; that is, luminance ramps had little influence on the threshold for white whereas that for luminosity was remarkably lowered. We confirmed the existence of “glowing gray”, and speculate the perception of luminosity and white are independent of each other, contrary to the intuitive assumption that luminosity can occur at higher luminance than white.

[2P076] Attention as a new parameter in modeling brightness induction

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Attention has been demonstrated to enhance both contrast sensitivity and spatial resolution of an observer’s vision (Carrasco et. al. 2004), and to differentially modulate the Magnocellular (M) and Parvocellular (P) channels of visual information (McAlonan et. al. 2008). However, the role of attention has generally been ignored in constructing models of brightness perception. We propose a new filtering model of brightness perception, which we term as the Attentive Vision Filter (AVF). AVF mimics the visual pathway by linearly combining the outputs of the M-channel & the P-channel, through a weight parameter termed as the Factor of Attention (FOA). The M and P channels in turn are modelled using Gaussian based spatial filters. We find that for various brightness illusions there are two specific values of the FOA that can explain either brightness-contrast or brightness-assimilation types of illusions. We then compare our model with the classical filtering based ODOG (Blakeslee & McCourt 1999, 2004) model, an established model of brightness perception. It has been found that in case of the White & Shifted-White stimuli ODOG fails significantly when grey illusion patches are extended in length beyond a threshold. We show that the proposed model does not suffer from this limitation.

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[2P077] Predicting Discomfort Glare

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Discomfort glare is the perception that a light is visually uncomfortable, though vision is unimpeded. This is an important factor in various lighting applications. Many models are available for predicting glare, but they’re not very accurate when predicting glare from non-uniform sources. We have developed a computational model that can predict the discomfort that is elicited by luminaires with an inhomogeneous luminance distribution at the exit window. The model uses a Ratio of Gaussians method to calculate the center-surround activation of retinal ganglion cells. Our model calculates the activation across the entire retina and uses the amount of activation as a predictor of the level of discomfort that will be experienced. We collected data from subjects to validate our model’s results. We presented LED luminaires with different pitches (distance between LEDs) at different distances and eccentricities. Subjects rated each luminaire using a subjective scale. We found a relationship between the visual angle of LED pitch and size and the perceived level of discomfort. These results can be attributed to the fact that the ganglion cell receptive field sizes increase with eccentricity. Our model seems to be able to link the perception of discomfort to the physiology of the retina.

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[2P078] Perceived emotional valence of faces is affected by the spectral slope but not the brightness of the image

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It has been speculated that image properties, such as brightness and the spectral content of an image, play a role in the processing of emotional valence of human faces. Here, we studied whether these image properties affect the perceived emotional valence of neutral faces by manipulating the properties in face photographs. Additionally, we created neutral cartoon faces (“smileys”) and manipulated the properties of their background. We asked participants to rate the

emotion of the (photographed and cartoon) faces on a continuous-looking scale from positive to negative. Brightness did not affect the perceived emotional valence in neither face photographs nor cartoon faces. Our data, thus, are not compatible with a brightness bias for faces. The manipulation of the spectral slope, however, affected the rating: Faces in images with a slope that is steeper than the original slope (i.e., enhanced low spatial frequencies) were perceived as more negative than those with a shallower slope (i.e., enhanced high spatial frequencies). Thus, enhancing low spatial frequency power in face photographs leads to more negative emotional valence. This effect was restricted to face photographs and was not observed in cartoon faces.

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[2P079] Turning a horse into a unicorn: How a double dissociation can be produced by custom-made mask functions in a response priming experiment.

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In our response priming experiment, participants respond to the color of a target preceded by color primes while a metacontrast mask is presented simultaneously with the target. We use four custom-made mask functions where the mask's luminance contrast is systematically coupled with prime-target SOA so that it can be varied without changing the target. The mask intensity was either steady (weak vs. strong) or varying (ascending vs. descending) with increasing SOA. This decoupling of the different properties of the mask (luminance contrast) and target (color contrast), made it possible to produce a double dissociation between masking and response priming. Priming effects increase with SOA in all four mask functions (weak vs. strong / ascending vs. descending), even though the prime discrimination performance either strongly increases or strongly decreases with SOA. Compared to the steady mask conditions, increasing and decreasing mask functions produce a much steeper dissociation pattern. We conclude that mask and target properties should be varied independently, and that custom-made mask functions can strongly amplify or even enable double dissociations between visibility and priming.

[2P080] The brightness of noisy textures

**Jose F Barraza, Andrés Martín**

ILAV, CONICET, Argentina

It is well known that the brightness of a surface depends on a variety of factors. Luminance is one of the main determinants of this brightness and its articulation in the image may produce changes in the perception. We investigate how a patch, which was textured with luminance noise, is perceived in comparison with an homogeneous one. Our hypothesis was that the two patches must be perceived as equally bright when their mean luminance were the same. To test this hypothesis, we performed two experiments. First, we estimated by mean of flicker photometry the brightness equality between textured and homogeneous patches. Secondly, we used a two-alternatives-unforced-choice paradigm to measure the brightness PSE between textured and homogeneous patches. The first experiment showed that subjects found the minimum flicker situation when textured and homogeneous patches had the same mean luminance, which indicates that the visual system is effectively sensing mean luminance. However, the results of the second experiment show a systematic perceptual bias indicating that the textured patch was perceived darker than the homogeneous patch. This result suggests that textures modify the brightness of surfaces perhaps, because its interaction with the background is different than when the surface is homogeneous.

[2P081] Influence of diffusibility of illumination on the impression of surface appearance

**Yoko Mizokami, Yuki Nabae, Hirohisa Yaguchi**

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The appearance of object surface could be largely influenced by lighting conditions. It is known that the components of specular and diffuse reflection change depending on the diffuseness of illumination. However, it has not been systematically analyzed how surface appearance is influenced by the diffuseness of illumination. We investigated how the impression of surface appearance of test samples with different roughness and shape changes under diffused light and direct light using real samples in real miniature rooms. We prepared plane test samples with three different levels of surface roughness and spheres with matt and gloss surface. A sample was placed in the center of a miniature room with either diffuse or directed light, and observer evaluated its appearance. We used a semantic differential method to

examine what types of factors were influenced by the diffusibility of illumination. The result of analysis based on 20 adjective-pairs showed that glossiness and smoothness were main factors. Samples tended to appear less glossy and smoother under diffused light than direct light, and their difference was larger in a sample with rough surface. This implies that we should consider the surface properties of objects when examining the influence of diffusibility of illumination on surface appearance.

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[2P082] The direction of lightness induction is affected by grouping stability and intentionality

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The relationships among perceptual elements in a visual field determine both contrast and assimilation phenomena: Perceptual differences are enhanced in contrast and decreased in assimilation. Gestalt psychologists raised an intriguing paradox by explaining both phenomena as the result of perceptual belongingness; in fact, Benary proposed that belongingness determines contrast, whereas Fuchs suggested that it determines assimilation. We propose that both grouping stability and grouping intentionality are related to this paradox. In four experiments we manipulated both stability and intentionality, to verify whether contrast or assimilation will occur. We found that intentionality and multi-stability elicit assimilation; whereas non-intentionality and stability elicit contrast. Results are discussed within the previous literature on the relationship between lightness induction and perceptual belongingness.

[2P083] Mechanisms underlying simultaneous brightness induction: Early and innate

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In the simultaneous brightness induction illusion, two equi-luminant patches, one placed on a darker background than the other, appear to have different brightness. An understanding of the underlying mechanisms is likely to illuminate the larger issue of how the brain makes photometric judgments. A specific question in this regard concerns the role visual experience plays in inducing this illusion. Our work with newly sighted children through Project Prakash has demonstrated immediate susceptibility to the simultaneous brightness illusion after sight onset, suggesting that the computations underlying this percept are driven by innately specified circuit mechanisms. To investigate the nature of these mechanisms, we conducted studies with normally sighted individuals using binocular displays that had subtly different monocular components. Specifically, the two eyes were presented with opposite shallow luminance gradients, which fuse into a homogenous cyclopean view. Probe dots were placed transiently on one or the other of the monocular inputs. We found that eye of origin, though not evident consciously, had a profound influence on the eventual brightness percept of the probe dots. We infer that the mechanisms underlying these brightness percepts are at a stage of visual processing that precedes binocular information fusion.

[2P084] Receptive fields for Illumination effects.

**Alejandro Lerer, Matthias Keil, Hans Supèr**

Cognició, i Desenvolupament, Universitat de Barcelona & Institut de Neurociències, UB, Catalonia

Little is known about how or whether dedicated neurons of the visual cortex encode gradual changes of luminance (GcL). We approach this question computationally, where we describe possible advantages for explicitly encoding GcL, and explain how corresponding putative neurons could be used for estimating the illumination direction. With this objective, we compiled three sets of intrinsic images (IIs) by extracting low and high spatial frequencies from natural images. The third set contains the full frequency range. Each set of IIs was subsequently whitened with the ZCA transformation, and dictionaries with receptive fields (RFs) were learnt from each set via unsupervised learning. In the end we used the dictionaries for comparing the encoding efficiency of natural images, and found that GcL could be encoded by dedicated neurons about three times more efficient in terms of energy expenditure than with neurons that respond to the full or high spatial frequency range. Furthermore, the RFs of the three dictionaries can classify image features (ROC curves with close to 0.95 accuracy), into reflectance-related or sharp changes in luminance and gradual changes in luminance. We also propose a “utility” of GcL neurons for estimating the local or global direction of illumination within a visual scene.

[2P085] Common and different mechanisms behind White's illusion, simultaneous contrast illusion and the Mach band illusion

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We assume that lightness illusions show individual differences concerning their intensity, since the underlying biological parameters of each individual might slightly differ, too. We measured the intensity (N=130) of the White illusion and simultaneous lightness contrast illusion using cancellation technique, and that of the Mach band illusion by a matching paradigm. For the latter, subject adjusted the width and the lightness of a white and a black Gaussian bar on a grey background until it matched the appearance of Mach bands that were displayed right above these reference bars. Our results show that the intensities of the White illusion and that of the simultaneous contrast illusion significantly correlate, whereas neither of these two illusions correlates with the Mach band illusion. We conclude that the underlying neural mechanism behind the Mach band illusion is different than the one behind the White and the simultaneous contrast illusions. We also conclude that there is a common neural mechanism behind the simultaneous contrast and the White illusions. This common mechanism, however, cannot be lateral inhibition, since the White illusion cannot be explained by lateral inhibition.

[2P086] Centre-Surround Antagonism in the Perception of Motion in Depth

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Duration thresholds for motion direction increase with stimulus size, for a high-contrast stimulus, but not when contrast is low. This has been attributed to centre-surround antagonism in motion-processing neurons (Tadin, et al., 2003, Nature, 424, 312-315). Here we measured duration thresholds for lateral motion and binocular motion in depth (defined by both binocular disparity and inter-ocular velocity differences). Our aim was to test whether the pattern of threshold elevation was similar for the two types of motion. We measured duration threshold with high- (92%) and low-contrast (3%) Gabor stimuli with sizes ranging from 1.5 to 5 degrees, spatial frequency of 1 cpd and speed of  $2^\circ \text{ s}^{-1}$  on the retina. Across 12 observers, we found the characteristic pattern of threshold increase with size for both lateral motion and motion in depth; thresholds for the largest size were 33% higher than for the smallest, for both motion cues. This suggests that the initial processing of motion in depth may use similar mechanisms to those used for two-dimensional motion.

Funding: EPSRC

[2P087] A new analytical method for characterizing nonlinear visual processes

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One of fundamental goals of system neuroscience and psychophysics is to characterize functional relationship between sensory inputs and neuronal or observer's perceptual responses. The conventional methods, such as reverse correlation and spike-triggered data analysis techniques, however, have limitation to identify complex and inherently non-linear neuronal/perceptual processes since these methods rely on the assumption that the distribution of input stimuli is spherically symmetry or Gaussian. Here, we propose a new analytical method, named Watanabe's method, for identifying a nonlinear system without requiring any assumption on stimulus distribution. Then, we demonstrate the results of numerical simulations, showing that our method outperforms the conventional spike-triggered data analysis in the parameter estimation of V1 neuron model using natural images whose distribution is non-Gaussian. As an example of application to real psychophysical data, we investigated how multiple sinusoidal gratings with different spatio-temporal frequencies are integrated to judge motion direction. Our analysis revealed the fine structure of second order kernel (the interactive effect of two gratings on direction judgement), which is consistent with the findings in previous studies of visual motion and supports the validity of our methods for nonlinear system identification.

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[2P088] Kinetic cue for perceptual discrimination between mirror and glass materials

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Even under unnatural illumination, human observers could discriminate between mirror (with completely specular reflected surface) and glass (with transparent and refracted medium), when the object was rotating (Tamura et al., VSS2016). In this study, we investigated what kind of kinetic information contributes to the perceptual discrimination of these materials. Stimuli were horizontally-rotating 3D objects with mirror or glass materials, which were rendered under real-world (natural), color inverted and binary noise (unnatural) light fields. Subjects were instructed to observe the stimulus for 1,000 ms and were asked to judge its material (mirror or glass) according to 2AFC paradigm. We found that observers performed the mirror/glass discrimination well even under unnatural light fields and without contour information if the object was rotating. Relating to this, we found that the spatial variation in the horizontal component of the optic flows significantly differed depending on the materials. The horizontal motion component was more spatially uniform in mirror objects than glass. These suggest that observers were able to discriminate materials directly and/or indirectly from the relative motion between the object and surface reflection pattern.

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[2P089] The interaction between image motion and surface optics in material perception

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Image motion and surface optics have been independently shown to contribute to material perception. We conducted an experiment to explore how these properties might interact. We created novel animations of materials ranging from soft to hard bodies that break apart differently when dropped. Animations were rendered as point-light movies varying in dot density, and “full-cue” optical versions ranging from translucent glossy to opaque matte under a natural illumination field. Observers used a scale to rate each substance on 30 different attributes, categorised into “optical”, “motion”, and “inferred” attributes. The results showed several interactions within and between ratings of optical and dot stimuli. In addition, correlations between motion and inferred attributes produced several discrepancies between optical and dot stimuli. For example, ratings of “shattering” correlated with “crumbling” for dot stimuli, but were independent for optical stimuli, suggesting that subtle distinctions between these motions are only accessible through (and possibly determined by) surface optics. Furthermore, ratings of optical stimuli on these motion attributes contradicted dot stimuli ratings. Perceived differences between hard and soft bodies were also notably more pronounced for optical versus dot stimuli. These novel findings demonstrate a critical interaction between motion and surface optics in the perception of materials.

[2P090] Sensitivity and precision to speed differences across kinetic boundaries

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Kinetic boundaries play an essential role in the processing of motion information, in segregating a moving object from the background, and in evaluating objects' depth. In natural conditions, the independent motions of objects of different shape generate various combinations of velocity vectors at the motion boundary. Here, we examined how the sensitivity and precision to speed differences across the motion discontinuities varied depending on their speed, direction, and size. The stimuli consisted of band-pass dots presented in a circular aperture. The motion of the standard and the test with different combinations of speed and direction in the two semi-circles generated a vertical boundary. The standard moved horizontally to the left or the right with a constant speed. The direction of the test motion was varied between 8 possible directions in the range  $0^\circ$  to  $315^\circ$ . Four observers had a task to discriminate which semi-circle contained the faster motion. Our data show a significant bias that depends on the angular difference between the motion vectors at the boundary and whether the standard motion is towards or away from it. The results are discussed with respect to the role of area MT and motion processing in spatial layout determination.

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[2P091] Computing the IOC from Gabor filter outputs: Component Level Feature Model version 2

**Linda Bowns**

When an object translates in a scene it is imperative that its contrast is independent of its movement, and yet the dominant models of human motion processing (i.e. spatio-temporal energy models) have used contrast to compute a correlate of motion, namely “motion energy”. The Component Level Feature Model (CLFM) of motion processing, (Bowns 2011), uses established properties of spatio-temporal energy models, namely spatial Gabor filters, and the Intersection of Constraints rule (IOC), for computing direction (up to a reflection), but does not use “motion energy”, and importantly, is invariant to contrast. This paper describes modifications to the Component Level Feature Model that are sufficient to enable accurate computation of ‘absolute’ direction and speed. Results from a MATLAB simulation of CLFM v2 are reported here for a range of stimuli, including two component plaid stimuli, as well as flat spectrum stimuli, i.e. translating random dot patterns with different dot densities. These results together with those described in Bowns (2011, 2013) provide strong proof of concept of the Component Level Feature Model.

[2P092] Comparing perception of motion-in-depth for anti- and de-correlated random dot stimuli

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Movement in depth (MID) can be detected using two binocular cues: change of disparity over time (CD) and interocular velocity differences (IOVD). To investigate the underlying detection mechanisms, stimuli can be constructed with only CD, only IOVD, or both cues (FULL). Two different methods to isolate IOVD have been employed frequently: anti-correlated (aIOVD) and de-correlated (dIOVD) motion signals. Czuba et al. (2010, *JNeurophysiol*, 104, 2886 - 2899) found similar direction discrimination sensitivities for aIOVD and FULL stimuli. We set out to compare aIOVD, dIOVD, and FULL stimuli by measuring motion coherence thresholds using random-dot stereograms. For all conditions, stimuli represented a cloud of 3D dots, moving either towards or away. In the FULL condition, signal dot motion spanned a cylinder in depth with the signal dots randomly scattered through the volume. When reaching the end of the cylinder, signal dots flipped to the opposite end and continued their motion. Noise dots had similar correlational properties as signals but were randomly repositioned with variable lifetimes. Motion coherence thresholds were similar for aIOVD and FULL for most observers but consistently differed from thresholds for dIOVD. Our findings suggest that aIOVD and dIOVD stimuli do not isolate identical MID mechanisms.

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[2P093] Event-based model of vision: from ATIS to hierarchical motion processing

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Formulating the hierarchical function of the visual system by various models is a great part of vision research. However, each model includes an unavoidable degree of simplifications and assumptions about the scene, visual system and their interaction. Herein, we have addressed a significant limitation of conventional models in neuroscience and computer vision, raising from unrealistic stimulation: the scene is sampled by frames in regular time intervals, resulting in huge redundant input, also during the spatiotemporal periods without any change in the light structure of the scene. Empirical evidences suggest that biological vision is asynchronously stimulated instead of relying on frame-like sampling, and this operational principle is consistent with the response characteristics of retinal cells (temporal resolution 1 – 10 ms). We have introduced a motion processing model stimulated with ATIS (Asynchronous Time-Based Image Sensor) that provides highly asynchronous and local luminous data from moving scene, so called visual events. In this event-based framework we have implemented a hierarchical probabilistic model of motion processing, compatible with independent activation of photo-receptors. The theoretical insights of our model stresses on efficiency of asynchronous time-based computation as a principal neural strategy demonstrated in delay compensation, precise tracking and on-time actions.

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[2P094] Spatial context alters the contribution of motion-coding mechanisms to contrast detection

**Alison Chambers, Neil Roach**

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Contrast sensitivity can be substantially modulated by the presence of nearby stimuli. For instance, the ability to detect a target stimulus presented at the leading edge of a drifting grating is dependent on the relative phase of the two stimuli (Roach et al., 2011). Previously we have shown this phase-specific modulation of sensitivity is characterised by several unusual properties, including dependence on the absolute, but not relative spatial frequency of the target and inducing gratings. Here we develop a multiscale image-based model of motion coding to provide insight into the mechanisms underlying these effects. When drifting target gratings are presented in isolation, simulated contrast sensitivity is determined by the responses of space-time oriented filters with tuning preferences that are matched to the stimulus. Critically however, this is seldom the case when targets are presented along with inducing gratings. We demonstrate that phase-dependent modulations of sensitivity arise through the recruitment of filters that are not well matched to the target, but that are co-activated by both target and inducing stimuli. The model accounts for the spatial frequency tuning of these effects, as well as a range of additional properties (e.g. dependency on inducer contrast).

[2P095] Global motion influences the detection of motion-in-depth

**Kait Clark, Simon Rushton**

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Detecting motion-in-depth is more difficult than detecting equivalent lateral motion (e.g. Tyler, 1971). Because there is an early averaging of left and right motion signals, some work suggests the two monocular signals could effectively cancel out when an object moves only in depth (e.g. Harris, McKee, & Watamaniuk, 1998). In the literature on “flow-parsing” (Rushton & Warren, 2006), it has also been shown that an early subtraction of global components of motion from the retinal image isolate scene-relative object movement (Warren & Rushton, 2009). Here we examine the relationship between motion-in-depth and flow-parsing processes. Using a display with a probe object within an array of background objects, we first measured reaction times to detect the motion-in-depth of the probe in the presence of static background objects. As expected, reaction time was maximal when the movement of the probe was directly towards the observer (pure motion-in-depth). When the objects moved in a radial pattern on the opposing side of the screen, the trajectory that produced the maximal reaction time changed. This change was in line with a subtraction of global motion prior to the detection of motion-in-depth, suggesting an early contribution of global motion information to the perception of motion-in-depth.

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[2P096] Gravity-specific representation in human EEG

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Processing gravitational motion is essential for the survival of terrestrial species like human beings. Evolved within the Earth’s gravitational field, the human brain has developed specific mechanisms sensitive to visual gravitational motion, as if it has internalized the law of gravity. Here we investigated whether such internal model of gravity is selectively tuned to gravitational acceleration. We recorded electroencephalogram (EEG) of observers who viewed basketballs moving downwards or upwards at various accelerations (9.8, 4.8, 14.8 m/s<sup>2</sup>) or moving in duration-matched uniform motion, and their task was to estimate the duration from the ball occluded by a grey bar till it crossed the bar. EEG amplitude at the parietal and occipital sites showed a significantly enhanced differentiation between gravitational motion (9.8 m/s<sup>2</sup>) and its matched uniform motion, as compared with the other motion pairs (4.8 or 14.8m/s<sup>2</sup>).

Crucially, this effect was only observed when the motions were in the downwards rather than in the upwards conditions. These results provide EEG evidence for the internalization of gravity law in the human brain, suggesting that visual motion processing involves neural mechanisms specifically tuned to gravitational acceleration.

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[2P097] Extra-retinal information for disambiguating depth from motion parallax

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In contrast to ambiguous depth perception of kinetic depth effect (KDE), perceived depth from a conventional motion parallax display is unambiguous when the stimuli were yoked to monocular observers’ head movement (Rogers &

Graham, 1979). One possible account for this difference is that visual system uses some extra-retinal information that disambiguates the perceived depth from the motion parallax display. The information can be vestibular signal (Rogers & Rogers, 1992) or pursuit eye movement signal during translational head motion (Nawrot & Joyce, 2006). In order to test the latter pursuit eye movement signal theory, we investigated whether depth reversal would occur when observers viewed the conventional motion parallax stimuli through a head mounted display (HMD) yoking to their head movement. Sinusoidally corrugated surfaces with 3 different spatial frequencies (0.067, 0.2, 0.467 cpd) were presented on an external display or a HMD, and observers reported whether the surface corrugation below the fixation cross was convex or concave. Results showed that the rate of depth reversal was significantly above chance level when the corrugation spatial frequency was 0.2 cpd, but not with other spatial frequencies. These results suggest that the visual system uses some extra-retinal signal other than the pursuit eye movement signal.

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[2P098] Investigating the sound-induced flash illusion in people with ASD: An MEG study

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The sound-induced flash illusion (SiFi) is an audio-visual illusion whereby two beeps are presented along with a single flash. Participants typically perceive two flashes if the auditory beeps are presented in rapid succession. This illusion has been used to demonstrate that specific populations exhibit multisensory deficits (e.g., in people with autism spectrum disorder (ASD), older adults, older adults prone to falling, and people with mild cognitive impairments). In these populations, the behavioural outcome is the same but the underlying neurological reasons can be completely different. Using magnetoencephalography (MEG), we previously demonstrated that older adults perceive more illusion, compared to younger adults because of increased pre-stimulus beta-band activity. In the current study, a group of young people with ASD were presented the SiFi. Once again, they perceived significantly more illusions, across a wider range of stimulus-onset asynchronies, compared to healthy control. Using MEG, we find that this is due differences in pre-stimulus alpha activity between the two populations. The specific source locations will be discussed. These results suggest that while different populations exhibit the same audio-visual behavioural outcomes, the underlying network maybe very different.

[2P099] Comparing Finger Movement Directions and Haptically Perceived Texture Orientation

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Exploratory movements and haptic perception are highly interlinked. We observed for grating textures with sine-wave ridges that, over the course of exploration, exploration direction is adjusted to be orthogonal to ridge orientation (Lezkan & Drewing, 2016). In the present experiment we measured perceptual and movement responses to texture orientations between  $-60^\circ$  (counter clockwise) and  $+60^\circ$  (clockwise) from movement orthogonal. Participants explored textures along a predefined path. In the perceptual experiment part they reported whether the texture was rotated clockwise. In the movement part an additional movement in a free chosen direction followed. Besides psychometric curves, we fitted “movometric” curves to the proportion of trials with clockwise shifting of movement direction. The pattern of “motor judgments” reflected the adjustment towards moving orthogonally across the gratings and showed that, similar to perceptual judgments, the required change in movement direction was more frequently recognized when the deviation from orthogonal was large. The precision of motor judgments was somewhat lower than perceptual precision, but both for perception and movement, precision was higher for textures with higher periods as compared to lower periods. Taken together, our results suggest that the same signals are used for perception and motor control in the haptic perception of gratings.

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[2P100] Musical training modulates brain recalibration of audiovisual simultaneity

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In order to overcome differences in physical transmission time and neural processing, the brain adaptively recalibrates

the point of simultaneity from its daily experience of different audiovisual events. Whether extended experience with specific audiovisual events modulate this recalibration process is still unclear. Musical expertise is a perfect model to discriminate among people with different levels of experience with audiovisual events. We tested a group of 11 drummers, 11 musicians (e.g., guitarists and pianists) and 11 non-musicians on a simultaneity judgment task before and after adaptation with two audiovisual events. For the flash-beep displays, the participants' point of subjective simultaneity shifted in the direction of the adapted lag, while for the drumming displays a shift in the direction of the audio leading lag was found irrespective of the direction of the adapted lag. The effect of adaptation for the musicians and drummers was larger than and in the opposite direction to that of non-musicians, while sensitivity to audiovisual asynchrony was greater in drummers than either musicians or non-musicians. These findings demonstrate that musical training modulates the recalibration to audiovisual events in the temporal domain, and that playing the drum enhances sensitivity to audiovisual simultaneity more than playing other instruments.

[2P101] Comparing ambiguous apparent motion in tactile and visual stimuli

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We examined the haptic version of the apparent motion quartet. In the visual version, alternating flashes of diagonal pairs of dots produce apparent motion in the horizontal or vertical direction. Proximity is important: if the dots form a rectangle, apparent motion favours the shorter over the longer sides. Here, we attached vibrating factors to the thumb and index fingers of both hands. Apparent motion was felt either within hands (index finger to thumb) or across the empty space between hands. Subjects slowly moved their hands toward and away from each other and indicated when the felt motion changed from within to between the hands. Subjects reported that the motion organisation was not always clear but were able to complete the task. The point at which motion within and between the hands was reported equally often occurred when the distance between the vibrators on the two hands was 44% greater than that between the vibrators on the thumb and index finger of each hand. Thus, surprisingly, sensations across the empty space between hands act as if they are closer together than those across the space within the hands. The switch-over ratio was compared between touch and vision over various configurations.

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[2P102] Multisensory adaptation: How visual are haptics?

**Stefan J Breitschaft, Claus-Christian Carbon**

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Aftereffects and adaptation are widespread phenomena in perception. Kahrmanovic, Bergmann-Tiest and Kappers (2009) found divergent haptic aftereffects after adaptation to rough and smooth stimuli. As haptic perception depends on several extero- and interoceptive inputs (see haptics framework by Carbon & Jakesch, 2013), we aimed to test, whether haptic adaptation can be induced by cross-modal adaptors such as extreme visual adaptors or additional mental imagery of extreme adaptors as well. 36 participants rated the roughness of ten abrasive papers ranging from 60 to 600 grain via a 101-point scale (smooth 0–100 rough). After baseline-rating participants got a haptic-, visual- and imagery-modality-condition, each containing a randomly ordered extreme smooth and rough adaptation-block, beginning with an 20-second-adaptation-phase in every trial, followed by a rating phase. Data of the first evaluation block were analyzed by means of between-participants-ANOVA. Results mirrored previous adaptation effects from the haptic domain (indicated by an adaptation effect to an extreme rough adaptor and contrast effect to an extreme smooth adaptor) demonstrating top-down effects here. Decreased perceived roughness was found in the visual-rough-condition, meaning an adaptation effect was induced by visual adaptation. In contrast, mental imagery yields an assimilation effect of roughness perception towards the adaptation effect.

[2P103] The apparent elongation of a disk by its rotation as haptic phenomenon

**Akira Imai<sup>1</sup>, Yves Rossetti<sup>2</sup>, Patrice Revol<sup>2</sup>**

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

longer to the turning hand. This apparent elongation of the disk could be called as "rotating-disk" illusion (Cormack, 1973). The phenomenon assumed to involve some illusory mechanisms in both hands. We tested the robustness of this illusion in experiment 1, and then divided the effects on this illusion by both hands into each one of hand. Eight participants rotated five disks one by one, and estimated perceived size of each disk as same way as Cormack's. The apparent size of disk was growing rapidly for 30 seconds and not to become asymptotic within 60 seconds suggesting that our results were feasible for those of Cormack. In experiment 2, we constructed a device which made participant rotate the disk by only one hand. The illusion did not increase by the rotation of preferred-hand, but appeared to grow gradually by the rotation of non-preferred-hand. The apparent elongation did not occur as effects of rotation by preferred-hand, but did appear as those by non-preferred hand, suggesting that the holding fingers usually used to rotation might have great influences on the illusion.

#### [2P104] Distinct Patterns of Bias in Visuo-haptic and Haptic-visual Slant Matching Tasks

**Juan Liu, Hiroshi Ando**

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Real-world tasks can often involve multiple sensory inputs encoded in different reference frames and previous studies have suggested that the CNS activates multiple internal representations for cross-modal tasks. Here, we explored whether cross-modal slant matching tasks of different target modality and response mode (e.g. visuo-haptic and haptic-visual tasks) combine visual and kinesthetic information in the same way. In our experiments, participants were asked to manually (H) or visually (V) adjust a test board to set it parallel to a reference board perceived visually (V) or haptically (H) in the midsagittal plane of three dimensional space. Our data show that although egocentric bias is observed in all of the four target-response modality conditions (VV, VH, HH, HV), the deviations in VH and HH tasks are much larger than those in HV and VV tasks. Furthermore, the bias in VH and HH conditions is influenced by the angle difference between reference and test locations, while that in VV and HV conditions is affected not by the reference location, but by the test locations. The distinct patterns of bias suggest different information-combining processes for VH and HV cross-modal tasks, which may be related to their response modalities.

#### [2P105] Hearing one's eye movements: effects of online eye velocity-based auditory feedback on smooth pursuit eye movements after transient target disappearance

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Due to poor proprioceptive and kinesthetic signals, eye-movements are a "cognitive black hole" as individuals can tell very little on the sequence of eye movements performed to reach a "visual goal". Here, we investigate whether providing an auditory feedback coupled to eye-movements helps improving oculomotor control (Boyer, 2015). To that aim, we asked untrained participants (N=20) to track a horizontally moving target disappearing after 900 ms behind occluders of different kinds (visible or invisible uniform masks; static or flickering textures; 4 blocks of 80 trials). Observers were to maintain smooth pursuit for 700 ms after target disappearance, a task known to be very difficult (Madelain & Krauzlis, 2003). In half the trials, participants received an auditory feedback based on eye velocity: eye data (EyeLink1000) were used to control the cutoff frequency of a filtered pink noise. The resulting sound mimics eye-speed fluctuations, with saccades muting the sound feedback. Results indicate that pursuit is best maintained on a flickering background, as compared to other occluders. No clear effect of sound on pursuit maintenance was found, but large inter-individual differences were observed, with sound improving or sometimes degrading pursuit gain, suggesting different cognitive and oculomotor profiles, a point that will be discussed.

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#### [2P106] Perceived audio-visual simultaneity as a function of stimulus intensity

**Ryan Horsfall, Sophie Wuerger, Georg Meyer**

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Recent behavioural findings suggest that auditory-visual integration mechanisms feed into separate 'action' and

'perception' streams (Leone & McCourt, 2015). Our experiment aimed to replicate this research with different stimulus parameters to evaluate its robustness. Two experimental tasks were used: a temporal order judgement (TOJ) and a simple reaction time task (RT). The stimuli for both tasks were identical bimodal flash/bleep stimuli with varying stimulus onset asynchronies (SOAs) (-200, -150, -100, -50, 0, 50, 100, 150, 200 msec). Three stimulus intensity conditions were run: dim light/quiet sound; dim light/loud sound; bright light/quiet sound. In the TOJ task participants had to indicate whether the visual stimulus preceded the auditory stimulus or vice versa. In the RT task observers had to respond as quickly as possible to the onset of the bimodal stimulus. Our preliminary results suggest that stimulus intensity affects perceived simultaneity (TOJ task). Observers' reaction times tend to be shortest at physical simultaneity but our preliminary data do not allow us to demonstrate significant differences between the perceived point of simultaneity and the SOA yielding minimum reaction times. Further results, including the effect of varying stimulus intensities across both tasks, alongside the introduction of a simultaneity judgement task, will be discussed.

[2P107] Integrating vision and haptics for determining object location

**Mark A Adams, Peter Scarfe, Andrew Glennerster**

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Both vision and haptic information are useful for determining the location an object, but currently little is known about how these cues are combined by freely moving observers. Here we examined whether people combine vision and haptic cues optimally according to a maximum likelihood estimator (MLE). To do this we used a novel methodology integrating immersive virtual reality and haptic robotics. In the haptic-alone task, participants reached out to touch three reference spheres placed on a circle (radius 22cm) and then a target sphere. Using 2AFC paradigm, participants judged whether the target was above or below the plane defined by the reference spheres. Participants wore a head mounted display (HMD) with a blank display. For the vision-only task, the spatial and temporal aspects of the stimuli were identical but the spheres were presented in virtual reality using the HMD. For vision and haptics, both cues were available, allowing people to explore the visible targets by touch. Precision for the vision-alone task was similar to that in the haptic-alone task. The observed PSE for the combined cue stimulus was compatible with a MLE prediction based on the sensitivity and bias for the individual cues.

Funding: EPSRC

[2P108] The clash of spatial representations: Modality switching knocks out the Simon effect

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Different sensory modalities represent spatial information in radically different formats that must be integrated in a unified reference frame for action. On the perceptual side, converging evidence suggests a dominance of vision over other senses in coordinating spatial representations, in an eye-centred reference frame. However, current research mainly focuses on stimulus processing, neglecting the relationship between stimulus and response. In this study, we contrasted stimulus-response spatial compatibility effects via Simon task, across modalities (vision and touch). When tested in isolation, vision operates in an external spatial frame of reference (left-right hemifield), whilst spatial reference frame in touch is defined anatomically (left-right body parts). Interestingly, when vision and touch are intermingled unpredictably, hence relevant spatial reference frames mixed, we found that the Simon effect disappeared for the visual modality, but persisted (in its native anatomical reference frame), for touch. Our results highlight the importance of action-oriented reference frames in spatial representations. We believe that stimulus-response contingency is in charge of spatial information management.

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[2P109] The variation in the signaling frequency in a multisensory experimental study causes different modality effect on the quality and quantity of the equilibrium function

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The multisensory EEG and behavioral studies of the audiovisual complex with the signal-frequency manipulation show a significant interaction effect caused by signaling frequency, sensory modality, and individual differences on the

psychophysical measures. In the present study the audiovisual complex was examined by means of the stabilometry, i.e. an objective measure of body oscillations during upright standing indicating changes in psychophysiological state and executive control functions. Participants were tested in two modality conditions, i.e. visual and auditory ones, with the respective modality information presented at 3, 5, and 10 Hz in each condition. The quantity and quality of the equilibrium function was evaluated prior to exposure (the pre-stimulation stage), during the exposure (the stimulation stage), and after the exposure (the post-stimulation stage). The results obtained showed significantly negative effect of the 5-Hz stimulation on the equilibrium function, regardless of the sensory modality involved, whereas the 3-Hz stimulation had a moderately positive impact in case of the auditory condition, and the 10-Hz stimulation had a strongly positive effect in the visual one.

[2P110] Perceived timing of multisensory events

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Temporal coincidence of events is an important cue for multisensory integration. Even though the brain accommodates timing differences between senses (Fujisaki et al., 2004; Vroomen et al., 2004), underlying mechanisms are still not completely understood. We investigated temporal integration of visual and auditory events in two experiments. Stimuli had varying magnitude of asynchrony between the senses (e.g. visual event presented 50ms before auditory). In the first experiment, participants estimated the onset of the stimuli following a self-paced key press. The task was to answer whether an event (visual, auditory or multimodal) appeared sooner or later than the average temporal onset of stimuli (method of single stimuli). In the second experiment, participants detected the onset of randomly timed multisensory events (speeded response). They were explicitly asked to attend to only one modality, ignoring the other sensory event. In the first experiment, the point of subjective equality was mainly driven by the attended modality, but it was also affected by the non-attended. In the second experiment, reaction times were mostly driven by the attended modality, but were also slightly influenced by the non-attended. Overall, our results suggest that both modalities contribute to the perception of timing of multisensory event.

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[2P111] Haptic shape adaptation is not object dependent

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When touching a slanted surface, the impression arises that after a period of time the surface appears less slanted or even level (adaptation). If subsequently presented with a physically level surface, this surface will be perceived as slanted in the opposite direction (adaptation aftereffect). Haptic shape perception, however, relies on both posture information as well as cutaneous (touch) information. The question arises whether haptic shape adaptation is object or posture based. If haptic adaptation is object-related it should only occur if an object is actively touched. Posture adaptation should affect haptic shape perception regardless of whether an object is touched during adaptation. To address this question, participants adapted to a virtual slant using the index fingers of both hands. In one condition, adaptation was induced by actively touching the surface (object present) in a second condition, participants adapted by keeping their fingers in mid-air at indicated locations (object absent). Results showed adaptation aftereffects for both adaptation conditions to equal extents, regardless of whether an object was present or not. This indicates that haptic shape adaptation can be fully explained by posture adaptation (proprioception). This implies that object constancy heavily depends on previous postures being similar.

Funding: This work was funded by the DFG Cluster of Excellence: Cognitive Interaction Technology 'CITEC' (EXC 277)

[2P112] Comparing physiological arousal for visually and haptically explored stimuli

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Although it is frequently reported that vision dominates over the other sensory modalities, it is still unclear whether this effect is related to a greater state of arousal. Here we report the results of a study on the psycho-physiological reactions to materials explored either by vision or by touch. While a group of participants (Group 1) was slowly stroked on the

forearm by means of different materials, a second group of participants (Group 2) visually explored the materials. The participants' task consisted in rating the pleasantness of the stimulation (Group 1) and the imagined pleasantness of being touched by those stimuli (Group 2). Skin conductance responses were also recorded in both groups. The results revealed that tactile exploration of the materials induced higher skin conductance responses as compared to visual exploration; this difference was higher for women than for men. The materials were rated as less pleasant when presented visually than when presented haptically. The results of an additional preliminary study (Group 3) showed that when participants watched videos of a person being stroked their arousal increased more than in Group 1 and 2. These findings are relevant to investigate the mechanisms of sensory dominance and visuo-tactile hedonic perception.

[2P113] Visual mechanisms in the face-sensitive posterior superior temporal sulcus facilitate auditory-only speaker recognition in high levels of auditory noise

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When listening to someone's voice we often also view their corresponding moving face. Even in the absence of facial input the brain recruits a face-sensitive region, the fusiform face area (FFA), to enhance auditory-only recognition of speakers known by face ("face-benefit"). These visual mechanisms could be particularly important under noisy listening conditions. Here, we used fMRI to examine responses in face-sensitive regions while participants recognised auditory-only speakers (previously learned by face or visual control) in low-SNR (-4dB) or high-SNR (4dB) listening conditions. We observed that in high-SNR conditions the behavioural face-benefit score was associated with increased FFA responses. Conversely, in low-SNR conditions the recognition of face-learned speakers engaged the bilateral face-sensitive posterior superior temporal sulcus (pSTS), regions sensitive to dynamic facial cues. The face-benefit score correlated significantly with functional connectivity between the right pSTS and a voice-identity region in the right anterior STS. We interpret these results within the framework of an auditory-visual model where stored facial cues are used in an adaptable manner to support speaker recognition. In high levels of auditory noise listeners may try to rely more on dynamic aspects of the voice and complementary dynamic face identity cues for recognition.

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[2P114] Response times in audio-visual cue-conflict stimuli

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How are response times affected by conflicting sensory modalities? We recorded perceptual reports and RTs for discrepant audio and visual cues. A shape subtending approximately 10 deg was displayed twice during 83 ms separated by 333 ms on a monitor. The size of the shape changed between the two occurrences so as to simulate a displacement in depth. Coincident with the visual displays, white noise was played through headphones with varying loudness also simulating a distance change (inverse square law). Participants reported whether the target was approaching or receding. Across trials, we varied mean displacements of the audio-visual targets and introduced a variable conflict between the two cues. Perceptual reports were modulated by the average displacement, regardless of the conflict between the cues, indicating that they were almost equally weighted, with a very small advantage (5% on average) for the visual cue. RTs appeared to be modulated entirely by the perceived displacement of the target. There was no evidence that cue conflicts had any impact on RT distributions (AUC=0.51 on average), suggesting that responses were mediated by a single decision process accumulating a fused estimate of the cues.

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[2P115] "When sounds speak faster than words": Audiovisual semantic congruency enhances early visual object processing

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The present study examined crossmodal semantic priming effects elicited by naturalistic sounds or spoken words on early stage of visual picture processing where the picture was detectable but its category had yet to be fully determined. In each trial, an auditory prime was followed by a picture which was presented briefly and then masked immediately. The participants had to detect the presentation of any picture (detection task) or any picture belonging to the category

of living- (vs. non-living-) things (categorization task). In the detection task, naturalistic sounds elicited a crossmodal semantic priming effect on picture sensitivity (i.e., a higher  $d'$  in the congruent than in the incongruent condition) at a shorter stimulus onset asynchrony (350 ms) than spoken words (1000 ms). In the categorization task, picture sensitivity was lower than in the detection task, but it was not modulated by either type of auditory prime. The results therefore demonstrate that semantic information from the auditory modality primed the early processing of a visual object even before knowing its semantic category. The faster crossmodal semantic priming effect by naturalistic sounds than by spoken words was attributable to the former's accessing meaning directly, whereas the word's meaning is accessed via lexical representations.

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[2P116] Effect of audio-visual source misalignment on timing performance

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This study investigates the psychophysical effect of audio-visual source displacement on auditory timing performance. Two speakers hidden behind a screen were placed along the horizontal meridian at various separations. Each speaker produced a white noise burst using a range of onset lags and subjects reported their temporal order. Predictably, performance improved with increasing speaker separation. This allowed us to equate performance by choosing the speaker separation corresponding to 50% improvement. This provided a baseline for Experiment 2: each trial was accompanied by two synchronous disks projected horizontally onto the screen at various angles of displacement relative to the speakers. The luminance of both disks changed abruptly coincident with the first noise burst, then again with the second burst. Performance improved maximally when the audiovisual signals were aligned then deteriorated gradually with increasing disk eccentricity. Intriguingly, even small audio-visual misalignments in the direction of fixation bore no improvement in auditory TOJ performance. These results suggest that the perceived (ventriloquized) location of auditory events, rather than their physical location, limit the resolution with which humans make auditory timing judgments.

[2P117] Adaptation to softness in haptic perception - temporal and spatial aspects

**Anna Metzger, Knut Drewing**

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Recent sensory experience (temporal adaptation) and nearby surround (spatial adaptation) can influence perception. We studied the impact of temporal and spatial adaptation on haptic softness perception. Participants compared two silicon rubber stimuli (standard and comparison) by indenting them simultaneously with their index fingers and reported which one felt softer. To induce temporal adaptation, an adaptation stimulus was indented repeatedly with the index finger before the standard was explored with it. To induce spatial adaptation the adaptation stimulus was indented with the middle finger at the same time as the standard was explored with the index finger. We used adaptation stimuli with higher, lower and same compliance as the standard stimulus. We measured Points of Subjective Equality (PSEs) of two standard stimuli to a set of comparison stimuli, and compared them to PSEs measured without adaptation. We found temporal adaptation effects: after adaptation to harder stimuli, the standard stimuli were perceived to be softer, and after adaptation to softer stimuli, the standard stimuli were perceived to be harder. Adaptation to softness suggests that there might be neural channels tuned to different softness values and that softness is an independent primary perceptual quality.

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[2P118] Spatiotemporal interactions in the ventriloquist effect

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The location of auditory stimulus is perceptually shifted towards a synchronous visual stimulus presented in close proximity, a phenomenon called ventriloquist effect. We explore how illusion is modified by the combined influence of spatial discrepancy and asynchrony. Participants reported whether sound came from left or right of fixation while we presented visual stimulus with 8 spatial discrepancies ranging up to 25° and 3 temporal discrepancies (synchronous,

and two equal but opposite asynchronies). Participants also performed temporal order judgments to draw attention to asynchrony. We calculated the location that was perceived straight ahead to determine the weight assigned to visual information while assessing sound location. Our results confirm that synchronous visual stimuli influence perceived auditory location, and the influence decreases with increasing spatial discrepancy. With small spatial discrepancies, judgment precision improves beyond the level of audio-only judgments for all three asynchronies. We also found strong visual capture with audio-first asynchronies of about 120ms and small spatial discrepancy. Finally, in synchronous trials participants adjusted the weight given to vision based on the magnitude of asynchrony tested in conditions. These findings highlight a complex pattern of interactions in the ventriloquist effect that depend on the combined spatial and temporal discrepancy.

[2P119] Investigations of inter-ocular grouping for luminance- and contrast-modulated stimuli

**Jan Skerswetat, Monika A. Formankiewicz, Sarah J. Waugh**

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Rivalrous luminance stimuli (L) presented dichoptically, each containing parts of two images, can generate periods during which one image is perceived due to inter-ocular grouping (IOG) or processing beyond the monocular level. We investigated the effects of different stimulus visibility level on IOG using L and luminance-modulated noise (LM) stimuli and compared the results with those of contrast-modulated noise (CM) stimuli. Rivalrous grating stimuli, 2 deg in diameter, were constructed such that half of each contained a horizontal, and the other half a vertical, 2 c/deg sinusoid. Contrasts for L- and LM-stimuli were 0.98, 0.08, 0.03 and 0.78, 0.10, 0.06, respectively. The contrast-modulation depth for CM-stimuli was 1.00. Participants had to indicate whether exclusive horizontal or vertical IOG, superimposed, or any other percept, was seen. IOG for L- and LM-stimuli was perceived proportionally more [ $p < 0.05$ ] for all contrast conditions compared to CM-stimuli. Decreasing L and LM contrast led to an increase of IOG. CM-stimuli produced mainly superimposed percepts, suggesting binocular combination rather than IOG. The results suggest different initial processing sites for IOG and superimposition as well as a predominately binocular processing site for CM compared to L- and LM-stimuli.

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[2P120] Differential modulation of foreground and background in early visual cortex by feedback during bistable Gestalt perception

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A growing body of literature suggests that feedback modulation of early processing is ubiquitous and central to cortical computation. In particular stimuli with high-level content have been shown to suppress early visual regions, typically interpreted in the framework of predictive coding. However, physical stimulus differences can preclude clear interpretations in terms of feedback. Here we examined activity modulation in V1-V2 during distinct perceptual states associated to the same physical input. This ensures that observed modulations cannot be accounted for by changes in physical stimulus properties, and can therefore only be due to percept-related feedback from higher-level regions. We used a bistable dynamic stimulus that could either be perceived as a large illusory square or as locally moving dots. We found that perceptual binding of local elements into an illusory Gestalt led to spatially segregated modulations: retinotopic representations of illusory contours and foreground were enhanced, while inducers and background suppressed. The results extend prior findings to the illusory-perceptual state of physically unchanged stimuli, and show also percept-driven background suppression in the human brain. Based on our prior work, we hypothesize that parietal cortex is responsible for the modulations through recurrent connections in a predictive coding account of visual processing.

[2P121] Figure-ground organization interferes with the propagation of perceptual reversal in binocular rivalry.

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How perceptual organization emerges through the dynamics of the hierarchically organized visual system is essential

to understand human vision. Figure-ground organization is a typical Gestalt phenomenon emerging through dynamic interactions between the local properties and global configurations of images. To investigate this dynamics, we analyzed the effect of figure-ground organization on a “traveling wave” in binocular rivalry where the reversal of perceptual dominance is triggered at a particular location and spreads in a wave-like fashion. The traveling wave was induced in a semi-circular pattern with either a small, a large or no occluder present in the middle of the semi-circle. The semi-circle was presented either vertically or horizontally. Ten participants participated in the experiments. The subjects’ task was to report if the traveling wave reached the first edge of the occluder and if it reached the end of the semi-circle (target) by a key press. In the vertical configuration, the probability of the traveling wave reaching the target was reduced by the presence of the occluder. In the horizontal condition, this effect was not evident. This suggests different dynamics of neural interactions when global signals are processed intra- and inter- hemispherically. Funding: NK: Fund for Scientific Research Flanders (FWO) post-doc grant 12L5112L, JW: Methusalem program by Flemish Government METH/08/02 and METH/14/02

## [2P122] Hysteresis in Processing of Perceptual Ambiguity on Three Different Timescales

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Background: Sensory information is a priori incomplete and ambiguous. Our perceptual system has to rely on concepts from perceptual memory in order to disambiguate the sensory information and to create stable and reliable percepts. In this study we presented the Necker lattices and disambiguated variants with different degrees of ambiguity in ordered sequences and studied the influence of memory on the perceptual outcome. Methods: Fifteen healthy participants observed two periods of ordered lattice sequences with stepwise increasing and decreasing ambiguity and indicated their percepts. Two experimental conditions differed by the identity of the starting stimulus. We compared differences in the effects of presentation order on perception between conditions and periods. Results: Perception of stimuli with stepwise increasing and decreasing ambiguity followed psychometric functions, with maximal ambiguity at the inflection points. We found significant hysteresis-like lateral shifts of the psychometric functions between conditions and periods. Discussion: Our results indicate memory contributions to perceptual outcomes on three different time scales from milliseconds over seconds up to lifetime memory. The present hysteresis paradigm allows differentiation and quantification of memory contributions to the perceptual construction process.

## [2P123] Under what conditions is optokinetic nystagmus a reliable measure of perceptual dominance in binocular rivalry?

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Current computational models of multistable perception (Pastukhov et al, 2013) are focusig on the dynamic balance of competition, adaptation, and noise under conditions of binocular rivalry (BR). Optokinetic nystagmus (OKN) has recently been exploited as an objective measure of perceptual dominance in BR (Frassle et al, 2014). BR-OKN might also reveal meaningful differences in the dynamic balance of perception in patients with known perceptual alterations, therefore, it is a promising paradigm for translational studies. In spite of its objectivity, a significant drawback of the paradigm is that BR induced OKN heavily depends on instructions as well as on a number of stimulus parameters (spatial frequency, speed, frame size, fixation marks, etc). We have investigated the impact of those with the purpose of establishing a standard paradigm of BR-OKN. Eye-movements of adult observers, induced by sinusoidal gratings drifting in opposite directions were recorded, and the impact of instructions and stimulus parameters were systematically tested. We concluded that under a number of conditions, OKN is not readily induced in naïve subjects, however, an optimal instruction/stimulus configuration exists where BR-OKN is a reliable measure of perceptual dominance, and seems stable and general enough to be used both in modeling and translational studies. Funding: Supported by OTKA NN 110466 to I.K., and DFG funding to J.B.

## [2P124] Social influences on binocular rivalry

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Rival stimuli compete for access to visual awareness under conditions of binocular rivalry. Typically, the dominant percept alternates between two dichoptically viewed images every few seconds. For example, in face-house rivalry, images of faces dominate for longer periods than those of houses. The emotional expression of facial stimuli can also alter dominance durations, such that faces depicting fearful or happy expressions dominate longer than neutral expressions. Extending research of this kind, here we report two studies in which face-valence was manipulated via social-learning experiences. In Experiment 1, valence was varied by pairing positive or negative personality-related information with faces. In Experiment 2, it was manipulated through the status of players (i.e., excluder or includer) in a ball tossing game (i.e., Cyberball) that is commonly used to trigger ostracism. In both experiments, we show that face dominance is significantly longer for stimuli associated with negativity, thereby demonstrating the effects of social learning on binocular rivalry.

[2P125] Sensitivity and response criteria in reporting binocular rivalry

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Observers typically report binocular rivalry by pressing one key whenever and for as long as one rival image is dominant and another key whenever and for as long as the other image is dominant. Deciding when to press a key involves sensitivity to the dominant image and response criterion. We studied sensitivity and response criterion with unambiguous combinations of the two images to determine if they are correlated with reports of binocular rivalry between the same images. Sixty-six participants pressed keys to report binocular rivalry between 4-minute displays of dichoptically orthogonal oblique gratings. Then they performed a 2AFC task to dioptic displays of optical superimposition of the two rival images, ranging over seven values, from one image's having 90% contrast and the other's having 10% contrast, to the two images' having 50% contrast. We presented the combined images for either 250 ms or 1000 ms. We found that the median binocular-rivalry dominance duration was high when participants had a liberal response criterion in the 250-ms 2AFC optical-superimposition task. No other possible correlations were significant. These results suggest that sensitivity does not affect reporting of binocular rivalry but response criterion does.

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[2P126] Differentiating aversive conditioning in bistable perception: avoidance of a percept vs. salience of a stimulus

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Bistable perception mostly depends on basic image characteristics, but there is also growing interest in the influence of psychological factors (top-down effects) on perceptual inference. An interesting case is given for the putative effect of negative valence on bistable perception because this could either lead to a decrease of perceptual dominance (cf. avoidance in instrumental conditioning) or an increase (cf. psychological salience). Here, we tested the hypothesis that two different types of conditioning can indeed be separated for that case. In a randomized 2-groups design, participants received either a standard pavlovian conditioning procedure where a visual stimulus A (but not B) was repeatedly paired with an aversive sound (group#1); or they received an aversive instrumental conditioning where the outcome of the perceptual inference process during binocular rivalry (i.e. perceptual dominance of stimulus A but not B) was paired with the aversive sound (group#2). In a subsequent binocular rivalry test, relative dominance of the conditioned percept/ stimulus increased for a short time in both groups, but dropped thereafter only in the instrumental conditioning group (group#2), yielding a significant time x group effect. This result supports the claim of differential top down effects on perceptual inference that go beyond attention.

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[2P127] The interaction between temporal properties and spatial density of the mask on continuous flash suppression effectiveness

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Continuous Flash Suppression (Tsuchiya & Koch, 2005) is a paradigm, in which a series of different Mondrian

patterns is flashed to one eye at a steady rate, suppressing awareness of the image presented to the other eye. CFS has been widely used to investigate visual processing outside of conscious awareness. CFS may depend on the flashing mask continually interrupting visual processing before the stimulus reaches awareness. In this study, we investigated the relationship between masking effectiveness and two mask parameters: temporal frequency and spatial density. We investigated the suppression effectiveness of a wide range of masking frequencies (0-32Hz), using a breakthrough CFS paradigm with photographic face and house stimuli while systematically varying the spatial density of the masks. We found that the break-through contrast differed dramatically with temporal masking frequency as well as spatial density. We fitted the data with a skewed Gaussian function. The peak frequency changed with the spatial density of the masks: the peak frequency increased with reduced spatial density. There was no significant difference in peak frequency between face and house stimuli. These results are consistent with the idea that temporal factors in processing the mask influence its effectiveness in dominating access to awareness.

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[2P128] Attentional modulation of binocular rivalry

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Binocular rivalry (BR) involves a different kind of visual selection from that observed during selective attention, where attending to one of the two stimuli does not render the unattended stimulus invisible. Here we studied the effect of directing attention implicitly onto one rival image on subsequent BR tasks. We designed a numerosity task (NT) embedded in BR (NT+BR). We inserted two types of elements into one of the rival images. Thus, a participant must attend to that image in order to perform the NT, that was to report which element was more numerous. The BR stimuli were two  $\pm 45^\circ$  gratings. The participants performed the NT+BR task and finally repeated the BR task. The main manipulation was to focus the observers' attention implicitly on one of the competing images. Our results show that the manipulation of the attentional focus significantly increased the durations of dominance periods, but not the perceptual alternation frequency. This suggests that the frequency of BR alternations is an identifying feature of one observer's perception, and the frequency is not sensitive to the attentional manipulation.

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[2P129] EEG correlates of memory contribution to perceptual disambiguation

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Perception of ambiguous figures (e.g. Necker cube) is unstable and alternates spontaneously between different interpretations. Tiny figural changes can disambiguate an ambiguous stimulus, stabilize its percept and increase the amplitudes of two event-related potentials (anterior P200 and posterior P400). In the present study we investigated the influence of sensory evidence and memory on the two ERP amplitudes. Methods: We presented pairs of Necker lattice variants and varied ambiguity of the first (S1) and second (S2) stimulus in four separate conditions. Participants indicated their percept of S1, and identical or changed percepts of S2 compared to S1. EEG to S2 was selectively averaged with respect to the ambiguity of S1 and S2. Results: The amplitude of the S2-related P200 was inversely correlated with the ambiguity of S1. P400 amplitude, in contrast, was inversely correlated with the ambiguities of both S1 and S2, with largest amplitudes when both stimuli were unambiguous. Discussion: The latencies of the two ERP components indicate that both occur during higher processing steps, after lower-level visual analysis. They can be functionally separated by their different dependence on memory content. Remarkably, the influence of memory content on both components indicates a re-evaluation of perceptual constructs at each processing step.

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[2P130] Long- and short-term memory in repeated visual search

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When the same display is searched twice or thrice, short-term memory supports visual search: In a subsequent search,

participants find only those items faster which they had recently inspected in a previous search. In contrast, when a display is searched many times, long-term memory is involved as search performance increases continuously across trials. Here, we investigated whether both short-term and long-term memory support a repeated search with many repetitions. We had participants search a display 60 times while we recorded their eye movements. The display either remained the same throughout (static condition) or, as a control, the items switched position after each search while the layout remained stable (switch condition). The results showed that long-term memory supported search in the static condition: Search became faster with repetition. However, participants seemed not to benefit from short-term memory: Recently inspected items of a previous search were not found faster in a subsequent search. This suggests that searching a display many times involves memory processes different from those required for searching a display only twice or thrice.

[2P131] Influencing working memory using social and non-social attention cues

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Information processing requires working memory (WM) for goal directed behaviour. We therefore investigated how and under what conditions three central attention cues, which vary in sociability and meaning, could influence WM accuracy. We measured WM for four, six and eight coloured squares as a function of non-predictive central cues (gaze, arrow, line-motion). Squares at encoding were cued validly, invalidly or not cued. Across experiments, we manipulated memoranda location at encoding to be unpredictable (squares appeared on one side of the cue only; Unilateral) or predictably balanced (squares on both sides; Bilateral), and cue-target onset time – 150ms/500ms SOA. Valid gaze cues significantly enhanced WM at 500ms but not 150ms SOA, indicating volitional rather than reflexive processes. This gaze effect was strongest when squares location was unpredictable (Unilateral). When Bilateral, gaze effected WM at higher loads only. The arrow cue (500ms SOA) mirrored the gaze effects in the Bilateral condition, but did not influence WM for unilaterally presented items. A valid line-motion cue (150ms SOA; known to orient attention) enhanced WM but only in the Bilateral condition at low memory loads. Thus, different cues influence WM as a function of cue meaning, memoranda laterality, cue-target timing, and memory load.

[2P132] Neural correlates of color working memory: An fMRI study

**Naoyuki Osaka<sup>1</sup>, Takashi Ikeda<sup>2</sup>, Mariko Osaka<sup>2</sup>**

<sup>1</sup>Psychology, Kyoto University; <sup>2</sup>Osaka University

We investigated, using an fMRI, how color visual patches could be memorized either in visual or verbal working memory depending on the color category borders? Successive color matches across the hue categories defined by distinct basic colors strongly activated the brain's left inferior frontal gyrus and left inferior parietal lobule possibly due to the phonological loop (PL) which is thought to be localized in the inferior parietal region in the left hemisphere (BA 40; working as short-term phonological-verbal- store) in connection with Broca's area (BA 44 and ventral part of BA 6 known as the vocalization area). These basic colors are likely verbally encoded in the left prefrontal cortex under the verbal working memory system. However, color matching within the same hue category having slight hue differences activated the right inferior frontal gyrus possibly due to the visuospatial sketchpad (VSSP) connected with the right inferior frontal area (visual short-term store) in the prefrontal brain under the visual working memory system.

[2P133] Working memory precision for emotional expressions of faces

**Kaisu Ölander, Ilkka Muukkonen, Viljami Salmela**

Institute of Behavioural Sciences, University of Helsinki, Finland

We investigated whether the memory precision for images of human faces depends similarly on the memory load as the precision for primary visual features. Images of 60 identities from the Radboud and FACES databases were continuously morphed between a neutral and emotional (angry, disgusted, fearful, happy or sad) expressions. We measured 1) psychometric functions for emotion intensity discrimination of two simultaneously presented faces, 2) distribution of adjustment errors of intensity for 1-5 faces after a 2 second retention period, and 3) error distributions for a single face while remembering orientation of 1-3 Gabor gratings. Mixture model defined by univariate and Gaussian distributions was fitted to the data. The discrimination thresholds did not depend on the emotion intensity. As a function of memory load, the precision of all facial expressions and grating orientations decreased with a similar

slope. However, both discrimination and memory precision varied across emotions, and were best for happy and worst for sad faces. Importantly, precision for a single face was not affected by the gratings. Coefficient of univariate distribution was low throughout conditions. Consistent with previous studies, the results suggest that the memory precision depends both on the memory load and on the complexity of the stimuli.

[2P134] Verification of the reliability of MEG source localization using VBMEG in visual short-term memory

**Mitsunobu Kunimi, Nobuo Hiroe, Maro G. Machizawa, Okito Yamashita**

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Previous studies using current source estimation technique in magnetoencephalography (MEG), for example, beamformer and minimum-norm, have reported involvement of the intra-parietal sulcus (IPS) and the intra-occipital sulcus (IOS) during the maintenance of visual information in visual short-term memory (VSTM) (e.g. Robitaille et al., 2010). However, such results of current source estimation may be unreliable because of its underlying ill-posed nature of the inverse problem, provoking a need for test-retest verification. Here, the test-retest reliability of MEG source estimation by the VBMEG (Sato et al., 2004), a source estimation algorithm with high spatial resolution, was examined on neural activities associated with VSTM. Five healthy young adults repeatedly performed a color-change detection task (two set sizes x two hemifields) while brain activities were recorded in an MEG on two different days. Although there were some individual differences on the current sources reflecting set-size effect, consistent activations were identified in the regions around the IPS and the IOS ([BA] 7, 19, 39, 40) for all the participants across different days. We provide further evidence of the IPS and the IOS as neural basis of VSTM.

Funding: This study was supported by the National Institute of Information and Communications Technology and Grant-in-Aid for Young Scientists B # 15K17335 from the Japan Society for the Promotion of Science.

[2P135] Color affects memory not totally but shortly

**Haruyuki Kojima, Ayasa IMURA**

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Red background color enhanced memory performance (e.g. Mehta & Zhu, 2009, Science) and so did red illumination color (Kojima, 2012, ECVF). The present study further investigated the influence of color on learning and memory. METHODS: In Experiment 1, participants were shown two-character non-words, serially one by one, which were colored red, blue or black with white background on a PC monitor. The characters were clear enough to read. They were asked to memorize and reproduce them (fifteen words). In Experiment 2, participants ran with black characters on colored backgrounds. In Experiment 3, stimulus characters were all black on white. They were instructed to write down the words on a paper either with a red, blue, or black pen. Twenty students with normal color vision participated in the each experiments (within-subject design). RESULTS: The total performance did not show any difference among three color conditions either in the three experiments. However, in part, the performance was lower in red than other colors during the middle serial positions in Experiment 2 ( $p < .05$ ), while it was better with blue pens than red or black in the last two words in Experiment 3 ( $p = .05$ ). The color may affect to the short-term/working memory.

[2P136] Rapid Access to Visual and Semantic Representations in Iconic Memory

**Jasmina Vrankovic, Veronika Coltheart, Nicholas Badcock**

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We can easily understand the visual environment despite our eyes moving to take in new information three to four times per second. This rapid information flow may initially be registered in iconic memory, a brief high-capacity store containing literal visual representations. Evidence for semantic representations in iconic memory has not been demonstrated. This study investigated whether visual and semantic representations can be accessed in the very early stages of visual memory. Arrays of six objects were presented for 50ms, 150ms, or 250ms. Following array offset, a cue specified full-report (recall of all six objects) or partial-report (recall of one object). Experiments 1 and 2 investigated whether location information (pointer to spatial location) and semantic information (instruction to report object from a particular category) could cue recall. In both experiments, partial-report performance was significantly greater than full-report performance and recall improved with longer exposure duration. Experiments 3 and 4 investigated the duration of visual and semantic representations by delaying cue presentation. Visual representations decayed significantly when the cue was delayed by 100ms. Semantic representations did not decay for cue delays of up

to 500ms. These findings challenge the initial conceptualisation of iconic memory and its role in subsequent stages of memory.

[2P137] Integration of context and object semantic representations during rapid categorisation within and between the cerebral hemispheres

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Previous research has demonstrated the importance of context-object associations in rapid scene categorisation, showing facilitation arising from semantic consistency. We aimed to disentangle the perceptual and representational bases of this effect, presenting briefly the context and the object within the same image (Experiment 1) or in two separate simultaneous images, with the object embedded in 1/f coloured noise (Experiments 2-4). Using a divided-visual-field paradigm, we also examined the role of the functional asymmetries of the cerebral hemispheres (unilateral presentations, Experiments 1-2) and of hemispheric co-engagement (bilateral presentations, Experiments 3-4) in image categorisation. Participants had to report both the context and the object. We found a consistency effect, although slightly reduced, even for separate presentations, suggesting that the semantic memory for context-object associations is activated partially regardless of whether the two levels are integrated in the same percept. While we did not show any hemispheric difference in the consistency effect, we reported some evidence for a processing superiority of the right hemisphere for context information and of the left hemisphere for object information. Moreover, better performance for bilateral than unilateral presentations suggested a benefit due to interhemispheric interaction. Finally, better context than object categorisation supported a coarse-to-fine model of visual processing.

[2P138] The neural basis of serial behavioral biases in visual working memory

**Joao M Barbosa<sup>1</sup>, Christos Constantinidis<sup>2</sup>, Albert Compte<sup>1</sup>**

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Bump-attractor models offer an elegant explanation for the physiology and the behavioral precision of working memory via diffusing bumps. So far, this model has largely ignored the influence of previous trials, assuming a resetting of the circuit after the animal's report. Nevertheless, previous memoranda have been shown to interfere attractively with newly stored locations, consistent with a bump attractor perspective]: instead of being reset, the circuit keeps old memory representations as activity bumps that interfere with future trials. To address the neural basis of this interference, we analyzed behavioral and prefrontal neural data from monkeys performing an oculomotor delayed response task. We found that monkeys showed a bias towards previous reported locations, which was attractive for previous reports very similar to the currently memorized location, and repulsive for more distant previous reports. Although this could be explained by interacting bump attractors, we found that neuronal activity during the fixation period was only partially consistent with this view: pairwise correlations but not single-neuron activity showed the expected pattern for diffusing bump dynamics. This shows that during fixation the prefrontal network is still imprinted with previous memories, possibly underlying serial behavioral biases in working memory.

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[2P139] Dissociable brain networks revealed single-repetition learning in Braille reading and Braille writing-from-memory

**Lora Likova, Christopher Tyler, Kristyo Mineff, Laura Cacciamani, Spero Nicholas**

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Introduction. Fundamental forms of high-order cognition, such as reading and writing, are usually studied in the context of vision. People without sight, however, use (non-visual) Braille reading (BR) and Braille writing (BW). Are there rapid learning changes reorganizing the recruitment of neural resources in these complex tasks? There have been no previous functional Magnetic Resonance Imaging (fMRI) studies on BW. Consequently, no comparative learning dynamics analysis of BW vs. BR exists. Here, we report the first study of BW, and of rapid learning reorganization in both BR and BW-from-memory. Methods: fMRI was conducted in a Siemens 3T Trio scanner. Each of five paragraphs of novel Braille text describing objects, faces and navigation sequences was read in Braille, then reproduced twice by BW-from-memory, then read a second time (20s/task). Results and Conclusions: Remarkably, in both tasks, a

single repetition led to highly dissociable changes in the global patterns of activation across the cortex. Dramatic posterior-to-frontal shifts manifested repetition-suppression posteriorly (implying increased efficiency of lower-level processing) simultaneously with repetition-enhancement frontally (implying the engagement of additional, higher-order cognitive processing) with only the single repeat. In many regions, robust activation either completely evaporated or appeared de novo between the original and the repeat epochs.

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## [2P140] Temporal Processing of Visual Information and Its Influence on Visual Working Memory Representation

**Turgut Coşkun, Aysecan Boduroglu**

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The general approach of visual information acquisition into cognition favors a coarse-to-fine order such that lower spatial frequency (LSF) information is extracted earlier than higher spatial frequency (HSF) information. An alternative approach suggests some flexibility in information acquisition: For example, top down processes may modulate the initial usage of LSF (coarse) or HSF (fine). The aim of this study was to compare these two approaches focusing on the construction of visual working memory (VWM) representations. For this purpose, we utilized a change detection paradigm. The results revealed a flexible order in VWM construction. In the first experiment, when upright faces were presented, an initial Configural-LSF and a later Featural-HSF association were observed. Further, both LSF and HSF information were available at a very initial stage, after encoding the stimuli for 100 ms. In the second experiment, when face images were presented in inverted orientations, the performance of observers were reduced to chance level in the 100 ms exposure duration, for all conditions. Further, in the 500 ms condition, they had a tendency to represent inverted faces in HSF and featurally rather than in LSF and configurally. Thus, there was not a fixed coarse-to-fine order in VWM construction in face processing.

## [2P141] Remembering who was where: Visuospatial working memory for emotional faces and the role of oculomotor behavior

**Sara Spotorno, Margaret Jackson**

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Here we investigated for the first time face identity-location binding in visuospatial working memory (VSWM), and examined the influence of WM load and emotional expression. We measured eye movements during encoding of faces presented in random locations on a touchscreen, with WM loads 1 to 4 and angry vs. happy expressions. At retrieval, participants had to touch and drag a single neutral test face, centred on the screen, back to its original position. Performance was measured as (1) accuracy, whether the test face was relocated within 7-deg radius from its original face centre, and (2) precision of relocation within that region. We found accuracy and precision impairments as load increased, and an accuracy advantage for happy faces. Oculomotor behaviour affected mainly accuracy at higher loads (3 or 4) and independently of face emotion. There was a benefit of longer mean fixation duration overall on the tested face, and in particular of longer first ocular inspection, suggesting a crucial role of information gathering especially during early face encoding. Accuracy was also improved when the tested face was one of the last to be fixated, indicative of a recency effect that could protect against interference and decay.

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## [2P142] Exploring the shape-specificity of memory biases in color perception

**Toni P Saarela<sup>1</sup>, Maria Oikkonen<sup>2</sup>**

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Background: Perceived hue exhibits a memory-dependent central tendency bias: The perceived hue of a stimulus held in memory shifts towards the average hue of recent stimulus history. We tested whether different shapes elicit unique biases when their hue distributions differ, or whether all biases are towards the average hue across shapes. Methods: Observers compared the hue of two stimuli in a 2IFC task. A 2-second delay separated the reference (first) and test (second) intervals. Two shapes, a circle and a square, were used on different trials. Both had three reference values ranging from blueish to greenish in CIELAB color space; circles were on average greener and squares bluer. Test hue was varied, and on each trial the observer indicated whether it appeared bluer or greener than the reference.

Psychometric functions were fit to the proportion-greener data to estimate the perceived hue of the memorized reference. Results: All observers showed a memory bias: Blue hues were remembered greener than veridical, and vice versa. Shape had no systematic effect: Perceived hue was biased towards the average hue of all stimuli, not towards shape-specific averages. Conclusion: The memory bias for hue with simple 2D shapes depends on the overall, not shape-specific, hue distribution.

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[2P143] Topography of memory interference in visuo-spatial working-memory

**David S Bestue, João Barbosa, Albert Compte**

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Visuo-spatial Working Memory (vsWM) experiments suggest that prefrontal persistent activity underlies vsWM storage. Bump-attractor models elegantly link prefrontal physiology and behavioral vsWM precision via diffusing bumps of neural activity. We previously validated behaviorally a model-predicted memory bias whereby memory traces attract or repulse each other in the delay period. Here, we start to extend our bump attractor model from one to two dimensions by testing attraction/repulsion biases in the radial and angular dimensions. We conducted a vsWM task where fixating subjects remembered two nearby colored dots through a delay, and reported the location of the color-coded dot. In angle testing trials, the stimuli had the same radial location but different azimuthal angle, while in radial testing trials the stimuli were separated only radially from fixation. In angle testing trials we found changes in the delay-dependent bias between same azimuthal angles in different radial positions, suggesting an important effect of distance from fixation in vsWM rather than a radially-maintained angle effect. In radial testing trials, similar attraction/repulsion biases point to a bi-dimensional mapping of vsWM biases. Quantitatively, we found that similar visual distances entailed different delay-dependent biases for each set of trials, suggesting non-cartesian mapping of vsWM.

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[2P144] Left extrastriate body area shows sensitivity to the meaning of symbolic gestures: evidence from fMRI adaptation

**Agnieszka Kubiak, Gregory Kroliczak**

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Functional magnetic resonance imaging (fMRI) adaptation paradigm was used to test if semantic information contained in object-related transitive gestures and intransitive symbolic gestures is represented differently in the temporal and parietal cortex. Participants watched back-to-back videos (2.75s duration) where the meaning of gesture was either repeated or changed with movement kinematics controlled for. The just observed (typically second) gesture was imitated. Attention was controlled by showing trials with a single video. fMRI adaptation – signal decreases or repetition suppression – for watching both gesture categories were revealed in the lateral occipital cortex. Yet, intransitive vs. transitive gesture specific adaptation was observed only in the left caudal middle temporal gyrus (cMTG) and rostral extrastriate body area (rEBA). Repetition enhancement, i.e. signal increase, associated with watching transitive gestures was shown in the precuneus. Our outcomes support traditional views that cMTG represents the concepts of actions or the “conceptual how”, and the precuneus represents visuospatial processing. Notably, rEBA repetition suppression is consistent with sensitivity to action meaning or the “semantic what” of actions. Thus, fMRI adaptation reveals a higher-order function of rEBA and its seminal role in the semantic network.

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[2P145] To tell or not to tell: gender-related information modulates visual social cognition in healthy women and breast cancer patients

**Alexander N Sokolov, Marina A Pavlova, Sara Y Brucker, Diethelm Wallwiener, Elisabeth Simoes**

Women's Health Research Institute, Department of Women's Health, Eberhard Karls University of Tübingen Medical School and University Hospital

Implicit negative information perceived as a threat impedes visual social cognition (eg. Pavlova et al 2014): telling that men are usually better than women on the event arrangement, EA, task (with no initial gender differences) drastically reduces women's performance. When diagnosed with breast cancer, women face a lot of threatening information that

may hinder their cognition, decision making and eventually, coping with the disease. We examined whether gender-related information affected performance on visual social cognition task in patients with mastocarcinoma. Two separate groups of patients (aged 40–55 years) and two control groups of matched healthy women were administered the EA task with standard instruction. In addition, one patient and one control group were told that men were commonly better on the task. With negative information, patients scored lower than controls, and lower than patients with standard instruction, indicating effects of both disease and information. Remarkably, the lowest scores occurred in patients with negative information. The outcome shows for the first time the impact of disease and information on visual social cognition, presumably blocking visual cognitive processing. This offers novel insights on improving physician-patient communication for enhanced visual cognitive processing in oncologic and other diseases.

[2P146] Does better encoding lead to slower forgetting?

**Haggar Cohen, Yoni Pertzov**

Psychology Department, The Hebrew University of Jerusalem, Israel

Visual Working Memory (VWM) is a crucial and limited cognitive ability. Recent studies have shown that information in VWM is rapidly forgotten, but it is still unclear what processes modulate the rate of forgetting. Here we assessed the influence of encoding advantage and top-down predictions on rapid forgetting, using a delayed-estimation task. Initially, four oriented bars were displayed but one appeared slightly before the rest. Following a variable retention interval (one or six seconds), participants estimated the orientation of one of the bars by rotating a probe bar. In the first experiment, the bar that was given an encoding advantage was probed in 25% of the time (encoding advantage was not predictive); while in the second experiment it was probed 85% of the time (now encoding advantage was predictive). We found that longer delays and shorter display time, led to larger estimation errors, but the two factors did not interact. However, in the second experiment, the interaction was significant; hence, predictive advantage during encoding led to slower forgetting. We conclude that better encoding increases the overall precision of recall, but does not lead automatically to slower forgetting. On the other hand, top-down priority does modulate the rate of rapid forgetting

[2P147] Object maintenance beyond their visible parts in working memory: Behavioral and ERP evidence

**Siyi Chen, Thomas Töllner, Hermann J. Müller, Markus Conci**

Department of Psychology, Ludwig-Maximilians-Universität, Munich

The present study investigated the relationship between working memory (WM) storage capacity and processes of object completion for memorizing partly occluded shapes. To this end, we used a change-detection paradigm in which to-be-memorized composite objects (notched shapes abutting an occluding shape) were either primed to induce a completed object or, alternatively, a mosaic interpretation -that is, an uncompleted representation of the presented shapes (see Chen, Müller, & Conci, 2016, *J. Exp. Psychol. Hum. Percept. Perform.*). Our results showed an effect of completion despite constant visual input: more accurate responses were obtained for completed as compared to mosaic representations when observers were required to memorize two objects, but this effect vanished with four to-be-memorized items. Moreover, a comparable completion effect was also evident in WM-related EEG measures during the retention interval. Specifically, the amplitude of the contralateral delay activity was larger for completed as compared to mosaic interpretations (again, in particular, for the smaller memory set size). In sum, this study demonstrates that WM capacity is characterized both by the number and perceptual fidelity of the represented objects. These findings support the view of WM as reflecting a continuous resource, with capacity limitations depending on the structured representation of to-be-remembered objects.

### ***Tuesday August 30th Symposia presentations***

[21S101] Covert attention within the foveola

**Martina Poletti<sup>1</sup>, Michele Rucci<sup>1</sup>, Marisa Carrasco<sup>2</sup>**

<sup>1</sup>Psychological and Brain Science, Boston University; <sup>2</sup>New York University

Vision is not homogenous within the foveola, the high-acuity region of the fovea. Microsaccades are finely controlled

to compensate for this inhomogeneity by bringing the locus of highest visual acuity in the foveola on salient objects. But can such high level control also extend to covert attention? Measuring shifts of attention within the foveola is challenging because fixational eye movements displace the retinal stimulus by an area as large as the foveola itself. We circumvented this problem by using a custom apparatus to stabilize the stimulus on the retina. Our findings show that attention can be selectively allocated toward objects separated by only 20 arcminutes in the foveola, leading to faster detection of targets presented at the attended location. Covert attention within the foveola also enhanced visual discrimination within the foveola; in a spatial cuing task observers reported the orientation of a tiny bar that could appear at four different locations at 14 arcminutes from the center of gaze. Performance was higher and reaction times faster when the cue was informative about the target's location than when it was not informative or provided wrong information. Our findings reveal that the resolution of attention is much finer than thus far assumed.  
Funding: NSF- BCS-1534932, NSF-ORAPLUS-1420212, NIH EY18363

[21S102] Enhanced sensitivity to scene symmetry as a consequence of saccadic spatio-temporal sampling  
**Andrew I Meso<sup>1</sup>, Jason Bell<sup>2</sup>, Guillaume S. Masson<sup>1</sup>, Anna Montagnini<sup>1</sup>**

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Mirror symmetry is everywhere around us. Perhaps as a consequence, humans and other animals are highly sensitive to it. Our recent work has demonstrated that the presence of symmetry in synthetic scenes consistently distorts the directions of spontaneously occurring saccades, aligning them along the axis of symmetry. This key result is replicated across several task conditions including both free exploration and during active axis discrimination as well as under dynamically refreshed presentations. This leads us to conclude that there is an underlying automated mechanism in play. To explore this, we use the dynamically recorded eye movements for each instance of the stimulus to jitter the image and recreate each resulting spatio-temporal retinal image. We then simulate the temporal integration of this dynamic image and estimate the orientation energy present. The time scales of integration simulated determine whether the dots remain spatially independent or blur into elongated lines predominantly parallel to the axis of symmetry. In the latter case, symmetry becomes easier to detect with standard oriented luminance filter models. We propose and discuss an appropriate temporal component to standard symmetry models which exploits additional orientation information afforded by the saccades.

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[21S103] Perceptual re-calibration through transsaccadic change  
**Matteo Valsecchi, Karl Gegenfurtner**

Department of General Psychology, Justus-Liebig-Universität Giessen

Humans experience the visual world as being relatively uniform and unchanging as we move our eyes. This may appear puzzling considering the large inhomogeneities between the representations of the fovea and periphery in our visual system. In a series of experiments we demonstrate that exposing observers to consistent transsaccadic changes in the size of the saccadic target can generate corresponding changes in perceived size, so that over the course of a few hundred trials the relative size of a peripheral stimulus appears smaller if a transsaccadic size reduction was experienced. This re-calibration of perceived size can last at least until the next day and its effects are evident also in the opposite hemifield. Furthermore, the re-calibration is not induced if the transsaccadic change is applied to stimuli from which gaze is being diverted, but it can be induced using stimulus motion rather than gaze displacement. Overall our results point to the fact that our visual system maintains our impression of uniformity across the visual field through a continuous recalibration process. The prediction of postsaccadic foveal appearance based on peripheral input and the associated prediction error seem to be the main, though not the exclusive, source of the re-calibration signal.  
Funding: Deutsche Forschungsgemeinschaft DFG SFB/TRR 135 and EU Marie Curie Initial Training Network "PRISM" (FP7—PEOPLE-2012-ITN; grant agreement 316746).

[21S104] Why do we follow targets with our eyes during interception?  
**Cristina de la Malla, Jeroen B. J. Smeets, Eli Brenner**

Department of Human Movement Sciences, Vrije Universiteit Amsterdam

People usually look at objects with which they intend to interact. An obvious advantage of doing so is that this ensures

that one obtains the best possible spatial information about the object. A consequence of following moving objects with one's eyes is that this changes the way in which the object's motion is judged. Rather than judging its motion from the retinal slip of its image one must judge it from signals related to the movements of the eyes. This could be the retinal slip of the background, but it could also involve extra-retinal signals. A particular advantage of relying on information about one's eye movements to judge how a target is moving is that retinal slip of the target's image provides direct feedback about errors in keeping one's eyes on the target. This can be used to correct any errors in the initial estimate of the target's speed. Such corrections could lead to more precise interception that is more robust with respect to biases in visual processing. We will provide evidence that indeed it does: following a target that one is trying to intercept with one's eyes makes one slightly more precise, and much less sensitive to biases.

Funding: This work was supported by grant NWO 464-13-169 from the Dutch Organization for Scientific Research.

[21S105] The role of allocentric information when walking towards a goal

**Danlu Cen, Simon Rushton, Seralynne Vann**

School of Psychology, Cardiff University

Do allocentric position cues play any role in the visual guidance of walking towards a target? To date, egocentric direction and optic flow have been the primary focus of research. Here we addressed that oversight. Participants wearing prism glasses walked to an LED target on the far-side of a pitch-black room. They were separated into two groups: (1) participants in the familiar group underwent task preparation within the test room and so were familiar with the environment prior to walking; (2) participants in the unfamiliar group were prepared outside the test room so were unfamiliar with the room prior to walking. The two groups took different curving trajectories to the target. The curvature of the trajectory taken by the unfamiliar group was as predicted by the angular displacement of the prism. The curvature of the familiar group was not, it was significantly less. The effect of familiarity was found to be robust in a series of follow-on experiments that sought to isolate the roles of different cues. The findings suggest that observers with prior exposure to the environment may have formed a mental representation of the scene structure and spatial layout, which may contribute to the guidance of walking.

[21S106] From multisensory integration to new rehabilitation technology for visually impaired children and adults

**Monica Gori, Giulia Cappagli, Elena Cocchi, Gabriel Baud-Bovy, Sara Finocchietti**

U-VIP Unit for Visually Impaired People, Istituto Italiano di Tecnologia

Our researches have highlighted that blind persons have problems in understanding the relation between sounds presented in space (Gori et al 2014; 2015; Cappagli et al 2015), tactile information about object orientation (Gori et al 2010) and in encoding sound motion (Finocchietti et al 2015). Early-onset of blindness adversely affects psychomotor, social and emotional development. In 2002 children below 15 years of age with visual impairment worldwide were about 1.4 million (Resnikoff et al 2002). To date the most of the technology available (e.g. Kajimoto et al 2003) is not suitable for young children with visual disability. We developed a rehabilitative device for very young visually disabled children: the ABBI device (Audio Bracelet for Blind Interaction; [www.abbiproject.eu](http://www.abbiproject.eu)). ABBI is a new rehabilitative solution to improve spatial, mobility and social skills in visually impaired children. It is based on the idea that an audio feedback related to body movement can be used to improve spatial cognition. We performed a three months longitudinal study in 24 children and a one day study in 20 adults with visual disability. Our results suggest that the association between audio-motor signals with ABBI can be used to improve spatial cognition of visually impaired children and adults.

[21S201] Colour Physiology in Subcortical Pathways

**Paul R Martin**

Save Sight Institute and Centre for Integrative Brain Function, University of Sydney

Convergent results from anatomy, physiology, and molecular biology suggest that red-green colour vision is a relatively recent addition to the sensory capacity of primates, having emerged subsequent to evolution of high-acuity foveal vision. Signals serving red-green colour vision are carried together with high-acuity spatial signals on the midget-parvocellular pathway. The primordial blue-yellow axis of colour vision has by contrast poor spatial acuity and is served by the evolutionary primitive koniocellular visual pathway. In this symposium presentation I will review our

studies of the spatial and chromatic properties of parvocellular and koniocellular pathways, and show recent results concerning influence of brain rhythms on blue-yellow signals.

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[21S202] Color as a tool to uncover the organizational principles of object cortex in monkeys and humans

**Rosa Lafer-Sousa, Nancy Kanwisher, Bevil Conway**

Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, USA

The existence of color-processing regions in extrastriate cortex of humans and macaque monkeys is well established. But their location in the cortex relative to other functional regions, their selectivity for color compared with other properties (shape or category), and their relationship across species remains unclear. I will discuss recent imaging work in humans (Lafer-Sousa et al. 2016) using color as a tool to test a functional organizational plan across primate species for object-processing cortex, as suggested by imaging data in monkeys (Lafer-Sousa and Conway, 2013). I will argue that a comparison of the monkey and human results suggests a broad homology that validates the use of macaques as a model for human vision, provides insight into the computational goals of object cortex, and suggests how it evolved. The results appear to be consistent with a model of object cortex captured by parallel multi-stage processing of color, shapes and places, and support the idea that inferior temporal cortex can be carved into 3 or 4 somewhat separate areas. The work uncovers an extensive network of higher-order brain regions processing color. I will speculate about the functional role of these regions, informed by psychophysical observations and data available from the patient literature.

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[21S203] Neural processing of color in higher cortical areas

**Hidehiko Komatsu**

Division of Sensory and Cognitive Information, National Institute for Physiological Sciences

Human clinical observations suggest that higher visual areas play critical roles in color perception. We are gradually getting pieces of information to build integrated view of the functional organization and color processing in the higher areas. A significant step seems to occur at the primary visual cortex where nonlinear transformation of color signals convert two-axes into multi-axes representation of color where neurons tuned to various directions in the color space are formed. Such multi-axes color representation appears to be a universal principle of color representation across the visual cortical areas and is elaborated in higher areas. In the inferior temporal cortex of the macaque monkey, neurons tuned to a small range of hue exhibit properties closely associated with color perception. Neural mapping and fMRI studies in macaques are revealing gradually detailed picture on the functional organization of the higher cortical areas in relation to color where constellation of multiple subregions are observed. Our recent study (Namima et al. J Neurosci 2014) have shown that there is some important difference between these subregions in a way color signal is represented.

Funding: JSPS KAKENHI Grant, JST COI Program

[21S204] Understanding color preferences: from cone-contrasts to ecological associations

**Karen B Schloss**

Cognitive, Linguistic, and Psychological Sciences, Brown University

Fundamental questions in color cognition concern how and why colors influence thoughts, feelings, and behavior. Much of the research has focused on color preferences, but we are only beginning to understand why color preferences exist and how they are formed. The central role of cone-opponency in color perception makes it appealing to use as a framework for investigating color preference. Hurlbert and Ling (2007) led this approach, predicting hue preferences with weights along the cone-contrast axes (L-M, S-LM) and sex-differences with differential weighting along the L-M axis (attributed to evolutionary division of labor in hunter-gather societies). However, subsequent studies have challenged this approach, demonstrating its weaker performance for broader samples of color (Ling & Hurlbert 2009; Palmer & Schloss, 2010); the lack of L-M sex differences in infants (Franklin, et al., 2010) and other cultures (Taylor, et al., 2013; Yokosawa et al., 2015), and its comparable performance to models with non-biologically based axes (e.g., CIExyY) (Sorokowski, et al., 2014). Although the cone-contrast model can describe color preferences, it does not

provide a causal explanation (Schloss et. al, 2015). An alternative is that color preferences are determined by ecological experiences with colored object/entities (Ecological Valence Theory; Palmer & Schloss, 2010).

## [21S205] Color Psychophysics in the Distal Stimulus

**David Brainard**

Department of Psychology, University of Pennsylvania

The scene illumination and the surface reflectances of objects in the scene both influence the spectrum of the reflected light: information about these distal scene factors is confounded in the retinal image. To provide a stable perceptual representation of object color thus requires that the visual system make perceptual inferences from the inherently ambiguous proximal stimulus. This has been widely studied using adjustment methods that characterize object color appearance across changes in illumination. To gain additional traction, we have (in collaboration with Hurlbert's lab) measured thresholds for discriminating changes in scene illumination. On each trial, subjects choose which of two test scenes is illuminated differently from a reference scene, with the illumination change governed by a staircase procedure. Thresholds are extracted from the data. i) Thresholds in different illuminant-change chromatic directions vary systematically with the ensemble of surface reflectances present in the scene; ii) shuffling the locations of the surfaces as the illumination changes elevates thresholds, but does not make the task impossible. Measurement of illumination discrimination thresholds will allow determination of how efficiently the visual system uses the information available at various sites along the early visual pathways to make discriminations in the color properties of the distal stimulus.

Funding: EY RO1 10016

## *Tuesday August 30th Oral presentations*

### [21T301] Fast figure-ground organization in visual cortex for complex natural scenes

**Rüdiger von der Heydt<sup>1</sup>, Jonathan R. Williford<sup>2</sup>**

<sup>1</sup>Krieger Mind/Brain Institute, Johns Hopkins University; <sup>2</sup>Netherlands Institute for Neuroscience

Assignment of border-ownership is essential for understanding images of 3D scenes. To see if the visual cortex can perform this task in the real world we studied neurons in monkey cortical area V2 with static images of natural scenes. Each neuron was tested with a large sample of scenes. Contrast borders corresponding to object contours were presented in the receptive fields of edge selective neurons at the proper orientation. Responses were analyzed by regression and border-ownership selectivity was defined as the effect of side of object (object location relative to the contour). About half of the neurons showed a significant main effect of border ownership, and the mean border-ownership signal emerged at ~70ms, only about 30ms after the onset of responses in V2. But how consistent are the neural signals across scenes? We calculated the distribution of border-ownership signals for each recorded neuron and corrected for effects of random response variation. We found that a substantial proportion of neurons were over 80% consistent across scenes and some were over 90% consistent. Thus, the visual cortex seems to understand the scene structure even in complex natural images. How it performs this task so fast remains a puzzle.

Funding: ONR N000141010278, NIH EY02966, NIH EY016281

### [21T302] Serial dependence in context: the role of summary statistics

**Mauro Manassi, Wesley Chaney, Alina Liberman, David Whitney**

Department of Psychology, University of California, Berkeley, CA, USA

We experience the visual world as a continuous and stable environment, despite rapidly changing retinal input due to eye movements and noise. Recent studies have shown that orientation and face perception are biased toward previously seen stimuli (Fisher & Whitney, 2014; Liberman et al., 2014). This serial dependence effect was proposed as a mechanism to facilitate perceptual stability, compensating for variability in visual input. Although serial dependence was shown to occur between single objects, it remains unknown whether serial dependence can occur in the complex environment we experience in everyday life. Here, we tested whether serial dependence can occur between summary statistical representations of multiple objects. We presented a 3x3 array of nine Gabors with random local orientations, and asked observers to adjust a bar's orientation to match the ensemble orientation. We found evidence for serial dependence: the reported ensemble orientation was pulled toward the orientation of the previous Gabor array. Further

controls showed that serial dependence occurred at the ensemble level, and that observers averaged ~60% of the Gabors per trial. Our results show that serial dependence can occur between summary statistical representations and, hence, provide a mechanism through which serial dependence can maintain perceptual stability in complex environments.

Funding: Mauro Manassi was supported by the Swiss National Science Foundation fellowship P2ELP3\_158876.

[21T303] Responses of macaque ganglion cells to natural scenes: spatial and temporal factors

**Barry Lee, Manuel Schottdorf**

Neurobiology, MPIBPC;

We have described responses of macaque ganglion cells to stimuli derived from natural scenes (van Hateren et al., J. Neurosci., 2002) using a simplified stimulus just modulated in time and color. We here compare responses to a full spatiotemporal video to the simplified stimulus. A flower-show video, centered over the receptive field, was played back to ganglion cells, and repeated up to six times (150 frames/sec, 256x256 pixels). In the simplified stimulus, the average of central pixels was displayed as a uniform field. Coherence (bit rate) functions of responses were very similar for the full and simplified stimuli. Impulse trains under the two conditions were highly correlated. RFs derived from reverse correlation (luminance and chromatic) showed little indication of center-surround structure. For MC cells, the temporal MTF is very bandpass. High SF components move at high TFs, amplifying their response to fine detail. This swamps any effect of RF structure on responses. For PC cells, the response was largely driven by the |L-M| signal and no spatial opponency is present. We conclude that cell responses to natural scenes seem driven by temporal modulation as the eye scans the scene, rather than spatial structure in stimulus or RF.

Funding: NE113115

[21T304] Towards matching the peripheral visual appearance of arbitrary scenes using deep convolutional neural networks

**Thomas S Wallis, Christina M. Funke, Alexander S. Ecker, Leon A. Gatys, Felix A. Wichmann, Matthias Bethge**

Werner Reichardt Centre for Integrative Neuroscience, Eberhard Karls Universität Tübingen

Distortions of image structure can go unnoticed in the visual periphery, and objects can be harder to identify (crowding). Is it possible to create equivalence classes of images that discard and distort image structure but appear the same as the original images? Here we use deep convolutional neural networks (CNNs) to study peripheral representations that are texture-like, in that summary statistics within some pooling region are preserved but local position is lost. Building on our previous work generating textures by matching CNN responses, we first show that while CNN textures are difficult to discriminate from many natural textures, they fail to match the appearance of scenes at a range of eccentricities and sizes. Because texturing scenes discards long range correlations over too large an area, we next generate images that match CNN features within overlapping pooling regions (see also Freeman and Simoncelli, 2011). These images are more difficult to discriminate from the original scenes, indicating that constraining features by their neighbouring pooling regions provides greater perceptual fidelity. Our ultimate goal is to determine the minimal set of deep CNN features that produce metameric stimuli by varying the feature complexity and pooling regions used to represent the image.

Funding: Funded in part by the Alexander von Humboldt Stiftung, German Federal Ministry of Education and Research (BMBF), and the German Science Foundation (DFG)

[21T305] A numerosity-processing network throughout human association cortex

**Ben Harvey<sup>1</sup>, Serge Dumoulin<sup>2</sup>**

<sup>1</sup>Faculty of Psychology and Education Sciences, University of Coimbra; <sup>2</sup>Spinoza Centre for Neuroimaging Amsterdam

Perception of numerosity (the number of visual objects in a set) and other quantities is implicated in cognitive functions including foraging, attention control, decision-making and mathematics. We hypothesize that numerosity-selective responses are widely distributed throughout human association cortices, to allow interactions with multiple cognitive systems. Using ultra-high-field (7T) fMRI and neural model-based population-receptive field analyses, we describe numerosity-selective neural populations organized into six widely separated topographic maps in each hemisphere. These were found in visually responsive areas implicated in object recognition and motion perception

(occipito-temporal cortex), attention control (parietal cortex), and decision-making and mathematics (prefrontal cortex). Left hemisphere maps typically contained more low numerosity preferences, with more high numerosity preferences in the right hemisphere. Within each hemisphere, anterior maps contained a smaller proportion of high numerosity preferences than posterior maps, and maps differed considerably in size. Unlike sensory topographic maps such as visual field maps, numerosity tuning widths were very similar between these numerosity maps. All numerosity maps were in visually-responsive areas, but their placement and organization did not follow that of particular visual field maps. This similar representation of numerosity in many brain areas suggests a broad role for quantity processing in supporting many perceptual and cognitive functions.

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[21T306] Neuronal correlates of gist processing

**Lucy J Spencer, Alex Wade, Karla Evans**

Department of Psychology, University of York, UK

Humans can rapidly (~13ms) extract ‘gist’ (global image and summary statistics, including semantic categories) from visual scenes. This allows for rapid extraction of information for multiple categories, but these outputs can interfere destructively depending on the task at hand (Evans et al., 2011). We investigated the neural correlates of gist processing using a rapid event-related fMRI by presenting (200 msec) a linear combination of noise masks and ‘face’ and/or ‘place’ images in four quadrants of the visual field simultaneously. Observers’ task was to indicate the presence and quadrant of a pre-defined target category. We measured responses in pre-localised cortical regions and conducted additional whole-brain analyses. Category-selective activation in extrastriate areas support the involvement of ‘face’ and ‘place’ areas in gist perception. No top-down-driven activation in target locations were observed in V1, consistent with the observation of gist extraction without the ability to localize the target. Signal-detection analysis indicates activity in place selective areas predicts target perception (hits, false-alarms) while activity in face areas predicts the presence of the target itself (hits, misses). Finally, activity in the frontal and place selective areas were suppressed when an additional distractor stimulus was present, reflecting the destructive signal collision observed behaviourally.

[21T307] Giessen's hyperspectral images of fruits and vegetables database (GHIFVD)

**Robert Ennis, Matteo Toscani, Florian Schiller, Thorsten Hansen, Karl Gegenfurtner**

General Psychology, Justus-Liebig University Giessen, Germany

Vision is tuned to the environment in which we evolved. For example, it has been hypothesized that color vision is closely adapted to the spectral properties of our environment. Since food like fruit and vegetables presumably played a major role in evolution, we have developed a hyperspectral database of 29 fruits and vegetables. Both the outside (skin) and inside (fruit) of the objects were imaged. We used a Specim VNIR HS-CL-30-V8E-OEM mirror-scanning hyperspectral camera and took pictures at a spatial resolution of ~57px/deg by 800 pixels at a wavelength resolution of ~1.12 nanometers. A broadband LED illuminant, metameric to D65, was used. A first analysis of these images showed that (1) the frequency distribution of fruit/vegetable skin colors followed a power law, similar to natural scenes, (2) the skins were darker than the insides, and (3) inside and skin colors were closely correlated. More importantly, we have found (4) a significant correlation (0.73) between the orientation of the chromaticity distributions of our fruits/vegetables with the orientations of the nearest MacAdam discrimination ellipses. This indicates a close relationship between sensory processing and the characteristics of our environmental objects.

[21T308] Semantic integration without semantics? Meaningless synthesized scenes elicit N400 responses to semantically inconsistent objects.

**Melissa Võ, Tim Lauer, Tim Cornelissen**

Scene Grammar Lab, Goethe University Frankfurt

Seeing an object that is semantically inconsistent with its scene context —like a toaster on the beach— elicits semantic integration effects, seen in scalp ERPs as an increased N400 response. What visual information from a scene is sufficient to modulate object processing and trigger an N400 response? To approach this question, we created a synthesized texture from each scene containing identical summary statistics but without providing any obvious semantic meaning. We then presented objects on either images of scenes, their texture versions, or a color control background. To create semantic inconsistencies, we paired indoor and outdoor scenes with either a consistent or

inconsistent object thumbnail. We found a pronounced N400 response for inconsistent versus consistent objects on real-world scenes. Interestingly, objects on inconsistent texture backgrounds also elicited an N400 response with a similar time-course and topography, though less pronounced. A color control condition, however, showed no such response. At least for indoor versus outdoor scenes, our data suggest that even without direct access to the meaning of a scene, seeing its summary statistics might be sufficient to affect the semantic processing of an object. Whether this holds for more subtle inconsistencies—a toaster in a bedroom—remains to be seen.  
Funding: This work was funded by DFG grant VO 1683/2-1 to MLV.

[22T101] Confidence levels during perceptual decision-making are discrete

**Andrei Gorea, Matteo Lisi, Gianluigi Mongillo**

Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS, France

Are our decisions – and hence confidence therein – based on a full knowledge of the prior and likelihood probability functions as imposed by the normative Bayesian theory? We answer this negatively by means of a new experimental paradigm. Each trial consisted of two consecutive decisions on whether a given signal was above or below some reference value. The first decision was to be made on a signal randomly drawn from a uniform distribution. Correct/incorrect responses resulted into signals randomly drawn from respectively the positive/negative sub-intervals to be judged when making the second decision. Subjects were told so. A non-Bayesian observer was designed to have discrete confidence levels instantiated by one, two or three second-decision criteria representing different levels of the point-estimates of the evoked neural response. Synthetic data-sets reliably discriminated Bayesian from non-Bayesian observers. Over 9 subjects, the non-Bayesian observer with two or three confidence levels systematically outperformed the Bayesian observer in predicting the actual behavior. Contrary to current claims, confidence appears to be a discrete rather than continuous quantity. Simple heuristics are sufficient to account for confidence assessment by humans making perceptual decisions.

[22T102] Spatio-temporal probability integration during visual discrimination

**József Arato, József Fiser**

Cognitive Science, Central European University, Budapest

How specific statistical priors do we maintain? While it is known that past stimulus statistics influences later perceptual decisions, it is unclear how such effects would interact and influence decisions across different spatial locations. To test this, we used a visual discrimination paradigm with two target locations, and two abstract shapes that could appear in varying levels of Gaussian noise. The stimulus appearance probabilities shifted from the training block (always balanced) to the test block (unbalanced). In each trial, participants reported via fixation which of the two locations the stimulus would likely to appear, and using a touchpad, they chose which shape was presented. In the test of Exp. 1, object A was equally more frequent at both locations. In the test of Exp. 2, object A was more frequent at one location, but less frequent at the other location. In Exp. 1, strong priors emerged after the shift, as if participants were compensating to maintain the overall training probabilities. In contrast, in Exp. 2, participants followed the shift in appearance probabilities with their responses. This suggests that only simple priors emerge automatically, with more complex statistics, averaging might cause visual decisions to follow local probabilities more accurately.

[22T103] Informational value biases dominance in binocular rivalry

**Wolfgang Einhäuser<sup>1</sup>, Stephan Koenig<sup>2</sup>, Harald Lachnit<sup>2</sup>**

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Can informational value bias the interpretation of ambiguous stimuli? Here, we present a drifting grating to each eye. Gratings drift in opposing directions and the optokinetic nystagmus serves as objective measure of perceptual dominance. After each 10s presentation, observers are asked to press one of two buttons and receive a fixed monetary for responding correctly. Gratings of four colours are used: a neutral colour; two unambiguous colours that inform with certainty about the correct button, and one ambiguous colour that contains no such information. In each trial, the neutral colour is presented to one eye and one of the other colours to the other. Before this main condition, observers are passively exposed to each of the possible colour combinations (“exposure”); then they are trained on the response with the same non-neutral grating presented simultaneously to both eyes. Comparing main condition to exposure, we find that relative dominance of the ambiguous colour increases compared to the neutral one; a similar trend exists for unambiguous colours. Increased relative dominance results from shortened dominance durations of the neutral colour,

rather than from increased dominance of the others. Hence, informational value biases the perceptual interpretation of ambiguous stimuli by suppressing the uninformative (neutral) percept.

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[22T104] Classification videos reveal the information used to respond to an opponent's tennis stroke

**Sepehr Jalali, Sian Martin, Joshua Solomon, Kielan Yarrow**

Psychology, City University London, UK

Experts are able to predict the outcome of their opponent's next action (e.g. a tennis stroke) based on kinematic cues "read" from preparatory body movements. Here, we used classification-image techniques to find out how participants discriminate sporting scenarios as they unfold. We filmed tennis players serving and hitting forehands, each with two possible directions. These videos were presented to novices and club-level amateurs, running from 800ms before to 200ms after racquet-ball contact. During practice, participants reported shot direction under a time limit targeting 90% accuracy. Participants then viewed videos through Gaussian windows ("Bubbles") placed at random in the temporal (E1), spatial (E2) or spatiotemporal (E3) domains. Comparing Bubbles from correct and incorrect trials revealed the contribution of information from different regions toward a correct response. Temporally, two regions supported accurate responding (from ~50 ms before ball contact to 100+ ms afterwards, and, for forehands, from around the time of swing initiation, ~300 ms before ball contact). Spatially, information was accrued from the ball trajectory and from the opponent's head. Spatiotemporal bubbles again highlighted ball trajectory information, but seemed susceptible to an attentional cuing artefact. Overall, there is potential to help players improve by showing them from when/where they read information.

[22T105] Choice bias contributes little to perceptual decision making in appearance tasks

**Daniel Linares, Joan López-Moliner**

Departament de Cognició i Desenvolupament, Universitat de Barcelona; Universitat de Barcelona, Catalonia

Perceptual decision-making in performance tasks—such as classifying a stimulus as signal or noise—not only depends on sensory evidence, but also on choice biases, which can be readily estimated using the frequency of 'signal' reports for noise stimuli. It is unknown, however, whether choice biases occur when judging appearance. To address this question, we presented a grating that in different trials was tilted different degrees around vertical. We asked participants to imagine a reference point fixed above the grating and report whether the grating pointed left or right relative to it. For many participants, we found that the orientation that results in 50% probability of right responses was significantly different from vertical. If these biased orientations were not perceptual, but caused by individual choice biases—participants favouring one choice or response button when uncertain—they should be reversed when the same stimuli are presented, but participants needed to choose 'left' or 'right' relative to an imaginary reference below the grating. We found, however, the same biased orientations (or very small differences) when the imaginary reference was below indicating that perceptual decision-making in appearance tasks is mostly based on sensory evidence with little contribution of choice biases.

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[22T106] Effects of motion predictability on anticipatory and visually-guided eye movements: a common prior for sensory processing and motor control ?

**Anna Montagnini, Jean-Bernard Damasse, Laurent Perrinet, Guillaume Masson**

Institut de Neurosciences de la Timone, CNRS & Aix-Marseille Université, France

Human behavior is highly sensitive to regularities in the environment. For instance, the repeated presentation of a particular pattern of motion leads to anticipatory eye-movements coherent with the expected pattern. Such expectancy-based anticipation can be seen as the motor readout of an internal prior. The impact of this prior on visual motion processing remains largely unexplored. Recently, Yang and collaborators (2012) proposed that a bias in direction probability would affect the sensorimotor gain of visually-guided pursuit. We recorded eye-movements during a smooth pursuit task, where the probability of motion was either uniform across directions, or biased in favor of one particular direction. As expected, robust anticipatory pursuit was observed with the biased-context. In occasional probe-trials, two targets moved along orthogonal directions (e.g. Right and Upward), leading, with the uniform-

context, to the initiation of visually-guided smooth pursuit along their vector-average (e.g. the Right-Upward diagonal). In the biased-context condition, the vector-averaging pursuit was systematically shifted toward the most likely direction, this shift being independent from the actual direction of the moving stimuli. Our results argue against the hypothesis of a modulation of the visuomotor pursuit gain and provide a benchmark for alternative hypotheses on the nature and impact of the expectancy-based prior.

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[22T201] Visual BOLD response in late-blind subjects with Argus II retinal prosthesis

**Elisa Castaldi<sup>1</sup>, Guido Marco Cicchini<sup>2</sup>, Laura Cinelli<sup>3</sup>, Laura Biagi<sup>4</sup>, Stanislao Rizzo<sup>3</sup>, Maria Concetta Morrone<sup>1</sup>**

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The recent advance in retinal prosthesis technologies generates hope for partially restoring vision to blind people with retinal pathologies. However, these strategies require the visual system downstream of the retinal circuitry to be capable of transmitting and elaborating visual signals. We studied plastic remodeling in late blind subjects affected by Retinitis Pigmentosa and implanted with Argus II Retinal Prosthesis. We assessed the visual function of a group of seven subjects before and after implantation, with psychophysical techniques and four with fMRI. After the surgery the subjects were able to detect high contrast stimuli using the prosthetic implant and their performance correlated with the amount of training after the surgery. However, direction discrimination remained at chance level and there was no improvement of contrast sensitivity in either eye when not using the Argus II. Before the implant, the BOLD activity in V1 and LGN was very weak or absent. Surprisingly, after prolonged use of Argus II the BOLD response to visual inputs was enhanced, despite the absence of stimulus perception. This is the first study tracking the neural changes of visual areas in patients after retinal implant, revealing a capacity to respond to restored visual input even after years of deprivation.

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[22T202] OpenEyeSim: a biomechanical model for studying oculomotor control under normal and abnormal conditions

**Alexander Priamikov<sup>1</sup>, Bertram Shi<sup>2</sup>, Maria Fronius<sup>3</sup>, Jochen Triesch<sup>1</sup>**

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OpenEyeSim is a novel three-dimensional (3D) biomechanical model for studying oculomotor control. It models six extraocular muscles (EOMs) per eye as well as the elasticity of eye-surrounding tissues and muscle pulley dynamics. Virtual cameras placed in the eyes sense a 3D simulated computer graphics environment. This enables the simulation of both open-loop and visually guided closed-loop control of different kinds of eye movements including saccades, vergence, and smooth pursuit movements. Given biologically plausible EOM innervations taken from oculomotor neuron recordings, our model is able to generate realistic eye trajectories matching empirical observations. It can also model oculomotor disorders. By reducing the activation signals of specific muscles, we are able to simulate different types of strabismus. We provide examples of modeling four types of incomitant strabismus: isolated medial rectus palsy, isolated superior rectus palsy, Duane's syndrome, and abducens nerve palsy. Our model also facilitates the understanding of the joint development of oculomotor control and sensory coding in an active vision context. In conclusion, we propose OpenEyeSim as a versatile modeling platform for studying the development of oculomotor control in health and disease.

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[22T203] The brain does not fill-in the details: filling-in magnitude depends on the spatial frequency content of the region surrounding an artificial scotoma

**Joana C Carvalho, Remco Renken, Nomdo Jansonius, Frans Cornelissen**

Ophthalmology, University Medical Center Groningen

“Filling-in” (FI) occurs when in the absence of input, the visual system predicts the missing information. FI affects the ability for early diagnosis of glaucoma. However, neuronal mechanisms underlying FI are ill-understood. We tested the hypothesis that FI is mainly driven by the activity of neurons with large receptive fields (RF; presumably tuned to low spatial frequencies (SF)). In the experiment, participants looked at a screen that contained an artificial scotoma superimposed on a noise background (NB). Once participants indicated that the scotoma was filled-in, targets were presented at various locations in- and outside the scotoma. We determined sensitivity for detecting these targets on NB with various SF content. Results show that NB containing primarily lower SF interfered more with target detection than NB containing higher SF. Hence, FI strength depended upon SF content of the NB. We interpret this as evidence that low SFs drive FI. Next, we replicated the experiment while removing low SF from the NB. Now participants failed to fill-in, confirming our interpretation. We conclude that the activity of neurons that process low SF (and having larger RF) determines FI. Thus, the brain does not fill-in the details.

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[22T204] Improvement of vision after short-term deprivation of the amblyopic eye in adult patients

**Claudia Lunghi<sup>1</sup>, Alessandro Sale<sup>2</sup>, Antonio Lepri<sup>3</sup>, Angela Sframeli<sup>3</sup>, Aris Dendramis<sup>3</sup>, Domenico Lisi<sup>3</sup>, Martina Lepri<sup>3</sup>, Maria Concetta Morrone<sup>1</sup>**

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We have recently shown that the adult visual cortex retains a high degree of neuroplasticity: short-term monocular deprivation boosts the deprived eye, and decreases intracortical GABAergic inhibition (Lunghi et al 2011,2015). Physical activity enhances the effect (Lunghi & Sale, 2015). Here we show that depriving the amblyopic rather than the dominant eye improves amblyopic vision. In four adult anisometric patients, we patched the amblyopic eye for two hours over three consecutive days, then once per week over the next three weeks. During the patching, patients watched a movie while intermittently cycling on an exercise bike. Before and after each session we measured binocular rivalry, visual acuity (LogMar), stereoacuity (TNO) and letter contrast-sensitivity. Perceptual dominance of the patched eye increased after deprivation similar to typical controls. Over the four weeks of testing, contrast sensitivity and acuity improved in all four patients (0.15 LogMar), and patients with moderate anisometropia also recovered stereopsis. These results demonstrate that amblyopic vision can be improved by transiently depriving the weak rather than the strong eye (Zhou et al, 2013), probably by activating homeostatic plasticity. Physical exercise may be crucial for the recovery by potentiating the plastic potential of the visual cortex as observed in animal models.

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[22T205] Visual Behavior on Natural Static Images in Patients with Retinitis Pigmentosa

**Ricardo Ramos Gameiro<sup>1</sup>, Kristin Jünemann<sup>1</sup>, Anika Wolff<sup>2</sup>, Anne Herbig<sup>2</sup>, Peter König<sup>1</sup>, Michael Hoffmann<sup>2</sup>**

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Retinitis pigmentosa is a disease that causes peripheral visual field loss. Here, we investigated how the loss of peripheral vision affects visual behavior on natural images. Patients with varying degree of visual field loss and control participants freely observed images of three different sizes while eye movements were recorded. We examined whether visual behavior differs when the scene content is shown in varying extends of the visual field, investigating the spatial bias, saccade amplitudes, as well as the amount and duration of fixations. We found that controls and patients with moderate loss of peripheral vision showed a central spatial bias while observing the images. Patients with a severe loss showed individual exploration and systematically scan the whole image area especially on large images. According to saccades amplitudes, controls and patients with moderate loss preferred making short saccades throughout all image sizes. Patients with a severe loss made a higher number of large saccades on large images. The amount of fixations increased with an enlarging loss of peripheral vision, while fixation durations decrease. In conclusion, RP patients scan the images more strategically when the observed scene exceeds their visible field. Down-sizing the scene yields an exploration similar to healthy visual behavior.

[22T206] Motion-based segmentation is impaired in developmental dyslexia

**Richard Johnston, Nicola J Pitchford, Neil W Roach, Timothy Ledgeway**

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The visual system has to satisfy competing constraints of integrating features that belong to a common object, whilst segmenting those arising from different objects in the world. Evidence suggests that dyslexic readers have a selective deficit on tasks requiring the integration of local motion but not form (shape) cues. However, it is unclear if the perceptual deficit in dyslexia extends to segmentation. We explored this issue in thirty-eight adults with a wide range of reading abilities. Observers viewed a random-dot display divided spatially into horizontal segments. Adjacent segments contained either local motions in opposing directions or analogous static form cues depicting orthogonal orientations. Subjects discriminated this stimulus from one containing identical motion or form cues that were spatially intermingled. Coherence thresholds were measured for a range of segment sizes. Observers were unable to perform either task reliably when segments were smaller than a spatial resolution (acuity) limit that was independent of reading ability. Thresholds decreased as segment size increased, but for the motion task the rate of improvement was shallower for the poorest readers and the segment size at which performance became asymptotic was larger. Thus, both integration and segmentation are relatively impaired in dyslexic readers on tasks containing motion.

Funding: This project was funded by a PhD Studentship awarded to RJ

[23T101] High global motion sensitivity, associated with good maths ability, has white-matter and grey-matter correlates – MRI evidence from tract-based spatial statistics

**Oliver Braddick<sup>1</sup>, Janette Atkinson<sup>2</sup>, Natacha Akshoomoff<sup>3</sup>, Erik Newman<sup>3</sup>, Lauren Curley<sup>3</sup>, Anders Dale<sup>3</sup>, Terry Jernigan<sup>3</sup>**

<sup>1</sup>Experimental Psychology, Oxford University; <sup>2</sup>University College London; <sup>3</sup>University of California San Diego, USA

Impaired sensitivity to global motion, but not global form, characterises a range of neurodevelopmental disorders. Previously we reported (Atkinson et al, ECVF 2014) that children's individual differences in global motion correlated with relatively larger parietal and smaller occipital cortical areas. Here we explore variations in major fibre tract development, defined by tract-based spatial statistics (TBSS); in particular, the superior longitudinal fasciculus (SLF) which connects to parietal areas associated with global motion performance. In 125 typically developing 5-12 year-olds from the PLING study (Pediatric Longitudinal Imaging Neurocognition and Genetics), higher fractional anisotropy in the right SLF showed a positive association ( $p=0.003$ ), and the left, a negative association ( $p=0.02$ ) with global motion sensitivity. Other specific tracts did not show this relation, nor did global form sensitivity. Mathematical ability correlated with global motion, and showed a similar pattern. The parietal surface area expansion around intraparietal sulcus, associated with motion performance also showed asymmetry, but in the opposite direction. In conclusion, developmental variation in global motion sensitivity is linked to local white matter organization in SLF, as well as to regional cortical area differences, with a complex pattern of hemispheric asymmetry. These findings provide pointers for investigating the visual brain correlates of neurodevelopmental disabilities.

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[23T102] A unified model of 1D and 2D motion processing

**Alan Johnston**

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Johnston et al. (1999) described a model of velocity encoding in the primate brain based on a spatiotemporal gradient approach, in which neurons are characterised as spatio-temporal derivative operators. The strategy works well for moving 1D spatial patterns, such as lines or sinewave gratings however the method does not always give the correct answer for 2D pattern, as it is overly influenced by the direction of the local spatial gradient of the image brightness. For 2D pattern it is possible to develop a similar spatio-temporal gradient approach, however, typically the matrix one needs to invert to find the solution is indeterminate for 1D image pattern. This can be mitigated by introducing a constant on the diagonal of the matrix (e.g. Weiss et al. 2002). However, this general approach to degeneracy presents the problem of the choice of the value of the constant, which will introduce different degrees of error at each spatio-temporal location. Here we introduce an algorithm which provides an accurate estimate of 2D pattern motion but degrades gracefully to a correct solution for 1D pattern. The model provides an account of V5/MT neurons that respond to plaids but not gratings, which are anomalous for standard multistage motion models.

[23T103] Combining autistic traits and sensory thresholds to predict individual differences in perceived speed for two different motion phenomena

**Tom C Freeman, Zoe Meredith, Rebecca McMillin, Georgie Powell**

Psychology, Cardiff University

In a Bayesian framework, perceptual experience arises from the optimal combination of noisy sensory information and prior knowledge. Noisy sensory information can be captured by discrimination thresholds; while recent theories suggest that certain clinical disorders are related to differences in prior knowledge. Pellicano and Burr (2011), for example, suggested that autism is associated with less influential (flatter) priors. We therefore asked whether individual differences in two motion phenomena – the reduction of perceived speed during pursuit or at low contrast - can be quantified by a Bayesian model based on thresholds and autistic traits. In two experiments, we found well-known group-level reductions in perceived speed during pursuit and at low contrast, both accompanied by poorer speed discrimination. To account for individual differences, we combined trait measures and thresholds in a Bayesian model that assumed a slow-motion prior and fixed internal noise. The prior's variance was linearly related to the trait measure by a single scaling factor fit across each cohort. For both motion phenomena, the model accounted for individual differences well and better than reduced versions based on trait or thresholds alone. Individual differences in perception may therefore combine individual differences in sensory noise and predictable differences in prior knowledge.

[23T104] Retinotopic information is rendered invisible by non-retinotopic processing

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Classically, stimuli are rendered unconscious by backward masking or binocular rivalry, where it is usually assumed that the mask or the stimulus in the contralateral eye suppress the target. Based, on the Ternus-Pikler display (<http://lpsy.epfl.ch/research/retino/>), we present a new method to render stimuli invisible. We presented a black disk with a white dot on it. From frame to frame, the dot changed its position on a circular orbit creating an apparent motion percept of an either clockwise or counterclockwise rotation. Observers discriminated the rotation direction well with about 93% correct responses. The rotation is perceived in retinotopic coordinates. Next, we added a disk, also with a white dot, alternating to the left and right from frame to frame. The disks themselves, now, appear to jump back and forth in tandem. This “group motion” percept of the Ternus-Pikler disks, in turn leads to a non-retinotopic motion percept for the white dot, which renders the retinotopic rotation invisible (54% correct). When the contextual disk was removed, the original retinotopic motion percept for the white dot was immediately perceived. Hence, by adding contextual elements we can switch between different conscious percepts.

Funding: This work was supported by grant 153001, “Basics of visual processing: From retinotopic encoding to non-retinotopic representations”, of the Swiss National Science Foundation (SNSF).

[23T105] Perceptual gap closing induced by motion

**Patrick Cavanagh<sup>1</sup>, Nika Adamian<sup>1</sup>, Marianne Duyck<sup>1</sup>, Tatjana Seizova-Cajic<sup>2</sup>**

<sup>1</sup>LPP, Université Paris Descartes; <sup>2</sup>University of Sydney

When a moving stimulus crosses an area where there is no sensory response, it may appear to fill in across the gap. Here we examined a gap caused by an absence in the stimulus, not an absence of receptors. Subjects (n=8) observed a dot moving back and forth once every 1111 ms along a 15° vertical path with a 0° to 5° gap in the middle at 18° eccentricity. As soon as the dot reached one side of the gap, it immediately reappeared at the other side, introducing a spatial (but not temporal) discontinuity. After observing 3-5 sweeps of motion subjects reported perceived size of the gap by adjusting a gap in a static vertical line at fixation. Gaps smaller than 2° were not seen and the size of larger gaps was greatly underestimated. By contrast, if the dot simply alternated between the top and the bottom edges of the gap at the same rate, the gap size was judged almost veridically. Following up similar results for touch (Seizova-Cajic & Taylor, 2014), we are currently testing whether the motion trace perceptually extends over the missing segment (filling in) or whether space itself shrinks to eliminate the gap (stitching up).

Funding: The European Research Council under the European Union's 7th Framework Programme (FP7/2007-2013) / ERC grant agreement n° AG324070 to PC and the Australian Research Council (DP110104691) to TSC.

[23T106] Low-level mediation of directionally specific motion after-effects: motion perception is not necessary

**Michael J Morgan, Joshua Solomon**

Division of Optometry, City University London

Previous experiments have shown that adaptation to moving textures causes directionally specific repulsion in the angle of a subsequently viewed, moving probe. We used a 2AFC task with roving pedestals to determine the conditions for producing directionally specific repulsion with compound adaptors, each of which contains two oppositely moving, differently colored, component streams. In Experiment 1 oppositely moving dots in the adaptor were paired to preclude the appearance of motion. Nonetheless, repulsion remained strong when the angle between each probe stream and one component was approximately 30°. In Experiment 2 adapting dot-pairs were kept stationary during their limited lifetimes. Their orientation content alone proved insufficient for producing repulsion. In Experiments 3-5 the angle between probe and both adapting components was approximately 90° or 270°. Directional repulsion was found when observers were asked to visually track one of the adapting components (Experiment 5), but not when observers were asked to attentionally track it (Experiment 4), nor while passively viewing the adaptor (Experiment 3). Our results are consistent with a low-level mechanism for motion adaptation. It is not selective for stimulus color and it is not susceptible to attentional modulation. The most likely cortical locus of adaptation is area V1.

[23T201] Factors underlying individual differences in photopic and scotopic spectral luminous efficiency functions obtained from a century of archival data

**David H Peterzell<sup>1</sup>, Donald MacLeod<sup>2</sup>, Vicki Volbrecht<sup>3</sup>, Michael Crognale<sup>4</sup>, Kara Emery<sup>4</sup>, Michael Webster<sup>4</sup>**

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We used factor analyses of individual differences to confirm and explore mechanisms underlying spectral luminosity functions. Separate analyses of covariance matrices were performed on classic photopic and scotopic data from humans, and on photopic data from wild type (dichromatic) and transgenic mice (human L-cone transgene added) (Coblentz & Emerson, 1918; Gibson & Tyndall, 1923; Crawford, 1949 [series 1]; Kraft & Werner, 1994; Shabaan et al. 1998). In man and transgenic mouse, two Varimax-rotated factors from photopic data were bipolar. Their loadings coincided with absorption spectra for M and L photopigments; they had zero-crossings at deuteranopic and tritanopic confusion points (equal M or L responses in test and standard). A third factor was generally consistent with variability in the S photopigment. Similarities in results between man and transgenic mouse help confirm that factors from humans are L and M photopigments. From scotopic data, four obliquely-rotated factors coincided with (1) lens density, (2) macular pigment density, (3) rhodopsin density, and (4) Rhodopsin  $\lambda_{max}$  factors. (1) and (4) intercorrelated, presumably accidentally. Variability estimates for (3) slightly exceeded those for cones (Webster & MacLeod, 1988), while (4) was slightly less than reported by Bowmaker et al. (1975). Factors seem consistent with existing theory.

[23T202] Scotopic Inhibition in the Light-Adapted ERG?

**Christopher W Tyler**

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It is well-known that dark-adapted (rod) ERG responses increase in amplitude with flash intensity, saturating at mesopic levels to a constant response amplitude (Hood & Birch, 1992). The cone ERG behavior under light-adapted conditions is less well-known, but has been found to be proportional to mean intensity at medium temporal frequencies, increasing disproportionately at high frequencies (Wu & Burns, 1995). We studied human ERG responses to 2.5 Hz On-Off epochs of full-field stimuli at 480, 540 and 610 nm peak wavelengths, plus their sum (white), as a function of intensity over a 2.5 log unit range from scotopic to photopic levels. At the shorter wavelengths, the peak ERG amplitude first increased, then decreased, then increased again at the highest intensities. This result may be interpreted as the response of a scotopic and a photopic retinal system, with the scotopic system progressively reducing its response amplitude in the mesopic intensity range. Such behavior is not consistent with any model of saturating nonlinearity and/or (positive) power-law gain control but suggests an inhibitory influence on the scotopic signal at high intensities.

[23T203] Hue, slew rates, temporal filters and harmonics

**Andrew Stockman, Caterina Ripamonti, Andrew Rider, Peter West, Bruce Henning**

Institute of Ophthalmology, University College London (UCL), London, UK

Observers viewed M- or L-cone-isolating stimuli and compared slowly-on and slowly-off sawtooth-waveforms of the same mean chromaticity and luminance. Between 6 and 13 Hz, the mean hue of slowly-on-L-cone and slowly-off-M-cone sawtooth stimuli was redder and slowly-off-L-cone and slowly-on-M-cone stimuli greener despite all having the same mean chromaticity. Comparable effects were found with square-wave stimuli of varying duty cycle with the hue shift being in the direction of the more prolonged phase. We measured the temporal-frequency-dependence of these hue shifts on modulation depth and sawtooth slope. We also matched the hue variations to square-wave flicker with fixed or variable duty cycles. The complex results are consistent with a model in which the hue-change is limited by a “slew-rate” process that is better able to follow slower or more prolonged changes in the waveforms and therefore shifts the mean hue in that direction. Importantly, this process follows significant temporal filtering such that the phenomenon depends mainly on the first and second harmonics of the waveforms. For example, the discriminability of the hue change produced by sawtooth stimuli depends on the visibility of their second harmonic. Hue mechanisms with different slew rates may provide the basis for an explanation of Benham’s top.

Funding: BBSRC

[23T204] Individual differences in the perception of surface properties

**Christoph Witzel<sup>1</sup>, Sabrina Hansmann-Roth<sup>2</sup>, J. Kevin O'Regan<sup>1</sup>**

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This study investigates systematic individual differences in the way observers perceive different kinds of surface properties. We measured individual differences in colour perception with the famous photos of a dress and of a jacket, in colour constancy, in gloss perception, in the subjective grey-point and in the perception of an ambiguous image. Previous studies had shown strong individual differences for all these phenomena. These individual differences might have a common source, namely differences in how observer attribute features in the images to the surfaces or to their illumination in the images. In this case, individual variations should be correlated across these different kinds of phenomena. Results clearly showed that inter-individual differences in the perception of the colour and gloss of the dress are related to whether colour and gloss are attributed to the surface or to the illumination. However, the individual differences in the other tasks were independent of the dress and of each other. We found some evidence that the differences in reported jacket colours are due to differences in colour naming. These results suggest that inter-individual differences arise for various reasons and are unrelated across the different perceptual domains.

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[23T205] Thresholds for discriminating saturation are higher than those for discriminating hue

**Marina Danilova<sup>1</sup>, J Mollon<sup>2</sup>**

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Thresholds for saturation and for hue have seldom been explicitly compared, perhaps because a common metric is needed for comparing different directions in chromaticity space. Working within the framework of the MacLeod-Boynton diagram, we made measurements at reference points lying on lines that pass at either 45° or -45° through the background chromaticity (D65). The vertical (S/(L+M)) ordinate of the diagram was scaled so that thresholds in the two cardinal directions were identical at D65. At a given reference chromaticity, we measured thresholds for saturation (i.e. radial along a line passing through the chromaticity of D65) and for hue (i.e. tangential to a circle passing through the reference point and centred on D65). The attraction of this arrangement is that thresholds can be expressed in common units: the two types of discriminanda differ only the phase with which the short-wave signal is combined with the L/M signal. Except for reference chromaticities very close to the background chromaticity, thresholds were always lower for hue than for saturation. This general law is curious, since in many models the extraction of saturation is distal to the extraction of hue. We offer an explanation in terms of correlated noise in the cardinal channels.

[23T206] The hue of threshold-level tests compared to a six-mechanism model of chromatic detection

**Rhea T Eskew, Safiya Lahlaf, Timothy Shepard**

Color detection mechanisms are sometimes assumed to be univariant “labelled lines,” suggesting that stimuli detected by different mechanisms should differ in hue. We have measured detection contours in the LM plane under four chromatic noise masking conditions (no noise and three different noise chromaticities). The forced-choice detection results are very well described by a six-mechanism model (in which the mechanisms have the same color tuning but different sensitivities across noise conditions). Here we report asymmetric color matches of the threshold-level tests in all the noise conditions. Plotted in (u,v) color space, the matches fall into six, nonoverlapping clusters (across noise conditions). Those clusters correspond to the mechanisms, in the sense that when group of test angles is detected by a particular mechanism according to our detection model, their color matches fall in the same cluster. When a change of noise condition alters which mechanism detects a particular test angle (due to masking), the matching hue of that particular test angle changes from one cluster to another -- the cluster appropriate to the other mechanism. These results strongly support the labelled line assumption in the definition of color mechanisms, and confirm the six-mechanism model.

Funding: NSF BCS-1353338

### ***Wednesday August 31th Poster presentations***

[3P001] Equidistant intervals in perspective photographs

**Casper Erkelens**

Helmholtz Institute, Utrecht University

Human vision is extremely sensitive to equidistance of spatial intervals. Thresholds for spatial equidistance have been extensively measured in bisecting tasks. In spite of the vast number of studies, the informational basis for equidistance perception is unknown. There are three possible sources of information for spatial equidistance in pictures, namely, distances in the picture plane, in physical space, or in visual space. For each source, equidistant intervals were computed for perspective photographs of walls and ditches. Simple visual inspection shows that distances in the picture plane are not the source information. It requires a ruler to convince oneself that equidistant intervals in perspective pictures are really equidistant. Intervals computed for equidistance in physical space are acceptable on the basis of reasoning about the 3D layout of the depicted scene. Intervals computed for equidistance in visual space appear equidistant if the visual space is just two to six viewing distances deep. This finding is in agreement with the depth of visual space inferred from previously measured perspective angles between tracks of a straight railway line.

[3P002] Mona Lisa is always happy – and only sometimes sad

**Emanuela Liaci<sup>1</sup>, Andreas Fischer<sup>1</sup>, Ludger Tebartz van Elst<sup>2</sup>, Jürgen Kornmeier<sup>1</sup>**

<sup>1</sup>Institute for Frontier Areas of Psychology and Mental Health & University Eye Center, Freiburg, Germany; <sup>2</sup>Section for Experimental Neuropsychiatry Department for Psychiatry & Psychotherapy Albert Ludwig University Freiburg Germany

Mona Lisa’s (“ML”) face expression in Da Vinci’s well-known painting is considered to be emotionally ambiguous. In the present study we used the famous image to investigate the influence of context on the ambiguity of emotional face expressions. In Condition 1 we manipulated the painting’s mouth region and created a series of nine image variants changing stepwise from happy to sad expression. We presented the pictures in random order and participants indicated either happy or a sad face perception and rated their confidence on a 4-steps scale. In Condition 2 we reduced the range to only sad facial variants and decreased the step size between them. In both conditions, the original ML was perceived as happy. Furthermore, the face perception described sigmoidal functions of stimulus ambiguity, with participants’ confidence being weakest around the sigmoidal inflection points. Interestingly, the sigmoidal functions differed significantly between conditions, resulting in different perceptual stability values for identical stimuli. Furthermore, participants responded overall faster to happy than to sad face variants. The original ML is less ambiguous than the artist literature suggests. However, perception of emotional face content is relative and strongly depends on the temporal context, whereby the randomization excludes simple priming explanations.

[3P003] The big picture of aesthetics changes depending on the level of analysis

**Uwe C Fischer<sup>1</sup>, Claus-Christian Carbon<sup>1</sup>, Danaja Rutar<sup>2</sup>, Ivan Stojilovic<sup>3</sup>, Stefan A. Ortlieb<sup>1</sup>**

<sup>1</sup>Department of General Psychology and Methodology, University of Bamberg; <sup>2</sup>Department of Psychology University of

In aesthetic assessment we always face two varying perspectives: the individual raters and the rated stimuli. Therefore we should consider and differentiate at least within and between levels (Silvia, 2007). Measurement objects also can be individuals or images. We will discuss the implications of the different analysis of levels at first on a theoretical level and will then explore it exemplarily with a new dataset based on a study of 208 images of decorative and devotional objects. 36 students rated these stimuli in terms of six different adjectives. The two-level analyses for both measurement perspectives were realized as fully determined correlation models with MPlus. We found meaningful differences between the within and between level regarding the same bivariate correlations and also some differences between the focus on measurement objects. For example: the correlation between liking and perceived threat switches the algebraic sign considering within and between individuals. Also changes from zero to high correlations can be detected depending on the level. These differences underline the importance of recognizing both levels in aesthetic assessment measurement. Generalizations should also be done carefully regarding individuals or aesthetic stimuli as measurement objects.

[3P004] Individual differences in aesthetic evaluations of visual arts: Focusing on the aesthetic dimension of value and art-expertise

**Tatsuya Miyashita<sup>1</sup>, Atsushi Kimura<sup>2</sup>, Takashi Oka<sup>3</sup>**

<sup>1</sup>Graduate School of Literature and Social Sciences, Nihon University; <sup>2</sup>College of Risk Management Nihon University; <sup>3</sup>College of Humanities and Sciences Nihon University

The factors related to individual differences in aesthetic evaluations of visual arts are still unclear. Our previous study (Miyashita, Kimura, and Oka, in press) found that the aesthetic dimension of value (Spranger, 1921) is a crucial factor related to the individual differences in aesthetic evaluations based on cognitive aesthetics (goodness, liking). On the other hand, previous studies on individual differences in aesthetic evaluations have mainly focused on the factors related to art-expertise. Thus, we explored whether the aesthetic dimension of value and art-expertise would relate to aesthetic evaluations. Participants were 140 art students and 96 non-art students. Each participant was asked to rate aesthetic evaluations of six paintings by using four items of evaluations (beautiful, pleasant, good, and likable). They were also asked to complete a questionnaire assessing their degree of aesthetic dimension of value. Results of multiple regression analyses demonstrated that the aesthetic dimension of value significantly related to aesthetic evaluations based on cognitive aesthetics ( $\beta = .37, p < .001$ ), whereas the art-expertise didn't ( $\beta = .01, n.s.$ ). These results suggest that the aesthetic dimension of value would be a dominant factor related to individual differences in aesthetic evaluations of visual arts.

[3P005] Nobody likes a fake: Aesthetic value depends on perceived authenticity

**Aenne A Brielmann, Denis Pelli**

Department of Psychology, New York University

People spend incredible amounts of money for original artworks and live music. Why? Perfect copies and high-quality recordings are available for less than one percent the price. Newman and Bloom (2012) have shown that people assign a higher monetary value to art objects that have had direct contact with the artist, suggesting that authenticity is key to the work's perceived value. With two online studies, we assessed the relation between perceived authenticity and aesthetic valuation. In experiment 1, participants (N=38) watched a series of live-music videos and were told in half of the trials the singer was lip-syncing. In experiment 2, participants (N=20) looked at German advertisements and were informed with half of them that the models in the photographs had been retouched. In both experiments, ratings of beauty, pleasure, and attractiveness were positively correlated with perceived authenticity and lower for "fake" stimuli involving lip-syncing or retouching. Videos and models rated "definitely not" authentic were never deemed "definitely" beautiful or attractive. Thus the earlier Newman and Bloom findings on monetary value are here extended to aesthetic value, affirming claims by artists (e.g., choreographer Bill T. Jones) that a feeling of authenticity is essential to aesthetic experiences, such as beauty.

Funding: This research has been funded by New York University and supported by DAAD (Deutscher Akademischer Austauschdienst)

[3P006] The visual attention when viewing colored and black-and-white movies

**Pavel A Orlov<sup>1,2</sup>, Daria Pavlova<sup>1</sup>, Victor Yanchus<sup>1</sup>, Vladimir Ivanov<sup>1</sup>**

<sup>1</sup>Department of Engineering Graphics and Design, Peter the Great Saint-Petersburg Polytechnic University; <sup>2</sup>University of Eastern Finland;

We live in a world abounding with beautifully colored visual stimuli. Color encodes additional information and improves the recognition of natural scenes. Nevertheless, there is a strong tradition of the black-and-white film production. At the dawn of cinema, the black-and-white production was determined by technology of the time. This effect continues to be used by contemporary moviemakers, and we still love old black-and-white movies. Do black-and-white movies have a special effect on visual perception, or is it just a sentimental feeling? We performed two eye-tracker tests to identify the difference in visual attention associated with the colored and the monochrome stimuli. The first test employed static stimuli -- freeze frames from movies, both color and bleached. The second test involved dynamic stimuli -- monochrome and colorized video frames. We found no difference in the average number of fixations and the average fixation duration between color and monochrome stimuli. However, the patterns of viewing were noticeably different. The placements of fixation in color stimuli were more clustered and concentrated in the area of interest, while fixations in black-and-white stimuli extended to a much larger space. Our results show that the visual attention is different when viewing colored and black-and-white dynamic stimuli.

[3P007] An exploratory study on somaesthetics: judged beauty and difficulty of dance postures depends on the involvement of one's own body

**Rob van Lier, Anja Bos-Roubos, Arno Koning**

Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, The Netherlands

We studied the judged beauty of dance postures under conditions in which observers had different degrees of body involvement. The stimuli comprised photos of dance postures by a professional female dancer. In a pilot investigation the complexity of these postures were rated and then clustered in two categories: easy (low complexity) and difficult (high complexity). In the actual experiment, observers (all non-dancers) had to judge the beauty of the postures after mere observation (observation condition), after imagining the posture (imagery condition), and after actually mimicking the dance posture (mimicking condition). Next, observers had to judge the difficulty of the posture, the difficulty to imagine the posture and the difficulty to mimic the posture (counterbalancing conditions). For judged beauty a main effect of body involvement was found with the lowest ratings for mere observation, followed by the imagery condition, and with the highest ratings when actually mimicking the dance postures (for both easy and difficult postures). The judged difficulty in the observation and mimicking condition was as expected (easy for easy postures, difficult for difficult postures) and did not differ from each other. The difficulty to imagine the postures took an intermediate position. We discuss implications of body involvement on somaesthetics.

[3P008] Structure of experience of beauty: General and category specific dimensions

**Slobodan Marković, Vanja Čokorilo, Marija Trkulja, Tara Bulut, Katarina Rančić**

Department of Psychology, University of Belgrade, Serbia

The purpose of the present study was to specify to which extent the underlying structure of experience of beauty is general („beauty as such“) or category specific (e.g. human beauty, landscape beauty, etc.). In the Preliminary study 1, a set of 64 descriptors of beauty was specified (e.g. cute, elegant, magnificent etc.). In the Preliminary study 2, four sets of 24 stimuli were selected: humans, animals, nature and architecture. In the main study, participants judged the stimuli on the list of 64 descriptors. The Principal component analysis revealed six factors for each category. Amazing and Arousing beauty had similar structure in all four categories, Elegant and Cute beauty were common to all categories except architecture, Clear beauty was common to all categories except nature, Magical beauty was common to all categories except humans, Calming beauty was common to nature and architecture. Finally, two factors were category specific: Erotic beauty was specific for humans and Magnificent beauty for architecture. These results show that some dimensions of experience of beauty are general (Amazing and Arousing beauty), some dimensions are relatively highly general (Cute, Elegant, Clear, Magical and Calming beauty), while some dimensions are category specific (Erotic and Magnificent beauty).

Funding: This research was supported by the Ministry of Education and Science of the Republic of Serbia, grant number 179033.

[3P009] Attention Modulation on Children's Representational Drawings

## **Chen I-Ping, Lu Ying-Rong**

Institute of Applied Arts, National Chiao-Tung University

Two experiments designed to probe the modulatory effect of attention on the appearance of children's drawing were done in this study. In Experiment 1, 98 fourth grade children were recruited to copy a fishball skewer picture. There are three fishballs threaded on a skewer, one of them was made salient by putting on facial features. In Experiment 2, 73 children of the same age were given a picture of three piglets to copy. Each of the piglets was distinct from the others by a diagnostic feature. The hypothesis is that the salient features of the stimuli would catch more children's attention, and could potentially affect the representational proportion of these parts in the drawings. The size of the salient fishball and the diagnostic feature in the children's drawings was taken as the dependent variable. The results of both experiments show significant main effect of salient feature, the hot spots of attention being given larger size in children's drawings. An additional position effect was also found in Experiment 1 which again supports the idea that attention does modulate the appearance of children's drawings.

Funding: This study was funded by grant103-2410-H-009-042- from the Ministry of Science and Technology, Taiwan to the first author.

### [3P010] Evolution of symmetry in fractal tree and moss patterns

#### **Tim Holmes, Helen Scott, Johannes Zanker**

Research & Development, Acuity Intelligence Ltd; Royal Holloway University of London, UK

A 'natural' preference for symmetry is widely observed in biological systems and many aspects of human perception, and is often discussed by artists and arts historians as one of the key components of aesthetic experience. In the last few years we developed an objective method to assess preference (Holmes & Zanker, *i-Perception*, 2012), making use of unconscious eye movements while looking at a simultaneously presented set of stimuli – an iterative gaze driven evolutionary algorithm (GDEA). Recently the GDEA was successfully employed to assess the preference of human observers for symmetries in sets of randomly distributed disks (Makin et al, *i-Perception*, 2016), with participants preferring a slight asymmetry in the abstract pattern. Here, we designed a new stimulus that incorporates symmetry in a more holistic shape by generating fractal patterns that resembled trees (a vertically oriented branching pattern) and moss (branching out in all possible directions) using an algorithm in which regularity, complexity, and symmetry could be systematically varied and incorporated as stimuli within the GDEA. Over several generations of the algorithm, observers evolved patterns with symmetry properties, which were confirmed in perceptual control tests as being preferred relative to the less symmetric patterns.

Funding: ESRC grant (ES/K000187/1)

### [3P011] Mobile Eye tracking in the Gallery: Square murals by Sol LeWitt

#### **Johannes M Zanker<sup>1</sup>, van der Vliet Skye<sup>1</sup>, Jasmina Stevanov<sup>2</sup>, Tim Holmes<sup>3</sup>**

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Since Yarbus (1967) seminal work, research about the link between eye movements and different aspects of perceptual and cognitive processes remains in the focus of experimental aesthetics: what can we learn from spontaneous gaze patterns of naïve and the targeted gaze of trained arts experts? Are these patterns context dependent (laboratory vs. museum)? With the advent of more sophisticated mobile eye-trackers, we were able to investigate how people explore art works in their 'natural' environment. We used a TobiiGlasses2 system in an exhibition of Sol LeWitt in the Quadrat Bottrop (Germany), which featured a series of nested square murals with the signature colour combinations of the Bauhaus artist Josef Albers. Participants were invited to move around and explore the gallery at their leisure, and their eye movements were recorded together with a camera view of their field. We record rich data sets for each of 10 paintings, revealed characteristic patterns of fixations, predominantly in regions of colour boundaries. This demonstrates that, despite the challenges of recording precise measurements with a mobile eye tracker, such as turning/tilting the head, variations in spatial illumination, we were able to collect meaningful data outside the controlled conditions of the laboratory.

Funding: support by ESRC grant (ES/K000187/1)

### [3P012] Role of Action in modulating bottom-up attentional mechanisms

## **Kishore K Jagini, Meera Mary Sunny**

Center for Cognitive Science, Indian Institute of Technology Gandhinagar

Studies suggested that stimuli perceived as consequence of one's own action receive an advantage in processing. Recent study (Kumar et al., 2015) showed that a feature singleton captures attention through automatic action effect monitoring. Present study investigates the relative role of features in determining which stimulus binds with action and is perceived as action effect monitoring. That is we tested how action modulates attention when two feature singletons, in different dimensions (shape and color), were presented. In two experiments, we used an additional singleton paradigm to see how different feature dimensions bind with action based on their relevance and salience. In experiment-1, the target was a shape singleton while the irrelevant additional singleton was color. Participants completed two separate blocks where the search display either appeared automatically (no-action) after a pre-specified time or after participants pressed a key (action). Results showed that in the no-action condition, colour captured attention, but not in the action condition. However, such an asymmetry was not found in Experiment-2 when shape was the irrelevant singleton and colour was relevant. The results suggest that when more than one feature that could possibly be perceived as consequence of one's actions then the most salient stimulus is selected.

Funding: IIT Gandhinagar, Department of Science and Technology - Government of India

### [3P013] Global Enhancement but Local Suppression in Feature Based Attention

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A key property of feature-based attention is global facilitation of the attended feature throughout the visual field. Previously, we presented superimposed randomly moving red and blue dot kinematograms (RDKs) flickering at a different frequency each to elicit frequency specific steady state visual evoked potentials (SSVEP) allowing us to analyze neural dynamics in early visual cortex when subjects shifted attention to one of the two colors. Results showed amplification of the attended and suppression of the unattended color as measured by SSVEP amplitudes. Here, we tested whether the suppression of the unattended color also operates globally. We presented superimposed flickering red and blue RDKs in the center of a screen and a red and blue RDK in the left and right periphery, respectively, also flickering at different frequencies. Subjects shifted attention to one color of the superimposed RDKs in the center to detect coherent motion events in the to-be-attended color RDK, while the peripheral RDKs were task irrelevant. We found no reduction in SSVEP amplitude relative to pre-cue baseline, when the peripheral color matched the unattended one of the central RDK, indicating while facilitation in feature-based attention operates globally, suppression seems to be linked to the location of focused attention.

Funding: German Research Foundation

### [3P014] The role of overt attention in brain response to emotional images

**Michał Kuniecki<sup>1</sup>, Joanna Pilarczyk<sup>1</sup>, Aleksandra Domagalik<sup>2</sup>**

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Emotional objects attract overt attention more than neutral objects, even if images have been severely degraded. We wanted to find brain structures responsible for this effect. Fifty negative and neutral images were selected from databases of emotional images. Semantic regions of interest for each picture were obtained in a separate study. Pink noise was added to images in several proportions. Twenty healthy participants had fMRI scans while images in sequences from pure noise to lack of noise were presented with goggles equipped with an eye-tracker. Noise level explained activations in lateral occipital cortex, inferior temporal gyri, temporal fusiform cortex, middle and inferior frontal gyri, and frontal orbital gyri. In negative valence the noise level correlated with activations in precuneus, superior frontal gyri, and frontal medial cortex. Chance of looking at both negative and neutral objects explained activation in right lateral occipital cortex, related to object recognition. We show that structures involved in guiding attention to the semantic information are not valence specific. Activity in structures typically involved in emotional processing is linked to image clarity and onset. Thus, emotional response is not directly dependent on focusing overt attention on the key object, but rather on overall image presence and clarity.

Funding: This work was supported by the Polish National Science Centre (grant number 2012/07/E/HS6/01046).

[3P015] Comparing the allocation of visual attention to features and spatial locations

**Cody W McCants, Nick Berggren, Martin Eimer**

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When engaging in visual search, target-defining features are represented in attentional templates. Most studies of template-guided search have focused on non-spatial target properties (e.g., colour or shape). In the present study, we compared the efficiency of attention selection of spatially-defined versus colour-defined targets. Cues that specified either the location of the target item or its colour were presented 250ms before or simultaneously with a visual search display. Search displays contained a target and three distractors in four different locations and colours. Participants responded to the target's orientation. N2pc components were measured during task performance as electrophysiological markers of attentional target selection. Errors were more frequent when cues and target arrays were presented simultaneously, and target N2pc components were delayed. Spatial cues were associated with reduced error rates and an earlier N2pc onset, but only when cues were presented concurrently with search arrays. When cues preceded targets, there were no behavioural or N2pc differences between spatial and colour cues. These findings suggest that spatial templates can be activated more rapidly than featural templates. However, when sufficient preparation time is available, both types of templates are equally efficient in guiding attentional target selection.

[3P016] Object IOR in dynamic displays is modulated by social stimuli.

**Robert Swalwell, Daniel Smith**

Department of Psychology, Durham University, UK

The differences in inhibition of return (IOR) for emotional or social stimuli compared to non-social objects have been examined by a number of studies, although results have proven inconsistent. This inconsistency may be a result of previous research conflating location IOR and object IOR, as well as inconsistencies in the length of stimulus onset asynchronies (SOAs) across studies. The present experiment addressed these issues by comparing IOR between social and non-social stimuli using dynamic displays at three SOAs. Location and object IOR could be measured separately as objects moved between the appearance of the cue and the target. A within-participants design was used that compared two conditions, one using non-social (squares) and one using social (schematic faces) stimuli respectively. Object IOR was observed for the non-social condition, while object facilitation was observed in the social condition. Neither object nor location IOR was observed for the social condition at any SOA. This dissociation suggests that in dynamic displays, social stimuli are not subject to inhibitory cueing effects.

[3P017] Object-based attention in pigeons: Effects of enhanced independence between objects

**Kazuki Fujii, Yukiko Hoshino, Maki Katsube, Tomokazu Ushitani**

Graduate School of Advanced Integration Science, Chiba University

It is known that humans attend to cued objects, rather than to exact cued areas. Therefore, humans can respond to a target appearing within a cued object (Within condition) faster than to a target appearing within a non-cued object (Between condition). In contrast, our previous study demonstrated no evidence of such object-based attention (OBA) in pigeons, perhaps because pigeons might have not perceived the two identical rectangles used in the study well independently of each other. In the present study, we used different-colored, red and blue rectangles, and examined if reaction times in the Within condition was shorter than that in the Between condition. Results were consistent with OBA in pigeons, however, they might have been caused by attention to the color on which the cue appeared, rather than to the cued object. Therefore, we then used rectangles with a color gradation to present the cue and the target on different color grounds under the Within condition, and on the same color grounds under the Between condition. Results indicated no differences in reaction times between the two conditions, suggesting that not only color, but also other features might have defined the objectness for pigeons.

[3P018] Fear improves unconscious visual processing of coarse low spatial frequency information

**Manon Mulckhuyse, Maria Lojowska, Erno Hermans, Karin Roelofs**

Donders Institute for Brain, Cognition and Behavior, Radboud University, The Netherlands

Previous research showed that fear improves visual processing of low spatial frequency information. It has been suggested that this enhancement is mediated by a fast subcortical magnocellular pathway involving the amygdala. In

the current study, we investigated whether subliminally presented low spatial frequency information is enhanced due to fear. We used a visual orientation task consisting of a brief presentation (16.7 ms) of four low or high spatial frequency Gabor gratings centered around the fixation and followed by a mask that rendered the stimuli invisible. To induce fear, the color of the fixation signaled a 50% chance of receiving an electric shock, or a safe condition. Participants had to indicate whether one of the four stimuli had a left or right orientation relative to the remaining three vertical orientations. To assess visual awareness of the gratings, they additionally had to indicate the location (left or right) of the tilted grating. Results showed that when participants were incorrect on the location task, performance on the orientation of low spatial frequency gratings was above chance level under conditions of threat. These findings indicate that fear improves visual processing of low spatial frequency information even in the absence of awareness.

[3P019] Concurrent auditory rhythm enhances visual object salience

**Xiangyong Yuan, Yi Jiang**

State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences

Visual detection can be facilitated by matched auditory stimulation. The present study aimed to investigate whether rhythmic sounds can enhance the salience of visual objects that share the same rhythmicity. We created a grid visual display ( $7.9^\circ \times 7.9^\circ$ ) where 24 gray bars with clockwise or counter-clockwise  $22.5^\circ$  orientations from the horizontal or the vertical were randomly distributed, with half of their luminance modulated by a sine-wave temporal profile of 3.16 Hz and the other half 1.82 Hz. Concurrent sounds were amplitude-modulated by sine-waves of 3.16 Hz, 1.82 Hz or 2.5 Hz, making them either congruent with the luminance changes of half of the visual bars or not. During the audiovisual presentation, observers were required to detect a target bar which suddenly changed its orientation. Observers' detection accuracies were significantly increased once the frequency of the sound was congruent with that of the target bar. These findings suggest that concurrent auditory rhythms can simultaneously enhance the visual salience of multiple objects with congruent rhythmicity, with the effect likely mediated through the integration of neural oscillations.

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[3P020] Surprising non-salient stimuli detract attention from a novel color singleton

**Daniel Ernst, Gernot Horstmann**

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A common theme in visual attention research is whether attention is biased by bottom-up factors such as saliency, or by top-down factors governed by the task. Visual search experiments where participants see a novel stimulus unannounced and for the first time after several familiarization trials support a third factor, where attention is biased by novel and surprising features. Notably, recent experiments have shown that the surprising stimulus does not have to be singled out by saliency in order to capture attention. In a current eye-tracking study where in the surprise trial a singleton was presented for the first time, we manipulated the novelty of the non-singleton feature. In the familiar non-singleton color condition the surprise singleton is the only novel element, whereas in the novel non-singleton color condition, the non-singleton elements are likewise novel. If attention is biased towards novelty, we expect that the singleton captures attention earlier when the non-singletons had a familiar rather than novel color. Results supported this prediction, with gaze being directed earlier on the singleton in the familiar rather than novel non-singleton condition. These results further support the potential of surprising non-salient stimuli to attract attention even in competition with a surprising color singleton.

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[3P021] The Role of Attention on the Minimum Presentation Duration Required for Scene Recognition

**Berhan Senyazar, Albert Ali Salah, Inci Ayhan**

Cognitive Science Program, Bogazici University

It has been shown that little if any attention is required for scene recognition (Li, VanRullen, Koch, & Perona, 2002). The absence of the role of attention in scene recognition, however, has been challenged by Cohen, Alvarez, & Nakayama (2011) showing that basic-level scene categorization and object identification performance degrade while simultaneously performing an attention-demanding task. Here, we use the same dual-task paradigm, but in a broader

range of scene recognition tasks, including detection, recognition of spatial envelope and scene function, superordinate- and basic-level categorizations. While performing a recognition task on scene images embedded in a stream of masking patterns (Greene, & Oliva, 2009), participants simultaneously tracked multiple discs. For each task, target and distractor images were presented for seven duration levels (11.7-117ms). At the end of each trial, yes/no answers were reported for both tracking and scene recognition tasks. Data points were fit into a Weibull function to determine the minimum duration at which the percentage of correct answers reached 75%. D-prime values confirmed that the recognition tasks were more difficult for participants in dual-task than in control blocks. For all recognition tasks, there was a trend of higher presentation duration thresholds in dual-task blocks relative to baselines.

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[3P022] Visual direction of Brewster's phenomenon and the percept produced by Wheatstone's first stereogram

**Linda Lillakas, Hiroshi Ono**

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We examined Brewster's (1844) perceptual phenomenon that is produced by the same proximal stimulus as Wheatstone's (1838) first stereogram. It consists of a tilted line appearing in the median plane. Although it was difficult to maintain the required convergence, observers were able to achieve it when using fixation aids. We tested a different stimulus that also produced the same proximal stimulus. Observers reported the perception of a tilted line on the median plane; the top tilted towards or away from them, when the proximal lines produced uncrossed or crossed disparity, respectively. The finding is of interest with respect to the rule, suggested by Hering (1865), that the average of the two local signs and binocular eye position determine visual direction. It also indicates that the perception predicted by the rule had already been observed by both Brewster and Wheatstone. We will demonstrate this perceptual phenomenon with a stimulus different from those used by Brewster and Wheatstone.

Funding: NSERC to H. Ono

[3P023] Mapping the temporal and neural properties of binocular mechanisms for motion-in-depth perception

**Ryan T Maloney<sup>1</sup>, Milena Kaestner<sup>1</sup>, Joe Ansell<sup>1</sup>, Marina Bloj<sup>2</sup>, Julie Harris<sup>3</sup>, Alex Wade<sup>1</sup>**

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Two binocular sources of information can be used to compute motion-in-depth (MID): the change in disparity of an object over time (CD), or the difference in velocities on the two retinæ (inter-ocular velocity differences, IOVD). We isolated these cues in modified random dot stereograms and developed novel "control" versions of both that nulled the smooth motion-through-depth signal, while retaining all low-level and temporal characteristics. In a 2-interval forced-choice paradigm ( $n = 3$ ), we probed the spatiotemporal properties of the two MID mechanisms, measuring dot coherence (proportion of "signal" to "noise" dots) and dot contrast thresholds for detection of MID above the null control. Sensitivity for CD tended to peak at lower temporal frequencies (0.7-1.33 Hz) and intermediate binocular disparities (10-22 arcmin). The IOVD mechanism was biased towards higher lateral motion displacements and frequencies (2-6 Hz). We then adapted these stimuli for an event-related functional magnetic resonance imaging (fMRI) study ( $n = 5$ ), and compared the responses to the two isolated cues in visual cortex. The results suggest these differentially-sensitive binocular mechanisms probably act in parallel in the computation of motion-in-depth.

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[3P024] Inter-dimensional crosstalk in perceived three-dimensional position relative to a slanted array

**Harold Sedgwick**

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Observers monocularly viewed computer-generated, wide-angle images of a sparse, regular array of square tiles. The array was on a vertical plane slanted in depth around a vertical axis. On each trial a central target tile was displaced horizontally by varying amounts, including zero, either laterally (along the plane of the array), in depth (perpendicular to the plane of the array), or both. Observers reported the perceived direction of the displacement. The two types of displacement each produced shifts in the horizontal position of the image projected by the target, and each type also

produced changes in the projected size of the target's image. These image transformations together were sufficient to geometrically specify the three-dimensional displacement of the target. Observers' responses, however, showed substantial crosstalk, such that displacements parallel to the slanted array were often perceived as also having a component of perpendicular displacement, and vice versa. This finding replicated, with substantially different display parameters, that of an earlier study (VSS, 2015). The new parameters eliminated a bias, found in the earlier study, against perceived target positions behind the plane of the array. Implications for the perceptual formation of extended surfaces are discussed.

Funding: Schnurmacher Institute for Vision Research

[3P025] Perceived stimulus size and depth in virtual 3D space – Measurement of response force and simple reaction time

**Thorsten Plewan**

Ergonomics, Leibniz Research Centre for Working Environment and Human Factors

Stimulus intensity is strongly related to response force (RF) while there is an inverse relationship to simple reaction time (RT). Accordingly, RF increases and RT decreases as a target stimulus becomes more intense. There is additional evidence that those effects are not limited to changes in physical stimulus properties but can also be elicited via differences in perceived stimulus size. The latter, however, was recently challenged by an investigation in which perceived and physical stimulus size was varied in virtual 3D space. Therefore, in the present study this line of research was continued while participants' responses were recorded by means of a force key. Thus, RF was analyzed in addition to RT: Neither RT nor RF appeared to be susceptible to changes in perceived stimulus size. In contrast, there seems to be an interaction of induced depth (near vs. far) and stimulus size condition (perceived vs. physical). In particular, the measurement of RF indicates stronger responses related to targets which are presented closer to the observer, irrespective of their perceived size. From a methodological point of view, these findings emphasize that RF can provide additional insight into the processing of (virtual) 3D information.

[3P026] More 3D ambiguity is produced by less 2D information

**Vasily Minkov, Sergey Kutylev, Tadamasa Sawada**

School of Psychology, Higher School of Economics, Moscow

It is essential to control the stimulus and to understand its properties when studying the perception of a visual stimulus. These restrictions encourage vision scientists to use stimuli that have a minimum amount of information. For example, a triangle (or its representation by 3 points) has been used in many studies of 3D perception based on a single image or from a stereo-pair of images because the 3 points of a triangle are the minimum number needed to define a shape in a 3D scene. But, many computational theories suggest that the 3D interpretation of an image becomes more ambiguous when the information in the image is too limited. In this study, forward and inverse projections between a triangle in an image and another triangle in a scene were analyzed mathematically and computationally. The results of this analysis showed that the 3D orientation of a triangle in a scene is often undeterminable even when the shapes of the triangles in the scene and in the image are given. In this case, the number of possible orientations is zero, one, or even more. We will discuss prior studies, which used triangles as their stimuli, on the basis of these results.

[3P027] Is there a cost to binocular vision: A link between the statistics of binocular images and the effect of eccentricity on visual performance.

**David W Hunter<sup>1</sup>, Paul Hibbard<sup>2</sup>**

<sup>1</sup>School of Computer Science, Edinburgh Napier University; <sup>2</sup>University of Essex

The extent to which visual performance degrades with eccentricity varies substantially depending on experimental stimulus and task (Strasburger, Rentschler, & Jüttner, 2011). Performance for very low-level tasks, such as the minimum angle of resolution and grating acuity, degrades substantially less with eccentricity than positional tasks such as stereo-acuity and Vernier acuity (Levi, Klein, & Aitsebaomo, 1985). This implies at least two receptive field mappings in peripheral regions: a fine-grained system driving low-level tasks and a coarse-grained system driving higher-level tasks. Using statistical analysis of binocular photographs of everyday scenes, we found a link between the ability of a linear-non-linear neuron model, learned using ICA, to find binocular matches, and psychophysical measures of the effects of eccentricity and spatial frequency on stereo acuity. This link replicates across component

frequency and shows a strong effect of frequency on the rate of stereo-acuity decay, also matching known human performance (Siderov & Harwerth, 1995). We hypothesise that the apparent hierarchy in visual performance with eccentricity in binocular tasks is driven the reduction of redundancy between left and right images with increasing disparity, combined with the need for binocular processing in peripheral vision.

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[3P028] Predicting how similar two faces look, using deep neural networks and optimised stimuli

**Katherine R Storrs, Kamila Jozwik, Johnathan O'Keefe, Nikolaus Kriegeskorte**

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Artificial neural networks now rival human performance, even within expert domains such as face identification. Do they also capture subtle perceived similarity relationships among faces? Observers (N=26) rated the similarity of 232 pairs of photorealistic faces from a 3D generative model. We compared ratings to representational similarities in 16-layer convolutional networks trained on millions of images to recognise either objects or faces. Both networks explained almost all explainable variance in similarity ratings, with highest performance in intermediate layers. Features within the face-trained network better predicted ratings than those within the object-trained network in early and late, but not intermediate, layers. Most alternative models performed worse, including models from the face perception literature (angle in 'face space,' and facial configuration) and 'null' models (based on pixels or 3D face meshes). However, other models performed statistically indistinguishably from convolutional networks, including the Gabor-filter based 'GIST' model, and distance in face space. The success of GIST may be due not to its unique explanatory power, but to its high shared variance with more complex models for the image set used. We present a widely-applicable method for stimulus-set design that increases power to distinguish alternative models by iteratively selecting stimuli that reduce model correlations. Funding: MRC Postdoctoral Trainee fellowship to KS

[3P029] A Model for Binocular Summation of Chromatic Signals

**Hsiao-Yuan Lin, Chien-Chung Chen**

Department of Psychology, National University of Taiwan

We investigated binocular summation of chromatic information with a color matching experiments. In each trial, a test square ( $2 \times 2^\circ$ ) was dichotically presented to the observer. The test for the left and the right eyes had the same chromaticity, drawn from either isochromatic, L-M or S-cone axis, but differed in contrast. The task of the observer was to adjust the contrast of a match square, which had the same chromaticity and contrast for each eye, to match the appearance of the test. When the contrast difference between two eyes was small, the match contrast was about the average contrast of both eyes. However, when the binocular contrast difference was larger, the match was dominated by the higher contrast of the two eyes, regardless of the eye origin. Similar result was found in all colors, suggesting a common process underlying binocular summation in different color channels. The data can be fit by a divisive inhibition model in which the response of a monocular mechanism is a power function of contrast of stimuli presented to that eye divided by inhibition signals from both eyes and the performance is determined by a binocular mechanisms that linearly combines the monocular responses.

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[3P030] The role of stereo disparity in early processing of global shape configuration and local part structure during object recognition: an ERP study

**Zoe Oliver, Filipe Cristino, Charles Leek**

Psychology, Bangor University

This study investigates the role of stereo information in perception of three-dimensional objects and its interaction with processing information at different spatial scales. Two groups of observers, viewing in stereo or non-stereo, completed an object recognition task, making recognition judgments about novel 3D objects after learning a subset in training. For each object learned in training, 3 corresponding distractor objects were designed: differing in terms of volumetric local parts, spatial configuration or both. Analyses of the ERP waveforms showed that the earliest perceptual sensitivity to binocular disparity occurs over posterior locations during the P1 component (85-125ms), whereas differential sensitivity to volumetric parts and spatial configuration occur at posterior locations during the N1 component (145-195ms). These differences were modulated by stereo viewing: globally-weighted processing occurred earliest in the

stereo-viewing group, whereas the opposite pattern was observed in non-stereo. There was differential activity for all contrasts at the N2 component (270-320ms), indicating a possible temporal marker for image classification, observed in both viewing groups. The results show that stereo input modulates the perception of 3D object shape, and are consistent with the hypothesis that the recognition of multipart 3D objects involves parallel perceptual analyses of information at different spatial scales.

### [3P031] The Extraction of Disparity-Defined Structure Using Cyclopean Filtering

**Paul B Hibbard<sup>1</sup>, Ross Goutcher<sup>2</sup>**

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Many neurons in the primary visual cortex are sensitive to binocular disparity, and thus encode valuable information about 3D structure. These neurons tend to be tuned to absolute disparity, the difference in location of a corresponding region in the two retinal images. In contrast, the perception of depth depends on relative disparity, the difference in absolute disparity at different locations within the image. We show how spatial filtering in the cyclopean domain can be used to recover relative disparity from absolute disparity signals. This filtering allows for the encoding of important depth structure, such as 3D surface orientation and the presence of depth edges. Zeroth-order (absolute) disparity corresponds to zero-crossings in the cyclopean-filtered binocular cross-correlation. First-order depth variations, indicating the orientation of surfaces, can be identified by using filters tuned to different orientations in disparity-space. Finally, the location and orientation of depth edges can be determined using a cyclopean energy model, to provide a response that is invariant to absolute disparity. We show how these filtering operations can directly identify perceptually salient features of 3D structure (Wardle & Gillam, 2016), and relate them to physiological responses in extrastriate cortex (Bredfeldt and Cumming, 2006; Orban, Janssen & Vogels, 2006).

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### [3P032] Influence of stimulus orientation and closed figures on stereopsis

**Anna Ptukha, Pascal Mamassian**

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Real objects usually extend well beyond receptive fields of cells that first process binocular disparity. To investigate the extent to which the context influences local binocular information, we measured stereoacuity thresholds for a variety of simple figures. Observers viewed stereoscopically two types of stimuli presented in the fovea: two thin parallel lines or the same lines connected with horizontal segments so as to form a parallelogram. The lines could be vertically-oriented or tilted by an angle up to 60 degrees. After a short (200 ms) presentation used to reduce eye movements, observers reported which line appeared more proximal in depth. While it has been suggested that sensitivity to depth decreases as the cosine of tilt angle for lines (Ebenholtz and Walchli, 1965, Vision Research), we found that sensitivity is quite robust across stimulus orientations. For parallelograms, the overall sensitivity was reduced relative to that of two lines, and tilt had a stronger influence. To interpret our findings, we contrast two models. The first model is based on depth uncertainties generated from closed figures (Mamassian, 2008, ECVF) and those from the aperture problem. The second model is based on the non-separable coding of disparity and orientation (Farell, 2009, Vision Research).

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### [3P033] Synoptic viewing and monocular blur

**Maarten Wijnjtes**

Perceptual Intelligence Lab, Faculty of Industrial Design Engineering, Delft University of Technology

The vivid impression of three-dimensional depth is not only reserved to viewing a pair of stereo images: there are various ways of viewing that cause 'paradoxical' monocular stereopsis, also known as the 'plastic effect'. Although various viewing modes have been proposed throughout time, their strengths have never been compared. Here, we compared three viewing modes: monocular blur, synoptic viewing and free viewing. By designing a physical embodiment that was indistinguishable for all three experimental conditions, we kept observers naïve with respect to their differences. 197 observers participated in an experiment where the three viewing modes were compared by performing a rating task. Results indicate that synoptic viewing causes the largest plastic effect. Monocular blur scores lower than synoptic viewing but is still rated significantly higher than the baseline conditions. The results show that

synoptic viewing is not due to some kind of placebo effect. Furthermore, we empirically show for the first time that monocular blur leads to a plastic effect, although the strength is smaller than synoptic viewing. We discuss the results with respect to the theoretical basis for the plastic effect. We show that current theories are not described with sufficient details to explain the differences we found.

[3P034] Reading speed improvement with coloured filters: Is the advantage of preferred over non-preferred colours a placebo effect?

**Jane Cowan, Nick Scott-Samuel, Clive Franklish**

Experimental Psychology, University of Bristol, UK

Individually chosen coloured filters (overlays or lenses) are claimed to benefit reading for visual stress sufferers, but this could be attributed to a placebo effect. We investigated the effect of colour on reading for coloured filter users (visual stress group) and controls. Reading speed and accuracy were measured with an adult, speed, 'cloze' reading test, based on Andrews and Hersch (2010, JEP:General, 139, 299). Text colour was gradually changed between an individual's preferred colour and another, nearby, hue. Controls underwent the same procedure. Participants' awareness of the colour change was recorded. Reading speeds on the preferred colour were significantly quicker for the visual stress group, but not for the control group. However, only those who had noticed the colour change read significantly quicker, and there was no difference in reading speeds when participants didn't notice, indicating a placebo effect. Furthermore, a combined reading speed-accuracy measure revealed no significant difference between the two colour conditions. This suggests no overall reading benefit of applying a specifically chosen coloured background to text when compared to control. In our experimental conditions, the specificity of colour appears not to be the important factor to aid reading for those who may suffer from visual stress.

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[3P035] Better colour constancy or worse discrimination? Illumination discrimination in colour anomalous observers

**Stacey Aston, Jay Turner, Thomas Le Couteur Bisson, Gabriele Jordan, Anya Hurlbert**

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Colour constancy is the perceptual stability of surface colours under temporal changes in illumination spectrum. The illumination discrimination task (IDT) (Pearce et al. 2014) reveals worse discrimination for bluer illumination changes in trichromatic observers, indicating greater stability of scene colours or better colour constancy, compared with illumination changes in other chromatic directions. Here, we compare performance of "red-green" dichromats on the IDT to trichromats. The IDT is performed in an immersive setting, where a Mondrian-papered scene is illuminated by spectrally tuneable LED luminaires. Using a 2AFC paradigm and a 1-up, 3-down staircase procedure, we determine discrimination thresholds for illumination changes relative to a reference illumination (D65) in four chromatic directions in CIE1931 colour space, blue/yellow/red/green. Thresholds show an interaction between dimensionality of colour vision and the asymmetry in illumination discrimination ability across chromatic directions ( $p < 0.001$ ); dichromat observers do not exhibit the "blue" bias. Moreover, average thresholds (regardless of chromatic direction) are larger for dichromats than trichromats ( $p < 0.01$ ), indicating worse overall discrimination or better colour constancy. This contradicts the results of Alvaro et al. (2015) who, using a modified and simulated IDT, reported no difference in thresholds between normal and red-green dichromat observers for yellow/blue illumination changes.

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[3P036] Color Vision Perception: A trial to understand how the change in colour perception happens in "#thedress" phenomenon

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Aim: The visual perception and color perception are individual. "#thedress" is a digital photo of a dress, which is taken occasionally. Some people see the dress golden-white and the others blue-black on the screen. Science still couldn't explain how this happens. There is also a change in the perception of some people, if they look at the dress for the second, third, fourth time. Methods: The visual perception explanation of Yarbus combined with the physiologic sharpness of the "normal" vision in the visual field results in tiny spots of visual perception with high visual sharpness.

So one sees a small area which can be only seen in a certain colour. The environmental colour contrast of the six fixation points due to Yarbus, is dependent from the colour contrast of the pixels around the main six pixels. With the change of fixation pixels due to Yarbus model, the contrasting pixels change also. So the entire colour perception may change. Results: The colour perception change in #thedress may be due change in fixation pixels after the first “look”, and the contrast around the fixation pixels change also. This may be the reason of the change in the colour perception of #thedress.

Funding: None

[3P037] Is primate trichromacy optimized for detecting variation in face coloration?

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Primate trichromatic color vision has been hypothesized to be optimized for detecting variation in facial coloration. We tested an aspect of this hypothesis by asking whether trichromatic vision improves the ability to detect reproductive status. We used digital images of natural color variation of female rhesus macaques, whose face color becomes redder and darker according to their menstrual cycle phase. We presented proceptive and non-proceptive face pairs of each monkey, and asked human participants to select the proceptive face. We simulated numerous visual systems, including dichromacy (protanopia, deuteranopia and tritanopia), trichromacy with a narrower separation of L-M cone opsin pigment peak sensitivity and trichromacy with evenly separated LMS pigments, in addition to unmanipulated trichromatic vision (normal trichromacy). Performance in both normal and narrower L-M separated trichromatic conditions was better than in dichromatic conditions. Results indicated that participants in those trichromatic conditions used redness as an explicit cue, but also that lightness differences were important in determining the speed of signal detection. Overall, our results suggest that primate trichromatic color vision is advantageous for detecting meaningful variation in primate face color. Social signaling may favor the maintenance of opsin spectral tuning, though it is not necessarily optimized for detecting reproductive status.

[3P038] Evidence for a temporal component in the influence of the colour of the surrounding

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A surface's apparent colour depends on the colour of its immediate surrounding. Is this simply a consequence of colour judgments being based on chromatic edges in the retinal images, or could our incessant fixational eye movements partly be responsible for this? As a first step towards answering this question, we used a hue-cancellation technique to evaluate how jittering a scene affects the influence of the surrounding. The surrounding was either uniform, or divided into four sections so that the regions above and below the target surface had one colour, and the regions to its left and right had another. The scene was either jittered horizontally or vertically. The regions in the direction of the jitter had a stronger influence on the perceived colour than did the other regions. This difference was absent when the surface was separated from the surrounding by a black rim, even if the rim was much smaller than the amplitude of the jitter. It would therefore appear that the effect specifically arises from local changes in retinal stimulation, as normally result from our incessant eye movements, rather than from any successive exposure of parts of the retina to both the target surface and its surrounding regions.

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[3P039] Quantitative characterization of color vision using steady state visual evoked potentials

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Steady state visual evoked potentials (SSVEPs) have been widely noticed as clues for understanding perceptual/cognitive states in the visual area of brain. In this study, we used SSVEPs to elucidate color discrimination ability of individuals. In an experiment, we employed 30 subjects (20-81 years old). Of them, eighteen people had normal color vision. Four people had congenital red-green color deficiency. Twelve people had acquired cataract or glaucoma. The subjects were instructed to gaze at stimulus flickering along red-green, blue-yellow or achromatic directions in the L'u'v' color space, which were indistinguishable for protanopia and tritanopia. Flickering frequency

was manipulated in each experiment session (2, 3, 4, 5 or 10 Hz). During sessions, SSVEPs were measured at eight loci (POz, 3-4, 7-8 and Oz, 1-2) on the back of the head. In the subjects with congenital color deficiency, the SSVEPs elicited by the red-green stimulus were much smaller than ones in the normal subjects, whereas the SSVEPs elicited by the blue-yellow stimulus tended to be larger. In the subjects with acquired disease, the SSVEPs elicited by either stimulus became smaller according to progression of the diseases. In summary, we found that type of color vision can be quantitatively characterized by their SSVEPs.

[3P040] The role of visual coding in categorical perception of color

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Categorical perception of color (CPC) represents faster discrimination of shades from different than from the same color category. Since within-category shades share the same verbal code, their discrimination could be based only on visual code. We investigated visual coding in CPC using shape as visual interference. RT was measured in simultaneous color discrimination task (14 participants). Color stimuli around the blue-green boundary formed 6 within-category and 6 between-category pairs. For visual interference we used 3 different stimuli shapes (circle, square, hexagon) in 4 experimental conditions: neutral (all stimuli had the same shape), control (all stimuli had different shapes), congruent (target and test stimuli: same color, same shape), incongruent (target and test stimuli: same color, different shapes). CPC effect was significant ( $F(1,13)=39.53$ ;  $p < .001$ ), participants were fastest in congruent condition ( $F(3,39) = 7.37$ ;  $p < .001$ ). Our specific procedure revealed that within-category comparisons in congruent condition were equally fast as between-category comparisons with shape incongruence ( $F(3,39) = 3.90$ ;  $p < .05$ ), demonstrating that additional visual information (shape) enhances discrimination, especially in within-category comparisons. This provides a new and alternative confirmation of existing CPC hypothesis.

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[3P041] Testing for Multidimensional Color-Emotion Semantic Space

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Attempts to associate particular color concepts and specific emotions were rare although a strong connection was always assumed. We tested for a potentially wide range of semantic connections between emotions and color terms by asking 106 Serbian native speakers (age 19-79) to associate 20 emotions to 12 color terms. This particular dataset is part of a multi-national online survey, where participants are asked to indicate for each color term any number of associated emotions on 5-level intensity scale. We found a significant interaction between the color terms and emotions ( $F(209,42)= 18.46$ ,  $p < 000$ ), different color terms are associated with different emotions at different intensity. Also there is significant difference between the 12 color terms ( $F(11)=16.7$ ,  $p < 000$ ). Some color terms seem to evoke a single associated emotion (i.e. brown is just disgust) while some color terms cover a number of emotions and intensities (red scores high on 6 different positive and negative emotions; green and turquoise on 5 positive emotions). Factor emotion was also significant ( $F(19)=16.7$ ,  $p < 000$ ): anger, love, disgust, regret, fear and hate are associated to a single color; joy and pleasure are associated with 6 colors. Finally, we did not find particular emotion-color associations for compassion, contempt, guilt or shame.

[3P042] The development of a colour basic category in the Spanish language: Universal and relativistic factors related to the “celeste” colour category

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Three experiments provided the identification and colourimetric delimitations for the Basic Colour Categories (BCCs) of three dialects of the Spanish language (Castilian, Mexican and Uruguayan). The first experiment used elicited lists for identifying each dialect's Basic Colour Terms (BCTs). The second experiment used a naming task for establishing BCTs categorical equivalences. The third experiment used a boundary adjustment task for providing BCCs'

colourimetric delimitations in the CIELAB colour space. Main results were: (1) The Uruguayan included an extra BCC labeled by the “celeste” BCT (sky in English). (2) The three dialects included the same BCTs for naming their primary BCCs (their English equivalents are white, black, red, green, blue and yellow). Such coincidence appeared for only three derived categories (pink, orange and grey). For the other two categories (brown and purple) two alternative BCTs appeared (“marrón” or “café”; “morado” or “violeta”). (3) Excluding sky and blue, the three dialects provided similar BCCs colourimetric specification. (4) The Uruguayan BCT “celeste” identified a BCC used for naming a subset of the stimuli included in the Castilian and Mexican blue BCC. (5) When forced to do a differentiation between blue and sky stimuli, Spanish and Mexican participants performed as the Uruguayan ones.

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[3P043] Striate and extrastriate responses evoked by selective S-cone stimulation in human

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An important unresolved question in color vision science is the existence of a separate S-OFF pathway. Clear evidence about such a channel is obtained in psychophysical studies while morphological and electrophysiological data are controversial. The aim of our experiments was to compare characteristics of responses to blue-on-yellow increments and decrements in search of a new electrophysiological evidence about the presence of S-OFF pathway. To selectively stimulate the S-cones a modified two-colour method of Stiles was applied. Stimuli were suprathreshold blue light increments and decrements of three different durations (500, 1000 and 2000 ms) in order to separate the onset from the offset of the stimulus response. Visually evoked potentials (VEPs) were recorded from position Oz, PO7 and PO8. Laplacian analysis applied to the data showed that responses to the onset and offset of the increment and decrement stimuli at longer stimulus durations possess different characteristics. VEPs registered from the striate and extrastriate cortex were similar, thus supporting the assumption that there is no additional filtering of signals in V2. The results obtained support psychophysical data showing that separate mechanisms are responsible for the processing of incremental and decremental information in short-wave sensitivity system.

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[3P044] Colour spaces of red-green dichromats derived from multidimensional scaling: Effect of stimulus size and individual differences

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Thirty two red-green (R-G) dichromats (17 deuteranopes and 15 protanopes) took part in this experiment. They were required to complete a colour naming task using one of the 11 Spanish Basic Color Terms (BCTs: English equivalents are red, green, yellow, blue, brown, pink, orange, purple, white, black, grey). 101 stimuli were individually presented as circular patches of different size (2°, 4° and 8°) on a calibrated monitor over a grey background. We used the procedure described in a previous research (2014, Color Research and Application, 39, 360-371) to locate the BCTs using multidimensional scaling (MDS). INDSCAL analyses showed that the weighting of the 2D solutions found in the common space (i.e., chromatic and achromatic dimensions) varied as a function of stimulus size: the chromatic dimension stretched whereas the achromatic dimension compressed as stimulus size increased. ANOVA analyses for repeated measures showed a significant effect of stimulus size, the weight of the dimensions and their interaction. Moreover, individual differences were very well characterized by linear regressions analyses: the higher the slope, the higher the relative contribution of the chromatic dimension as stimulus size increased. The results will be discussed as a tentative way to quantify the importance of residual R-G discrimination.

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[3P045] Blue light reduces eye growth at high temporal frequencies but only at high contrast levels

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Purpose: Prior experiments in chicks have shown that blue light protected against temporal frequency dependent axial growth. The purpose of this study was to investigate the stability of blue light's protective effects on emmetropization when changing both temporal contrast and frequency. Methods: 12-day-old White leghorn chicks were exposed to LED light modulated at either low frequency (0.2 Hz) or high frequency (10 Hz) white (with blue) or yellow light (without blue), in one of four contrast conditions: 16%, 32%, 60%, 80%. Chicks were exposed to conditions for 3 days (mean illumination of 680 lux) and placed in the dark overnight. Changes in refractive and biometric measurements were made with a Hartinger Refractometer and a LENSTAR LS900 optical biometer. Results: White light protected the eyes against myopia; eyes became more myopic in yellow light (mean difference = -0.24 D;  $p=0.045$ ). A reduction in eye growth was only seen in white light in the 80% contrast condition at 10 Hz. (Tukey's HSD  $p<0.001$ ). Contrast changes did not affect refraction or choroidal thickness. Conclusions: White light protected against myopia when contrast was higher than 60%.

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[3P046] Evidence of Nonlinear Edge Mechanism in Cortical Responses to Color in the cVEP

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Neurons in primary visual cortex (V1) have characteristics that link them to the processing of fundamental aspects of color perception, for instance enhanced sensitivity for the edges of colored objects. We examined human cortical responses to color patterns by measuring the chromatic visual evoked potential (cVEP) with a 64-channel BioSemi system. Isoluminant appearance-disappearance checkerboard and full-field stimuli were used with chromatic excitation purities ranging from 0.03 to 0.53. Cortical topography indicated the cVEPs were highly localized at electrodes near Oz, pointing to V1 cortex as their major source. Remarkably, the cVEP waveform of the checkerboard pattern at Oz showed evidence of two different chromatic mechanisms: one was early, fixed around 100 ms for all excitation purities, whilst the other had a latency that decreased dramatically as excitation purity increased. In full field the N100 was stronger (characteristic of single-opponent cell contributions) and the other mechanism was absent (indicating it was due to edge-dependent double-opponent cells). Whilst the first mechanism was clearly linear, the other was strikingly nonlinear; this was confirmed by Fourier analysis which showed phase advances and large changes in the amplitude spectrum with increasing excitation purity. These data establish the existence of color-contrast-dependent non-linear dynamics in cortical processing.

[3P047] Colour simulation tools assessment: beyond colorimetric measurements

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Colour simulation tools perform scene transformations to mimic the colours presumably seen by observers with colour vision deficiencies. Current study applied Simulcheck method (2014, Journal of Vision, 14(8):15, 1–19) to two colour simulation tools (Variantor and Coblis). The assessment was applied with and without colorimetric measurements to test Simulcheck's usefulness when lacking photo-colorimetric equipment. Ten common observers performed two tasks. Pseudoachromatic Stimuli Identification task allows determining the hue angles (huv) of the pseudoachromatic stimuli: colours seen as red/green by normal trichromats but as grey by protanopes/deutanopes. Minimum Achromatic Contrast task allows computing the relative luminance (LR) of the pseudoachromatic stimuli. Computations were performed: (1) Using photo-colorimetric measurements; (2) using RGB values and Adobe RGB 1998 space estimations. The agreement between the huv values from both procedures indicated that huv can be adequately estimated using Adobe RGB 1998 when lacking a colorimeter – an expensive and unusual apparatus. However, the inaccuracy of the LR estimations make it advisable to compute LR using a photometer – an apparatus relatively cheap and easier to find. Results showed that Variantor was accurate to simulate protanopia but neither Variantor nor Coblis simulated accurately deutanopia.

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[3P048] Colour Visual Coding in trained Deep Neural Networks

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Neural networks trained for object recognition on large sets of natural image have recently been proposed as a new framework for modelling biological vision [Kriegeskorte2015. ARVS]. Following this idea we study a feedforward hierarchical architecture combining convolutional and max-pooling layers (5 conv, 3 pool) trained on around 1.2M images of the ImageNet dataset [Chatfield2014. BMVC]. A similar one [Zeiler2014. ECCV] achieved an impressive performance rivalling the representation in the human brain [Cadieu2014. PLoS]. On this net, we focus on the understanding of how colour is encoded from a RGB image through different layers. We compute an estimate of a decoded trained filter associated to a neuron in a convolutional layer. In this way, we get a spatio-chromatic representation of these filters projected onto image space that can be informative. We apply unsupervised methods to classify decoded filters according to their colour main axes agreeing with single and double opponent cells [Shapley2001. VR]. From this, we derive some interesting conclusions: (a) emergence of 3 chromatic axes in first layer (red-cyan, magenta-green, blue-yellow), (b) axes concentrate on a predominant one (red-cyan) up in the hierarchy, (c) number of colour-selectivity neurons decreases deeper in the net, which implies an increase in colour invariance. Funding: This project has been funded by Spanish MINECO, project: TIN2014-61068-R

[3P049] A comparison between illuminant discrimination and chromatic detection

### **David Weiss, Karl Gegenfurtner**

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A recent study used illumination discrimination as an indicator for color constancy and found elevated thresholds for bluish daylight illuminations (Pearce et al., PLoS One, 2014), suggesting an adaptation to of the visual system to natural illumination changes. We investigated whether illumination discrimination would be related to basic chromatic detection. For illumination discrimination, nine participants compared two successively presented scenes to a reference scene that could be rendered under illuminations shifting a neutral gray along 12 different color directions. The same observers performed a 4AFC detection task, detecting stimuli along the same 12 directions. We found elevated thresholds for discriminating bluish and yellowish illuminations along the daylight locus, compared to greenish and reddish illumination changes. Thresholds for the bluish direction were slightly higher than for yellow, as had been reported by Pearce et al. (2014). The threshold pattern for the detection experiment was similar, with thresholds along the daylight axis being larger than for red-green variations, and higher for blue than for yellow. The results suggest that the mechanisms underlying discrimination of illuminants might substantially overlap with those for chromatic detection.

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[3P050] Investigating the relationship between population receptive field (pRF) sizes and spatial resolution using chromatic stimuli

### **Lauren E Welbourne<sup>1</sup>, Freya Lygo<sup>1</sup>, Su Zhao<sup>1</sup>, Fraser Aitken<sup>2</sup>, Alex Wade<sup>1</sup>**

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Population receptive field (pRF) mapping in fMRI produces retinotopic maps and receptive field information from across the visual cortex using 100% contrast black and white checkerboard patterns, therefore they reflect the spatial tuning of neuronal populations responding to high contrast achromatic stimuli. Chromatic pathways tend to be spatially low-pass compared to luminance pathways, however, it is unclear whether these innate resolution differences are coupled with the receptive field sizes of neurons tuned to each of these pathways, and there are currently no reports of fMRI-based pRF techniques being applied to measure this in human subjects. In this study, we used a modified version of the ‘drifting bar’ pRF stimulus to produce three mapping conditions: achromatic luminance, L-M, and S-cone isolating. In addition, spatial frequency tuning responses were acquired using full field gratings for each condition (which matched the key pRF stimuli parameters). For all conditions pRF sizes increased with eccentricity and with ascending visual area, but no effect of condition on pRF sizes was observed – this pattern of data did not correspond to the amplitude responses from the spatial frequency experiment. The implications of these findings are discussed, and are further explored with data acquired from a dichromatic observer.

[3P051] Colour dimensions of transparent media

## Alexander Logvinenko

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Colour of a light is known to be specified in terms of hue, saturation and brightness. Colour of a reflecting object is also described by using three dimensions (e.g., Munsell Hue, Chroma and Value) that are, though, different from the light-colour dimensions. The first attempt to describe the colour dimensions of a transparent media (film) is reported here. A sample of 250 Lee filters was used. Using the partial hue-matching technique, four component hues (yellow, blue, red and green) were revealed. The filters are perceived as neutral (hueless), unitary or binary colour, which makes them similar to lights. Yet, the filter colours are arranged as a sphere, which makes them similar to object colours. Two more dimensions for media colours are their (i) (apparent) transparency, and (ii) (chromatic) purity. As the neutral filters have zero purity, they make up a one-dimensional continuum exemplifying transparency. A set of unitary colour lends itself to two-fold ordering: with respect to (i) transparency, and (ii) purity. A subset of filters of a fixed transparency value exemplifies the purity dimension. The transparency and purity of a filter are found impossible to reduce to the brightness and saturation of the light transmitted by the filter.

[3P052] Blue, white and pink—A cross-cultural comparison of kitsch and kič concepts from Bavaria, Serbia, and Slovenia

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The German word “kitsch” is also used in Slovenian and in Serbian (“kič”)—but does it refer to the same aesthetic concept? In a cross-cultural rating study 36 students from Slovenia (n=12), Serbia (n=12), and Bavaria (n=12) rated 233 images from the Bamberg Repository of Contemporary Kitsch (BaRoCK) in terms of liking, familiarity, determinacy, arousal, perceived threat, and kitschiness. Moreover, art expertise, ambiguity tolerance, and basic value orientation were assessed. In all three samples liking and kitsch were negatively correlated with average Pearson’s coefficients ranging from -.41 (Bavaria) to -.53 (Serbia). Two multilevel regression analyses revealed a consistent cross-cultural pattern: Liking was increased for arousing, familiar and determinate items and positively linked to the composite value dimension of self-transcendence which combines benevolence (i.e. well-being of one’s social environment) and universalism (i.e. sympathy and tolerance). In sum, kitsch/kič appears ambivalent: On the one hand it is depreciated for being unexciting, on the other hand it is perceived as unfamiliar and even threatening. This could indicate that the term kitsch/kič is used to express social distinction by dispraising of aesthetic phenomena which reflect a disparate value system.

[3P053] The first and the last time plasticity of Mondrian color induction

**Hiroki Yokota, Seiichiro Naito**

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Purpose: We investigate the color induction in Mondrian stimulus. The naïve subjects need a few minutes “adaptation” for the induction. Once the induction is established, it is irreversible. The author SN confirms the claim for hundreds of students. The independence of the primary colors are investigated. Methods: A Mondrian patch and the uneven illumination patch were superimposed. The center was physically gray surrounded by various color patches. The reports of the hue perception of the center gray was recorded in time sequence. Results: The first reports were almost always “gray.” Then, the reports changed to “cyan or blue” in a few minutes if the uneven illumination was red. The subjects failed to go back “gray”. The naïve HY conducted the experiment by himself and confirmed the results quantitatively. Discussion: A week later HY retained the induction. HY also had the induction for unseen color such as purple which are represented by experienced red and blue. Conclusions: For naïve subjects a few minutes was needed to see the induced colors. The acquisition of the induction was irreversible. The primary colors were independent for the induction. The induction worked on unexperienced color if its component primary colors were experienced.

[3P054] Does color affect physiological response to emotional images?

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Color vision aids natural scene perception and object recognition. Colors also have emotional connotations.

Surprisingly, previous studies showed that black and white emotional images evoke same physiological response as colored ones. Our goal was to examine whether correct, incorrect, and lack of color information modulate response to emotional images. A set of 180 negative, neutral, and positive images was selected from databases of emotional images (e.g., IAPS). Images' colors were transformed in the L\*a\*b\* color space. Transformed images of all emotional valences were rated as equally abnormally colored. Original, transformed, and black and white images were presented in a free-viewing task, while heart rate, electrodermal activity (EDA), and pupil size were recorded. All these parameters differed between emotional conditions, with largest heart rate deceleration, highest EDA response, and largest pupil size for negative images. Originally colored negative images elicited largest bradycardia, compared to abnormally colored and black and white images. EDA response latency for abnormally colored negative images was larger comparing to original and black-and-white images. Pupil size differed between color conditions in case of neutral and positive images, but not negative ones. These results show that color information modulates physiological response to emotional images.

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[3P055] Perceptual color change of face by lipsticks

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The complexion of makeup face was assimilated into the colors of eye shadows, like biological illusion. However, makeup artists practically experienced contrast effects by makeup. The present study examined how the colors of lipsticks changed those of make up faces. Twenty-four female students participated in the experiment 1. Four lipstick colors, red, pink, orange and violet, and a nude lip were examined. Using an averaged female face, four types of face, reddish/bright, reddish dark, yellowish/bright, and yellowish/dark, were prepared. A paired comparison in each face was done to decide a face, 1) redder or yellower, 2) lighter, 3) duller, and 4) becoming. The assimilation was confirmed in effect of the red or of the orange lipstick on the redness or the yellowness judgment and in effect of the violet one on the dullness. However, contrast effect was shown in the judgment of lightness. In all faces, the red lipstick was judged as the best one to make face look nice and the violet one tended to make the face duller. Experiment 2 confirmed the effects of lipsticks in the pair of dark and bright faces and revealed that two aspects of the assimilation effect, good one and bad one.

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[3P056] Variations in skin colour and its ecological relevance

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Background: Skin colour is determined by haemoglobin and melanin, the former modulating skin colour in two different ways: the concentration of haemoglobin leads to changes along a yellow-bluish axis in colour space, whereas oxygen saturation of haemoglobin (e.g due to blushing) results in short-term skin colour changes along the red-green axis and is associated with a specific change in the reflectance spectra (a 'W' spectral signature; Changizi et al. , 2006, Biol Lett. 2, 217). Changizi et al. argue that trichromatic vision may be optimised for discerning small colour changes associated with haemoglobin oxygen saturation. Purpose: We test this hypothesis by (1) comparing facial skin chromaticity and lightness values for different ethnicities and (2) by evaluating whether and at which body locations the spectral 'W' feature associated with oxygen saturation of haemoglobin is present. Results: Facial redness (a\*) is invariant across our four ethnic groups and the 'W' feature is present in all facial locations. Conclusions: The invariance of skin redness across ethnicities is consistent with the hypothesis that trichromatic vision may be optimised for discerning small colour changes associated with haemoglobin oxygenation. We find, however, no direct experimental evidence for an increased sensitivity along this colour direction.

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[3P057] Skin Colour Cues to Health and Fitness

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Carotenoids are antioxidant plant pigments that contribute to skin yellowness. We have studied how this aspect of skin colour relates to different health characteristics. In cross-sectional studies, high skin yellowness is a reliable cue to a healthy diet that is high in fruit and vegetables (and hence high in carotenoids). In 6 week longitudinal studies, increasing fruit and vegetable consumption by 2 portions/day is associated with visible increase in skin yellowness. Skin yellowness is reduced in individuals with high body fat and BMI (Body Mass Index or weight scaled by height) compared to those with normal BMI. Overweight status and high levels of body fat may reduce carotenoids by lowering antioxidant defences and increasing oxidative stress. In studies of 6-8 weeks of exercise training skin yellowness rises with increases in VO2 max estimates of fitness (reflecting greater efficiency in the body's ability to utilise oxygen). Fitness may enhance skin yellowness by upregulating endogenous antioxidants and protecting carotenoids. At the perceptual level, a moderate increase in skin yellowness (simulating gain in skin carotenoid) is seen as attractive and associated with higher fitness particularly in those who are fit themselves. Therefore skin colour provides a cue to multiple aspects of health.

[3P058] The “Camouflage Machine”: optimising patterns for camouflage and visibility

**Laszlo Talas, John G. Fennell, Roland J. Baddeley, Innes C. Cuthill, Nicholas E. Scott-Samuel**

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Sometimes it is important not to be seen; a well camouflaged predator may catch its prey rather than go hungry or a concealed wildlife photographer may get the shot. In the modern world much infrastructure is economically important, but it is often not aesthetically pleasing. While reducing visibility is obviously advantageous, maximising it can be equally so; highly visible warning displays and sexual signals can provide an animal significant evolutionary advantage. Enhanced visibility is also important for human use: emergency vehicles, motorbikes and cyclists' clothing, all work best if they are detected quickly. We present preliminary results in developing the Camouflage Machine; the easiest and most difficult to find plain coloured objects in a natural environment. Data were collected using stimuli displayed in full (trichromatic) and dichromatic colour, the latter being common in most non-human mammals. To be as realistic as possible, stimuli were constructed using overlays, with Bayesian optimisation employed to provide preferential samples and reduce the number of trials required. Deep neural networks were used to combine results. Results confirm the effective use of stimuli construction and trial optimisation, together with revealing the most effective colours for visibility and concealment in two real environments.

Funding: EPSRC

[3P059] How does color diagnosticity modulate subjective experience of full-color natural scenes?

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We usually have subjective experience that the entire visual field is in rich color, although color sensitivity is much reduced in the peripheral retina. This “pan-field color” phenomenon (Balas & Sinha, 2007) has been demonstrated by the finding that observers fail to detect a large achromatized region in either the central or peripheral visual field, when natural scenes were presented for a short time (e.g., 50 ms). The present study investigated the effects of color diagnosticity of natural scenes, which refers to the degree to which a scene is associated with a specific color, on the occurrence of pan-field color. The color of scenes was also manipulated (normal and complementary colors). Results showed that pan-field color was frequently reported with low color-diagnostic scenes in normal color. This finding was not consistent with the notion that pan-field color is mediated by color statistics of natural scenes. Additional experiments using signal detection theory showed that natural scenes in normal color resulted in a higher response bias for missing the achromatized region, but that high color-diagnosticity increased perceptual sensitivity to detect the achromatized region. These findings suggested that response bias, rather than actual color completion, mainly leads to pan-field color.

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[3P060] Effects of Color Distribution on the Impression of Facial Skin

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Both shape and color of human skin play important roles when assessing the visual quality of human faces. However,

effects of skin color distribution in human skin's appearance are unclear. We conducted psychophysical experiments to investigate how color distribution affects the impression of the quality of facial skin, such as transparency, health and age by modifying the size of color distribution of the skin. We measured bare skins of Asian women in their twenties by using a 2D luminance colorimeter. Subsequently, we cropped a patch of the cheek from each face image. Based on the images, we generated visual stimuli that have different color or luminance distribution size. All stimuli were presented on a calibrated LCD-monitor. The viewing distance was 90 cm. The image stimuli were presented in random order and there was no constraint on response time. Participants were asked to rate each image. We found that the optimal skin color distributions for an improved perceptual human skin appearance exist. A smaller size of luminance distribution is better for the skin's appearance than the original size but the size and the shape of the optimal color distribution depends on the estimated skin quality.

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[3P061] Implicit knowledge of the colours of natural scenes matches real colours

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Some studies suggest that there is a memory colour effect for familiar objects but whether this effect generalizes to natural scenes is unclear. Here we tested this hypothesis with an experiment where observers adjust the colour gamut of unknown natural scenes to produce realistic images. The stimuli were images of natural scenes unknown to the observers synthesized from hyperspectral imaging data. The images were rendered under D65 and could be manipulated to adjust the colour gamut in the CIELAB ( $a^*$ ,  $b^*$ ) by a multiplicative factor between 1.5 and 0.5. The images were presented on a calibrated CRT computer screen driven by a ViSaGe MKII. In the experiment the observers adjusted the gamut by actuating freely on a joy-pad. At the beginning of each trial each image was presented with its colour gamut compressed or expanded by a random factor. The task of the observers was to adjust the gamut such that the image appeared real. Data from five observers with normal colour vision shows that, on average, the gamut selected by observers was within 2% of the original one. These results suggest that observers have implicit unbiased knowledge of the colours of natural scenes.

[3P062] Yellow is more creative than you know: Exploring implicit color associations with the multidimensional IAT

**Marius H Raab, Anastasia Mironova, Claus-Christian Carbon**

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People have certain ideas which associations are caused by perceptions of colors (see Palmer & Schloss, 2010). But are these ideas about a given color similar across people? And do explicit and implicit associations match? Explicit (questionnaire) and implicit (multi-dimensional implicit association test "md-IAT"; Gattol, Sääksjärvi & Carbon, 2011) associations between primary colors and important attribute categories were analyzed in this study. In contrast to existing implicit studies like Soriano and Valenzuela (2009), we used more abstract categories not directly linked to emotional evaluation: attraction, creativity, cleanness, safety and quality. The colors red and green as well as yellow and blue were regarded. We found ( $N=30$ , each participant completing 6 (category) x 2 (color-pair) = 12 IATs) significant connections (d-measure) in our German-Bavarian sample for cleanness & blue, creativity & green, attractiveness & red, and—surprisingly—creativity & yellow. Our results indicate that colors are indeed implicitly associated with higher-order concepts like creativity and cleanness. A limitation of this approach is that with an IAT, categories (and likewise colors) can only be tested against another one and not regarded on their own. However, the multidimensional IAT compensates for this by allowing for more than one category and/ or color combination.

[3P063] The effect of ceiling color on interior space perception

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Experts in the field of architecture and interior design suggest that the color of a room's ceiling influences its perceived height. For example, low-saturated bluish ceiling colors are often assumed to visually enhance a room's height. However, in such reports, the different colorimetric parameters (lightness, hue, saturation) are typically confounded. Previously, we have found that achromatic rooms with lighter ceilings were perceptually higher than rooms with darker

ceilings. Here we report an experiment in which we independently varied the ceiling's lightness (dark, light), hue (red, green, blue), and saturation (low, high). The colorimetric values of the stimuli were controlled by means of a spectroradiometer. Subjects had to estimate the height of virtual interior spaces of varying physical height and color, which were stereoscopically presented on an Oculus Rift HMD. Our results show that the previously reported visual expansion of ceiling height for lighter compared to darker ceilings also applies to chromatic ceiling colors. Rooms with lighter ceiling colors were judged to be significantly higher than identical rooms with darker ceiling colors. In terms of hue, we found that green ceilings were judged slightly lower than red and blue ceilings. Saturation did not significantly influence the rooms' perceived height.

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[3P064] Object color change under natural illumination despite

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Color constancy prevents us to perceived color change under different illumination conditions. As color of objects determined by spectral reflectivity of object's surface, spectral distribution of illumination, and color-matching function, spectral feature have an effect on color appearance of object. We made new light source with very low CRI (Color Rendition Indexes), and a lot of these light sources change color appearance of objects despite the effect of color constancy. In this study we find out some of the object color change despite the effect of color constancy even under the natural white sunlight. In the case of two kinds of traditional dyed goods from Japan, i.e., so-called Kikujin (green and beige) we can find object color change despite color constancy. In the case of Kikujin (green), for example, looks green under day light, but change its color to orange under yellowish sunlight at sunrise and sunset. The reason why color constancy does not work in this case seems to be the combination of spectral features of object surface, light source, and color-matching function is very special, and ancient Japanese dyeing and weaving artisan utilize this color change to make fascinating dye goods.

[3P065] Models of crowding: a comparative study

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In crowding, the perception of an object deteriorates in the presence of nearby elements. Obviously, crowding is a ubiquitous phenomenon, since elements are rarely seen in isolation. Despite this ubiquity, there exists no consensus on how to model crowding. In previous experiments, it was shown that the global configuration of the entire stimulus needs to be taken into account. These findings rule out simple pooling models and favor models sensitive to global spatial aspects. In order to further investigate how to incorporate these aspects into models, we tested different types of texture segmentation models such as the Texture Tiling Model, a variation of the LAMINART neural model, a model based on Epitomes, a model based on filtering in the Fourier domain, and several classic neural network models. Across all models, simply capturing regularities in the stimulus does not suffice, as illustrated by a failure of the Fourier analysis model to explain our results. Importantly, we find that models with a grouping mechanism (such as the LAMINART model) work best. However, this grouping may be implemented in different ways, as we will show. Funding: This work was supported by grant 153001, "Basics of visual processing: From retinotopic encoding to non-retinotopic representations", of the Swiss National Science Foundation (SNSF).

[3P066] The role of focal and orientation components of attention in modulating crowding in central and peripheral vision

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In visual detection tasks performance improves when a cue, such as a dot, anticipates the position of the target (orientation component) or when its dimensions (as in the case of a small square) inform about the size of the attentional window (focal component). Here we examined the role of these two components of visuo-spatial attention,

orientation and focus, in modulating crowding in foveal and peripheral vision. The task required to discriminate the orientation of a letter “T”, close to acuity threshold, flanked left and right by “H”s. Two factors have been manipulated: the inter-letter distance and the cue type (a red dot, a small square, a big square). In fovea (experiment 1), only the small square significantly improved subjects’ performance, reducing the critical distance needed for identification. This suggests the relevance of focal attention in modulating foveal crowding. In peripheral vision (experiment 2) we found a significant improvement with the red dot and no advantage when a small square was used as a cue. This suggests that the orientation component modulates crowding in the periphery. Taken together the results indicate a behavioural dissociation of orientation and focus of attention in modulating crowding at foveal and peripheral locations.

[3P067] Crowding effects using negatively conditioned stimuli

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The degraded perception of a stimulus when it is surrounded by flankers is known as crowding. As the study of Faivre et al. (2012, *Front Psychol*) using emotional faces indicated an influence of emotion on crowding, we aimed at investigating emotional effects on crowding when using more letter-like stimuli. Therefore, we applied an evaluative conditioning paradigm: Landolt rings with opposing gap positions (e.g. up and down) were repeatedly paired with neutral respective negative IAPS-pictures. The two conditioned and two additional Landolt rings (e.g. gap positions left and right) were used as targets or flankers in a visual crowding task. In Experiment 1 the eccentricity of target presentation was varied while keeping the spacing between target and flankers constant. In Experiment 2 the spacing between target and flankers was varied while keeping the target eccentricity constant. In both experiments, the task was to indicate the gap position of the target while ignoring the flankers. The percentage of correct responses and reaction times were analyzed separately for trials in which the negatively conditioned Landolt Ring was used as target and when it was used as flankers. The results are discussed concerning a top-down influence of stimulus valence when processing visually cluttered stimuli.

[3P068] Visual crowding in natural images is affected by perceptual grouping of flankers

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‘Visual crowding’ is the situation where recognition of a peripherally presented target is impaired by the presence of nearby “flankers”. We investigate crowding using patches of image derived originally from photographs of natural scenes. Observers provided magnitude estimation ratings of the perceived difference between successively presented peripheral target patches that changed in “colour” (i.e. hue, lightness and/or saturation). The target patches were presented alone or were closely flanked by six distractor patches. The presence of flankers made from the same image patch as the target can affect the rating given to the target: when the flankers are all the same as each other, are of similar colour to the target and remain constant throughout the trial, ratings are significantly suppressed compared to the “alone” condition. However, there is less or no effect if the flankers also change during the trial, are very different in colour from the target or are made from a different image patch compared to the target. Suppression seems to be greatest if the flankers form a perceptual group with the target, and is least when the flankers again form a group amongst themselves but one that excludes the target.

[3P069] Distinct process for perceptual and numerical estimation of average across time

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Humans can estimate global trend of serially presented information of dynamic events. We have previously examined human judgment on overall (or average) orientation or motion direction of a single Gabor patch across time, and found that human judgments heavily depend on temporally local information at around stimulus offset or right before they make decisions: a recency effect (Sato et al., *VSS* 2013). Here, we applied the same analysis for the judgment of average of the number given as digits. In experiments, 20 single-digit figures (0-9), which temporally varied following a Gaussian distribution with particular mean and variance, were presented sequentially for 2 sec. Observers task was to judge whether the arithmetic average of digits was above 5 or below. The reverse correlation analysis revealed that observers equally weigh information across the entire stimulus presentation. It is not because digits varied discretely, since the control experiment in which observers judged the average orientation of a Gabor with 10 levels of

orientations showed a clear recency effect. These results indicate that distinct mechanisms are involved in perceptual and numerical estimations of temporal average.

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[3P070] Crowded and uncrowded perception of Cyrillic letters in parafoveal vision: confusion matrices based on error rates

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Most of our knowledge about the mechanisms through which language speakers discriminate letters is based on studies investigating Latin-based scripts. The Cyrillic script used in Russian which is characterized by a small number of descenders and ascenders might uncover some letter recognition peculiarities. We have tried to amend the situation in two eye-tracking experiments. In Experiment 1 (with crowding) after focusing on a fixation cross at the centre of the screen, participants saw a masked letter (surrounded by asterisks like \*ы\*) in the parafovea. Subjects had to name the letter. In Experiment 2 (without crowding) the procedure was the same except for the letter appeared alone (like ы). Letter delays were controlled by gaze-contingent boundary paradigm: the letter stimuli disappeared during the saccade from the fixation mark to the stimulus. The proportion of correctly identified letters across all the participants is 46% in the Experiment 1 and 84% in the Experiment 2. The confusion matrices for the crowded and uncrowded conditions revealed that aside from ascenders and descenders features, round shape and diagonal elements contribute much to the faster letter identification. Among factors deteriorating identification speed we could list the inclusion of one letter inside another (e vs. ё)

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[3P071] Identity-Crowding: Perception without Attention or Cognitive Inference?

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A letter presented in the visual periphery is harder to identify when flanked by close-by letters, an effect called crowding. In “identity-crowding”, the target and the flankers are the same. Recently, it has been argued that conscious perception without attention underlies superior performance with identity-crowded targets. The converse view is that cognitive inferences underlie superior performance. Here, we used appearance-based methods to investigate identity-crowding. Participants were presented with flanked and unflanked target letters in the periphery - the two flankers were either the same as the target or not. Eye tracking ensured that stimuli were only presented when observers kept fixation. Participants drew as accurately as possible how the stimulus appeared, and verbally reported what they saw. The results showed that identity-crowded targets were not perceived more accurately than “normally” crowded targets. Importantly, the number of perceived items in identity-crowding was frequently lower than the number of presented items (e.g., TT instead of TTT), a finding at odds with the ‘conscious perception without attention’ hypothesis. We argue that (seemingly) better performance in identity-crowding is due to perceived stimulus regularity in conjunction with the identification of a flanker, and discuss the role of prior knowledge, biases, and forced-choice methods in (identity-)crowding.

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[3P072] Crowded letter recognition: An objective measure of letter similarity

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Letter similarity is often derived from letter confusion probabilities which contain non-stimulus-driven components such as subjective response bias and influences of testing condition. Our goal is to develop an objective measure of letter similarity. For each pair of letters, we located the peak of cross-correlation matrix from which two orthogonal similarity scores were drawn: common feature (overlapped ink area) score and alien feature (non-target ink area) score. To capture the similarity between mirror-image letters, we also flipped one image horizontally or vertically to obtain two additional evaluations of common feature score for each letter pair. All four scores were then normalized to the

maximum common feature score (score for comparing identical letters). We modeled letter confusion probabilities in a crowded letter recognition task (recognizing the middle letters of trigrams presented on the horizontal meridian) as a function of the four similarity scores, and found that the scores can explain 22% of the variability of the confusion probability due to crowding. The common feature score is the best predictor. More common features are associated with greater confusion. Our findings demonstrate the feasibility of quantifying letter similarity objectively, and this quantification measure can account for considerable variation in letter confusion probabilities.

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[3P073] Perceptual learning following visual search decreases peripheral visual crowding

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Crowding is a constraint in peripheral visual information processing. One of the outstanding questions surrounding this phenomenon is the degree to which it is adaptive. Since crowding is a context-related process we hypothesized a relation with perceptual learning (PL) – another context-dependent phenomenon. PL is a form of plasticity which can result in both long- and short-term changes in perceptual performance. Here, we tested the hypothesis that PL affects the magnitude of crowding. We designed a behavioural study consisting of 2 alternating parts: Visual search (VS): observers had to identify a gabor target amongst a field of differently oriented gabor distractors while a gaze-contingent artificial scotoma forced them to use peripheral information only. Crowding magnitude was estimated using a 2AFC orientation discrimination task using gabors identical to those used in VS. Following PL, our results show a selective reduction in crowding strength just outside the scotoma region. Moreover, this location corresponded very closely to the VF location that the observers used to recognize the targets during VS. We conclude that crowding can be modulated by perceptual learning

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[3P074] Can we predict peripheral reading speed based on visual letter recognition performance for individual readers?

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Yu (ecvp,2015) found a significant correlation between visual-span size (the number of letters recognized in one fixation) and Rapid Serial Visual Presentation reading speed across individual readers at 10° eccentricity. In this study, we investigated if, as suggested by this study, a Bayesian observer model based on letter recognition could predict word recognition performance and RSVP reading speed. This model uses visual span profiles (VSPs, i.e. letter recognition accuracy versus position in the visual field measured at 106 ms) to predict letter information extracted from a word within one fixation. Based on this letter information, a lexical processing (LP) step is then performed to identify a word from a lexicon. The model was tested using VSPs from 20 subjects at 10° eccentricity to predict word recognition accuracies and the corresponding reading speeds. The model predicts a large individual variability in (1) the average number of errors in letter recognition per word before LP (range:[0.51-1.44]), (2) the proportion of words identified correctly before LP (range:[0.30-0.66]) and (3) the proportion of words identified correctly after LP (range:[0.46-0.85]). These predicted values are significantly correlated with actual reading speeds. However, reading speeds were overestimated by the model. Possible explanations for overestimations will be discussed.

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[3P075] Target discrimination is not affected by distractor expectation

**Josephine Reuther, Ramakrishna Chakravarthi**

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Visual crowding is an impairment in the ability to identify a peripheral object in the presence of flankers. This interference is thought to occur at the stage of feature integration, where features falling within a critical distance are pooled. One possible mechanism proposed for this phenomenon is a lack of a narrow enough attentional focus. In line

with this, it has been shown that cueing the location of the target object modestly alleviates crowding. Here we tested if expectations about distractor presence similarly influence object recognition in clutter. Finding such an influence would suggest that top-down signals can affect object recognition at stages as early as the feature-integration stage, as indexed by visual crowding. In three experiments, expectation was modulated implicitly or explicitly, either by manipulating distractor frequency or by indicating flanker presence through central cues. We found no influence of expectation on either the critical spacing or the target discrimination thresholds. The latter was true even outside of the critical distance for crowding, contrary to some previous accounts. These results suggest that the feature integration stage seems to be largely immune to higher-level factors such as expectation.

[3P076] Differential gains depending on relying more on time or space: evidence from a timing task  
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Our study tested whether optimality in sensorimotor decision-making depends on the domain the gain function is associated to: time vs space. A target moved approaching a line. Participants were rewarded depending on how close the target was when they pressed a button. Initial time to contact with the line was one second, but there were three different target speeds. Gain increased with proximity, spatial or temporal, depending on the condition, reaching a maximum at alignment. However, pressing it after that was penalized. Participants tried to maximize the final score. When compared to predictions from an expected gain maximization model, responses were too close to the line, what is interpreted as overconfidence. Most participants followed a spatial strategy in both conditions, responding at a certain position in space for all speeds. Nevertheless, participants won similarly in both conditions. A second experiment widened speeds and penalized a spatial strategy in the time condition, and vice versa. Although overconfidence remained, more participants in the time condition followed a temporal strategy. These were less variable, probably because they coped better with different speeds, leading to fewer penalizations and higher scores.

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[3P077] The neural basis of the paired-object affordance effect

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Recent behavioral studies indicate that right-handed individuals make faster action decisions on object pairs that appear in standard co-location for right-handed actions in comparison to object pairs that appear in a mirror location. In this fMRI study, we aimed to investigate the neural correlates of visual processing of thematic relations between co-acting objects (frying pan and spatula), depending of their co-location for right-handed actions. Fourteen right-handed participants made decisions about thematically related and unrelated object pairs. Pairs were either positioned in a standard location for a right-handed action (with the active object - spatula in the right visual hemifield, and the passive object - frying pan in the left visual hemifield), or in the reverse location. Behavioral results showed a benefit of positioning thematically related pairs in standard co-location when an action decision was made (deciding if the two objects are usually used together), but not when a more general contextual decision was made (deciding if the two object are typically found in the kitchen). Neuroimaging results showed that the left lateral occipital complex was more activated for standard than reverse locations. Our results provide novel evidence of close interrelations between thematic and action processing in the posterior semantic system.

[3P078] On optimal estimation from correlated samples

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Optimal estimation from correlated, as opposed to uncorrelated, samples requires different strategies. Given the ubiquity of temporal correlations in the visual environment, if humans are to make decisions efficiently, they should exploit information about the correlational structure of sensory samples. We investigated whether participants were sensitive to the correlation structure of sequential visual samples and whether they could flexibly adapt to this structure in order to approach optimality in the estimation of summary statistics. In each trial, participants saw a sequence of ten dots presented at different locations on the screen which were either highly correlated ( $r = 0.7$ ) or uncorrelated (in two

separate blocks of 260 trials), and were asked to provide an estimate of the mean location of the dots. In the high-correlation block, participants showed a trend towards overweighting the first and last samples of the sequence, in accordance with the optimal strategy given correlated data. In contrast, when exposed to uncorrelated inputs, the weights that participants assigned to each sample did not differ significantly from the optimal uniform allocation. Thus, it appears that humans are sensitive to the correlational structure of the data and can flexibly adapt to it so that their performance approximates optimality.

[3P079] Predicting perception from the electroencephalogram

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Internal noise in sensory systems limits processing by corrupting the fidelity of neural signals. We asked when neural activity could predict perceptual decisions by using multivariate analysis of event related potentials (ERPs). Observers saw two 1c/deg sine-wave gratings and reported the interval that appeared to have the higher contrast on each trial, while EEG activity was recorded at 64 scalp locations. One interval contained a pedestal grating with a contrast of 50%, the other contained the pedestal plus a target increment (0-16% contrast). We used a support vector machine algorithm to classify observer decisions by training on the selected/non-selected interval. When the stimuli were physically identical (0% target increment), classification was above chance in periods around 100ms, 250ms and 400ms for predicting the observer's decisions. This may reflect the influence of internal noise at different stages of processing. We also trained the algorithm on the observer's decisions in the 16% target contrast condition (where psychophysical performance was near ceiling) and then tested on the 0% target trials. Classification was above chance at around 100ms and 200ms, reflecting early components of the neural response. Future work will aim to resolve the anatomical locus of noise at different stages of decision making.

[3P080] Logistic mixed models to investigate implicit eye gaze and explicit choice predictions

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We investigated the proposition of a two-systems Theory of Mind (ToM) in adults. N=45 participants predicted the choice of one of two players after observing several rounds in a simple animated card game. Binary data (on/off target) from initial gaze direction and choice predictions of each participant were recorded and served as implicit and explicit measures of mentalising. We used Bayesian logistic mixed models to compare the two measures in a true- and false-belief task and estimated latent task- and subject-specific parameters. Theoretical considerations suggest that participants may rely on two systems with different signatures: an implicit and efficient system for initiating eye gaze and an explicit and flexible system for predicting choice. As expected task-specific parameters for explicit choice predictions reflect true and false beliefs. Surprisingly however, task-specific parameters for implicit eye gaze also discriminate between true and false-belief tasks. We speculate that anticipation in initial eye gaze may be the result of belief tracking over several rounds.

Funding: Erasmus KA2 TquanT

[3P081] Control of saccadic latencies in a choice paradigm

**Cécile Vullings, Laurent Madelain**

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Saccadic latencies are conventionally viewed as reflecting the accumulation of information during decision-making process but we have previously shown that latency distributions may be strongly affected by reinforcement contingencies (Madelain et al., 2007). Here, we probe the possibility to control saccadic latencies in a choice paradigm. Six subjects made saccades toward a horizontally stepping target within 80-300ms. For each subject we constructed two classes of latencies, "short" and "long", using the first and last quartiles (e.g. [80;151]ms and [185;300]ms respectively). We then concurrently reinforced each class in three blocked conditions (approximately 20000 saccades per subject) with different probabilities such that the relative frequencies of reinforcing "short" versus "long" latencies were 9/1, 1/9 and 1/1. We observed modifications of latency distributions depending on the experimental conditions: distributions shifted toward the shorter or longer tail or became strongly bimodal (e.g. modes = {135; 235}) and the relative proportion of latencies matched the relative proportion of reinforcers earned from each option (slope up to 0.95). Our results indicate that learned contingencies might considerably affect the allocation of saccades in time, and

provide strong evidence of a voluntary control of saccadic latency. The functional significance of this control extends well beyond information accumulation.

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[3P082] Developmental differences in canonical visual size during a drawing task

**Kentaro Inomata**

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Recent studies suggest that an object's size, relative to a frame of space, has a consistent ratio. Furthermore, this ratio is proportional to the size of the objects in the real world. This ratio information has been referred to as canonical visual size (Konkle & Oliva, 2011). The relationship between this size information and scene-selective areas has been recently examined (Gabay et al., 2016). However, the developmental underpinnings in this relationship have not been studied. Therefore, the present study examined developmental differences in canonical visual size. A drawing task was implemented for its ease of use with children (Seamon et al., 2002). Previous studies suggest that realistic drawing begins around the age of 8 years (Thomas & Silk, 1990; Higashiyama & Higashiyama, 1999). Thus, the study included children aged 6 to 14 years, and each drew 16 objects in the task. The size ranks of depicted objects in real world were assessed in previous study (Inomata, 2014). To assess the effect of frame size on children's drawings, paper size differed among participants (see, Konkle & Oliva, 2011). Results revealed differences in size ratios as a function age.

[3P083] Development of haptic and visual 2D shape recognition

**Krista Overvliet<sup>1</sup>, Ralf Krampe<sup>2</sup>**

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As opposed to recognising everyday objects, haptically recognising 2D shapes is difficult: recognition rates are generally low and exploration times high. To investigate the underlying mechanisms, we used a developmental approach and tested 78 participants in 5 age groups: pre-schoolers (4-5 years), first-graders (6-7 years), fifth-graders (10-11 years), young adolescents (12-13 years) and young adults (18-28 years). They performed a haptic object recognition task, a haptic 2D shape recognition task and a serial visual 'peekhole' version of the haptic 2D task. The results show that all age groups are excellent at haptically recognising everyday objects. Pre-schoolers and first-graders scored very low in both visual and haptic 2D tasks. From fifth grade onwards, participants were more accurate in the visual as compared to the haptic 2D task. However, accuracy in the haptic task improved only slightly in the young adolescent and adult age groups. Interestingly, haptic exploration times for correct items increased with age, while visual exploration times were constant over the age groups. The results will be discussed in terms of developmental trajectories of visual and haptic reference frames, visual mediation and working memory.

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[3P084] Gaze patterns to the focus of a radial optic flow in school age children

**Nobu Shirai, Tomoko Imura**

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Gaze patterns to the focus of a radial optic flow (FOR), one of the main visual cues to perceive and control the direction of self locomotion, were investigated in school age children (N = 30, from 5 to 12 years, mean age = 9.9 years, SD = 1.9) by using an eye-tracking technique. The children detected more sensitively the focus of a radial expansion flow which represents forward locomotion than that of a radial contraction flow which represents backward locomotion. Our previous study (Shirai and Imura, submitted) has shown that naive adult observers (N = 20, mean 20.1 years, SD = 0.9) indicated the similar "expansion advantage" in detecting FOR, while infants aged 4-18 months (N = 100, mean 334.6 days, SD = 135.9) did not. Taking the current and the previous results into consideration, we conclude that the "expansion advantage" in the detection of FOR develops by school age. Moreover, these results imply that the functional link between the control of self locomotion and relevant visual information such as optic flow may develop beyond infancy and become robust form by later childhood.

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[3P085] The development of facial expression recognition abilities from childhood to adulthood

## **Megan Willis<sup>1</sup>, Nicholas Badcock<sup>2</sup>, Nicole Ridley<sup>1</sup>, Romina Palermo<sup>2</sup>**

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While gradual improvement in the ability to recognise facial expressions of emotion in childhood and adolescence is well documented, less well understood is what underpins this improvement. Perceptual processing and emotional conceptual knowledge are key processes underpinning facial expression recognition abilities, but we do not fully understand how these skills develop relative to facial expression recognition, or their relationship to facial expression recognition performance at different stages of development. Twenty-six children (7-8 years), 20 adolescents (12-14 years), and 24 adults (18-35 years) completed a series of tasks assessing face identity matching, facial expression matching, emotional conceptual knowledge, and facial expression labelling. Across all tasks, children demonstrated poorer performance than both adolescents and adults. Non-parametric correlations revealed that greater matching performance (identity and expression) and emotional conceptual knowledge skills were associated with superior facial expression labelling performance in childhood. By adolescence, these relationships had weakened, although matching skills (identity and expression) remained associated with facial recognition labelling. By adulthood, only facial expression matching performance was associated with facial expression labelling performance. These results suggest that development of facial expression recognition skills over the course of childhood is linked to the concurrent development of perceptual skills and emotional conceptual knowledge.

### [3P086] The development of convergence and divergence to radial optic flow in infancy

#### **Elizabeth Nawrot<sup>1</sup>, Mark Nawrot<sup>2</sup>**

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Research finds a relationship between the development of depth perception and ocular motion functions including smooth pursuit and ocular following response. Infants' reactions to looming stimuli also suggest sensitivity to optic flow information that specifies distance. With radial optic flow, an expanding flow field elicits involuntary convergent eye movements while a contracting one elicits involuntary divergent eye movements. We measured the oculomotor response to radial optic flow in 99 infants two-to nine-months-old. The pattern expanded or contracted across eight 400 msec trials while eye position was monitored with a Tobii X120 eye-tracker. A subset of infants also viewed trials of a static version of the stimulus. On average, most infants in each age group demonstrated convergence to the expanding pattern and divergence to the contracting one. Moreover, the difference in velocity/gain between the convergence and divergence eye movements was significant,  $t(90) = 3.64$ ,  $p < .001$ . The presence of correct vergence eye movements in response to expansion and contraction provides further evidence that infants are sensitive to information that specifies motion in depth.

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### [3P087] Unisensory and multisensory development in typically and visually deprived children

#### **Giulia Cappagli, Sara Finocchietti, Elena Cocchi, Monica Gori**

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Early perceptual experience is fundamental for the development of cognitive processes, with early sensory loss having a dramatic impact on it both at behavioral and neural level. Several studies confirm that cognitive achievements in the typical development emerge gradually during the early postnatal life thanks to sensory experience, implying that adequate multisensory input during the first months is a prerequisite for the full development of cross-modal interactions. These results suggest that early onset of sensory deprivation can have long-standing negative effects on the development of unisensory and multisensory abilities. Indeed it has been shown that congenital visual deprivation not only prevents the cross-sensory calibration mechanism exerted by vision over the other sensory modalities but also negatively influences the development of multisensory integration processes. Understanding how the loss of vision consistently alters the development of perceptual and cognitive process is highly relevant to the updating of current rehabilitation strategies for visually impaired children. Here I review the main findings in the context of typical and altered unisensory and multisensory development in sighted and visually impaired people, highlighting the potential power of current research efforts into the development of new rehabilitative solutions to restore weakened abilities in children with visual disabilities.

[3P088] Age-related differences in object recognition tasks in preschool children

**Sergey Kiselev**

Psychology, Ural Federal University named by the First President of Russia B.N. Yelsin.

The aim of study was to reveal age-related differences in visual recognition of objects with interference in preschool children. The sample consisted of 35 4-years-olds, 42 5-years-olds, and 44 6-years-olds. The children were assessed with the "Visual recognition tasks" from Luria's assessment battery. A first task assesses the ability to recognize 11 overlapping objects. Second task requires children to recognize 12 incomplete visual objects. The results per task were evaluated by ANOVA. The main effect of age was significant ( $p < .01$ ), indicating that there are age-related differences in visual recognition between three age groups. The main effect of type task was also significant ( $p < .05$ ). The amount of correct identified objects in overlapping task was more than in incomplete task. We didn't reveal a significant interaction between type of task and age. This research demonstrates that there are clear age-related differences in the ability for visual recognition of objects with different kind of interference between three age groups of preschool children. However it can be assumed that the ability to recognize overlapping objects is maturing earlier than the ability to recognize incomplete objects.

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[3P089] Object-based visual attention assessed by eye vergence movements in early infancy

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We studied eye vergence to evaluate object-based visual attention through visual behaviour in early infancy and provide new insights on visual short term memory (VSTM) by eye vergences. For this purpose we measured the modulation in the angle of eye vergence (AoEV) in a sample of 43 children aged 12-37 months and compared it when presenting repeated images vs. novel images. We hypothesized, in line with our previous studies in children and adults on the novel role of vergence, that object-based visual attention would be evidenced by an increase in the AoEV, for repeated compared to novel items. Our data show that the eyes in infants converge for both repeated and novel images. In the repeated object condition, the eyes continue to converge reaching a maximum of vergence angle of 0.4 degrees around 200ms after stimulus onset. Thereafter the eyes start to diverge. In the novel object condition we observe a significantly weaker eye convergence. The results shown in the AoEV modulation for repeated items may indicate updating of memory for a stimulus that had been partially processed. Also, we speculate eye vergence to reflect a cortical anticipation or shift for orienting visual perception.

[3P090] Expression dependence in the perception of facial identity

**Annabelle S Redfern, Chris Benton**

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We address the issue of whether facial identity and expression are processed separately, or whether they interact. We do so by asking whether facial identity constancy is compromised by changes in expression. Using an identification task, participants learned the identities of two actors whose pictures had been taken from various Italian language movies (so called "ambient" images). Training was with either neutral or expressive face images, expressiveness having been determined experimentally. Both training groups were then tested with novel images of the actors that varied extensively in expressiveness. We found that training with expressive images was slower and more erroneous than training with their neutral counterparts. A second experiment extended testing in the neutral-training condition. We analysed performance on the test images for evidence of expression dependence. Participants were slower and less accurate in response to high expressive images than to low expressive images. This provides a compelling demonstration of expression dependence in our representation of facial identity. We interpret our findings as consistent with inter-related processing of identity and expression. We conclude that, far from being disregarded, expressions form an integral part of our mental representation of facial identity.

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[3P091] Categorical and dimensional representations of emotions tested by adaptation to dynamic facial expressions

## **Olga A Korolkova**

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Two influential theories of facial emotional expressions perception are the dimensional and categorical accounts. The former suggests that bipolar dimensions (valence and arousal) underlie all emotional states, whereas the latter proposes that qualitatively distinct emotional categories cannot be reduced to a particular basis. To test which theory better describes the structure of facial expressions space, we used perceptual adaptation paradigm with dynamic faces as adaptors. In a psychophysical study, participants (n=16) adapted to each of seven dynamic basic emotional expressions, after which categorized 80% neutral/20% expression morphs as one of seven emotions. The dimensional approach predicts selectively enhanced recognition for the expression opponent to the adaptor, and selectively reduced recognition after adaptation to the same expression. On the contrary, if the basic emotions are organized categorically, one expects only the selective reduction of the same expression recognition but no specific anti-expression enhancement. The results revealed that adaptation to happy face selectively enhanced sadness recognition but reduced recognition of happiness. Adaptation to disgust reduced recognition of both disgust and happiness. No specific pattern was found for other emotions. We suggest that opponent coding mechanism separates emotions along valence dimension, whereas for other emotion modalities the primary mode of representation is categorical.

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[3P092] Composite facial expressions: half-face diagnostic features dominate emotion discrimination

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We used composite facial expressions to explore the role of diagnostic features in upper and lower half-faces in emotion discrimination. Stimuli were images of six basic emotional expressions plus Neutral of a male poser (Ekman&Friesen, 1976), and 24 composites combining Happiness, Anger and Fear in upper or lower face with other 5 expressions. These three expressions concentrate their distinguishing features in a single half-face. Stimuli were presented in 930 concurrent pairs, each for 2000 ms. Eighteen participants rated pair wise similarity on a scale from 1 to 9. Full matrices were processed with PROXSCAL multidimensional scaling program. We retained a 5D solution (Stress = 10.3%). D1 and D3 captured lower-face variations: D1 separated X-Happiness (smiling mouth) from other stimuli, with X-Disgust and X-Sadness (closed mouth) at the other extreme; D3 opposed X-Anger (compressed mouth) and X-Fear, X-Surprise (open mouth). Other dimensions were upper-face: D2 opposed Fear-X, Surprise-X (wide-opened eyes) and other expressions; D4 separated Fear-X from Surprise-X, and Sadness-X from others; D5 separated Anger-X from others. Similarity processing treated diagnostic facial features as independent components. That is, the solution resolved into independent upper- and lower- face sub-spaces, with little sign of holistic aspects for these expressions of complex, hard-to-verbalise emotions.

[3P093] Dissociations of Face and Emotion Perception: A Case Study of Congenital Prosopagnosia

**David M Kurbel, Malte Persike, Günter Meinhardt, Bozana Meinhardt-Injac**

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Congenital prosopagnosia describes an innate, irreversible disorder of identifying others by their face. Although there is growing interest in determining impairments in distinct perceptual systems, previous literature primarily focused on basic face- and object-related abilities in congenital prosopagnosia. Since affected subjects report overall issues in social functioning, other areas of social cognition might show perceptual deficits as well. The present study conducts a broad test battery including tasks which are believed to contribute to social functioning processes. Applied tests incorporate face processing, emotion perception, language abilities and attention skills. A single case of congenital prosopagnosia was investigated and compared to a control group. The results show a distinct connection between face recognition and emotion perception and further indicate an overall impairment of face related tasks in congenital prosopagnosia, including face processing, perception of facial expressions and attention towards faces. In tests regarding non-face related tasks (vocalisation, language and object attention), no performance differences between the single case of congenital prosopagnosia and the control group were found, suggesting that these perceptual mechanisms remain intact and partly operate as compensatory mechanisms. In neurologically healthy subjects, an overall social functioning system was detected, consisting of face processing, emotion perception and language abilities.

[3P094] Face your body! Bi-directional shifts in emotion categorization following face-body integration

**Maya Lecker<sup>1</sup>, Ron Dotsch<sup>2</sup>, Gijs Bijlstra<sup>3</sup>, Hillel Aviezer<sup>1</sup>**

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Although most research on emotion perception focused on isolated faces, recent studies indicate that body context alters facial expressions' categorization. However, bodies are not immune to contextual influence. Given the face-body integration displayed, it seems plausible that facial expressions can influence bodies too. We hypothesized that perceptual similarity results in confusability, which contributes to contextual effects. However, the specific confusability patterns in emotion categorization differ for faces and bodies. For example, while disgusted and angry faces are highly similar, these emotions' bodies are distinct. Conversely, happy and angry bodies are similar, while these emotions' faces are not. Prototypical emotional faces and bodies from 4 emotional categories (disgust, fear, happiness, anger) were "planted" together in a fully crossed design. Participants (N=105 M-turkers) were required to categorize emotions of bodies (condition 1), faces (condition 2), or full persons (condition 3). Congruency effects were found in all 3 conditions, i.e. categorization accuracy of facial or body expressions was higher when the context was congruent. In addition, the specific pattern of contextual influence differed for faces and bodies, and high similarity played a key role in the shift pattern. Our findings suggest that context can alter face and body categorization in a bi-directional manner.

[3P095] Effect of Smiling on Perception of Facial Birthmarks of Different Sizes

**Ken Masame**

School of Nursing, Miyagi University

This research examined the effect of smiling by people with facial birthmarks. We examined whether a smile influences the visual saliency of a birthmark, and whether a smile improves personality impression, even if faces have birthmarks. Makeup was used to control birthmark size and intensity of pigmentation. Three conditions were determined for five model faces, namely, no birthmark, a small birthmark, and a large birthmark. Furthermore, neutral and smiling expressions were decided for each stimulus condition. Twenty-three participants were asked to rate the visual saliency of the birthmarks by magnitude estimation, and rate impressions among ten personality traits in six steps. A three-factor ANOVA for visual saliency showed that the main effects of facial expressions and birthmark sizes, and their interaction were significant. Smiling decreased the visual saliency of birthmarks, and this effect was stronger for large birthmarks. The birthmark had almost no effect on impression of personality in neutral faces. Smiling improved personality impression in general, but this improvement was slightly weaker for large birthmarks. These results suggest that the effect of smiling on large birthmarks is different for visual saliency compared to personality impression.

[3P096] Hiding emotions: The effects of masking facial regions on judgements of emotional similarity within "expression space"

**David Bimler, John Kirkland**

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If distinctions between the emotional content of facial expressions (FEs) are conveyed by cues within some specific region of the face, masking that region should distort the pattern of perceived emotional similarities among pairs of expressions. We generated four sets of 54 FEs by masking the eye region and mouth region of a male-poser and female-poser set (WF and MO). Each unmasked set contained six pure emotion prototypes plus Neutral, and 47 interpolated emotional blends. Ten subjects provided triadic similarity judgements for each set, for comparison with a pool of judgements previously collected for unmasked stimuli. The results were compatible with a four-dimensional geometrical model of "expression space", compressed in specific directions corresponding to the absence of emotion-distinguishing cues, but these directions were not always the dimensions of experiential emotion. For instance, for both posers, the eye-masked condition was equivalent to compression along a direction where eye-region cues dominated expressive variance, separating Fear and Surprise at one extreme from Sad at the other. The mouth-masked condition expanded both poser's models (increasing dissimilarities) along a direction with extremes of Fear / Surprise and Sad, and compressed the MO model along a Happiness direction, but not the WF model.

[3P097] Traditional Islamic Headdress and Facial Features Unconsciously Elicit Negative Emotions

**Trevor J Hine, Bhutto Sarah**

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There has been an increasing amount of negative media in the West against Muslims and Islam, leading to an increase in implicit negative feelings towards those identifying as Muslim through wearing traditional dress. The dot-probe and Continuous Flash Suppression (CFS) techniques were used to elicit an emotional response without awareness. Thirty-five participants in a dot-probe experiment were shown (16 msec) images of male or female faces, with unfriendly, neutral or friendly facial expressions and both Muslim or Western headcovering and features. There were significantly slower reaction times to upright faces than inverted faces, especially with some of the Muslim faces. The same faces were shown to 21 participants during CFS. Afterwards, the participants were required to rate a visible neutral face as unfriendly, neutral or friendly. A significant two-way interaction was found for Orientation (normal vs inverted) × Headdress (Muslim vs Western), where the neutral face was rated as significantly more unfriendly after unconscious exposure to Muslim faces as opposed to Western faces. These results indicate that faces displaying the traditional headdress of the Islamic faith, along with other facial features, unconsciously elicit a negative emotional response in Westerners when compared to Western faces.

[3P098] Crossmodal integration of emotional sounds and faces depends on the degree of autistic traits

**Arno Koning, Lena Mielke, Rob van Lier**

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We studied the influence of emotional sounds on the judged friendliness of faces. The faces were all computer generated and had a neutral expression, whereas the sounds could be qualified as happy, scary, or neutral, comprising 3 seconds of laughter, screams or noise, respectively. All faces were shown in two viewing directions: frontal (with the line of sight towards the observer) or sideways (with line of sight facing away by approx. 45 degrees). Participants were non-autistic, but filled in a standardized AQ test. There was a main effect of sound on the judged friendliness of the faces and an interaction effect of sound and viewing direction of the faces. More in particular, it appeared that participants with relatively low AQ-scores (less autistic traits) rated frontal faces to be more friendly when happy sounds were presented (as compared to sideways faces), but rated the sideways faces to be more friendly when scary sounds were presented (as compared to frontal faces). Additionally, when presenting the emotional sounds, the higher the AQ-score, the smaller the difference between the judged friendliness of the two faces (frontal versus sideways). The data suggest that cross-modal sensitivity was highest for participants that had the lowest AQ-score.

[3P099] Reading the Mind in the Blink of an Eye - A novel database for facial expressions

**Gunnar Schmidtman, Daria Sleiman, Jordan Pollack, Ian Gold**

Department of Ophthalmology, McGill University

The ability to infer emotions, or mental states of others, referred to as theory-of-mind (ToM), has traditionally been understood as a slow, conscious process. It has recently been suggested that some aspects of ToM occur automatically. We aimed to investigate this with respect to specific emotional states by using the 'Reading the Mind in the Eyes' Test (Baron-Cohen et al. 2001). A 4-AFC paradigm was employed to test the ability to correctly judge the emotional state of peoples' eye-region for different presentation times (12.5 - 400 ms & indefinite). Sensitivity to the stimuli increases with increasing presentation time up to about 75% correct response for 400 ms, but does not increase for longer presentation times. Moreover, despite consistent participants' reports of guessing, they performed well above chance. These results suggest that judging complex facial expressions from just the eye regions is an automatic and unconscious process. Additionally, we introduce a completely new database of 96 different facial expressions, based on the terms used by Baron-Cohen et al. (2001). Two professional actors were recruited to interpret the facial expressions. High quality pictures were taken under controlled lightening and perspective conditions.

[3P100] Is there a correlation between psychophysical visual surround suppression and IQ?

**Sandra Arranz-Paraíso, Ignacio Serrano-Pedraza**

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People take longer to discriminate the direction of motion of a high contrast stimulus when this is large compared to

when it is small. This paradoxical “visual surround suppression” is believed to reflect normal visual inhibitory mechanisms. There is a growing interest in the study of these mechanisms given the reduced visual surround suppression found in different clinical populations and the strong link with a reduced GABA concentration. Melnick et al., (2013), using a motion discrimination task, showed that intelligence strongly correlates with visual suppression ( $r=0.71$ ). Our aim is to figure out whether these results can be extended to other IQ measurements (RIAS test) and other visual suppression tasks (see Petrov, et al., 2005). We tested 27 participants (age-range 20-31y). Our results showed that: a) Intelligence doesn't correlate with any visual suppression task: Motion Suppression index vs. general intelligence RIAS ( $r=0.22$ ,  $p=0.27$ ); Spatial Suppression index vs. RIAS ( $r=-0.26$ ,  $p=0.177$ ). b) Duration thresholds for a moving small high-contrast stimulus showed a significantly high correlation with non-verbal intelligence ( $r=-0.54$ ,  $p=0.0036$ ) and general intelligence RIAS index ( $r=-0.46$ ,  $p=0.015$ ) but a small non-significant correlation with verbal intelligence ( $r=-0.25$ ,  $p=0.199$ ). Our results suggest that speed processing and not visual surround suppression is related to IQ.

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[3P101] Context improves motion speed estimation

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Instituto de Investigación en Luz, Ambiente y Visión, Universidad Nacional de Tucumán, Argentina

Velocity is always defined in relation to a frame of reference. The visual system shifts the reference frame from which it processes motion signals according to situation and context, e.g. the duncker illusion. We hypothesize that the visual system not only employs contextual stimuli to establish novel reference frames, but are also necessary to improve velocity calculation, i.e. velocity precision is impoverished when motion signals must be computed under isolated environments, even when the reference system remains known. To test this hypothesis we conducted speed discrimination tests under landmarked and isolated situations. Results show a significant increase in the webber fractions when stimuli were displayed in isolation. These results would indicate that contextual information may not only help establish novel coordinates systems when needed, but would as well help refine motion estimations under 'normal' (i.e. retinotopic) coordinate systems.

[3P102] Anodal and cathodal electrical stimulation over v5 improves motion perception by signal enhancement and noise reduction

**Luca Battaglini, Clara Casco**

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The effect of transcranial direct current stimulation (tDCS) and perceptual learning (PL) on coherent motion (CM) discrimination of dots moving coherently (signal) in a field of dots moving randomly (noise) can be accounted for by either noise reduction or signal enhancement. To distinguish between the two mechanisms we monitored the correct direction of CM discrimination as a function of coherence levels (psychophysical method of constant stimuli). Rather than having opposite effects on CM motion discriminability, we found that tDCS of both positive and negative polarity over V5 enhances discriminability but in a different way: anodal (a-tDCS) reduces the coherence levels to reach threshold (75% accuracy) whereas cathodal (c-tDCS) improves discriminability at subthreshold signal-to-noise levels. Moreover, results show that a late-PL also reduces CM threshold as a-tDCS does. These results suggest a dissociation between the neural mechanisms responsible for enhanced CM discriminability: either depression of the noisy uncorrelated motion, by c-tDCS, or increased activation of weak correlated motion signals by a-tDCS and late-PL.

[3P103] Migraine and the motion streak

**Louise O'Hare**

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The human visual system is believed to make use of orientation detectors to augment direction discrimination of motion stimuli through the use of “motion streaks” (Geisler, 1999). The effect relies on the speed of the moving object relative to the length of the temporal integration window of the observer. Therefore, the size of the motion streak effect could potentially be used as a proxy for estimating individual differences in temporal integration processes. Migraine groups consistently show poorer performance on global motion tasks compared to controls (e.g. Ditchfield et al., 2006), and it has been shown that this is not due to inadequate sampling (Shepherd et al., 2012) or increased internal

noise levels (Tibber et al., 2014). Global motion processing relies on sampling effectiveness, level of internal noise and ability to integrate motion signals (Dakin et al., 2005). This study investigated whether temporal integration processes are different in migraine and control groups, using a motion streak masking task. Results suggest a trend towards slightly elevated thresholds for the motion streak effect for those with migraine compared to those without.

[3P104] Further observations of the "Witch Ring" illusion

**David A. Phillips, Priscilla Heard<sup>1</sup>, Thomas Ryan<sup>1</sup>**

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We report further characteristics of illusions of expansion or contraction seen in "magic" novelty illusion rings, known historically as Witch Rings. In an earlier study we attributed the illusions to movement of the reflections the rings present with rotation (Heard and Phillips, 2015 Perception 44 (1) 103 - 106), noting that illusion was reduced and replaced by depth effects when animated variants of the stimuli were given size and acceleration perspective depth cues. We now report that the illusion and its reduction with perspective persist when stimuli are reduced just to V shaped patterns of streaming dots. Illusion is also sharply reduced by steady fixation. We analyse experimental data from 18 participants with ASL eye-tracker. We consider a possible relationship with similar effects of expansion and contraction, when a rigid V shaped fan of lines is raised or lowered rapidly in an observer's field of view. We call this the scrolling illusion, since it appears if such shapes chance to be present amongst rapidly scrolled computer screen content. We demonstrate however that the effect is attributable to the aperture problem, noting that it does not appear with dot patterns. It seems unlikely to be related to the Witch Ring illusion.

[3P105] Direction perception in center-surround multi-element configurations with varying contrast and velocity

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We examined how the difference in contrast, velocity, and orientation of moving elongated elements in a central and surround field affect the apparent direction of motion. The stimuli consisted of Gabor elements moving either parallel or orthogonal to their orientation with two different speeds. The surround motion direction varied from 0° to 315° with a step of 45°. The relative contrast in the center and periphery was varied. The Subject's task was to discriminate whether the central motion was to the left or to the right from the vertical downward. The results suggest a significant interaction between surround motion direction and the relative contrast, velocity, and orientation of the elements. The perceived direction in the center was repelled away from the surround motion direction most when the motions in the two fields of the configuration were orthogonal. The directional repulsion decreased with increasing speed and when the surrounding contrast was less in the center. The angular differences between the center and surround motion directions had stronger effect when the motion trajectory was parallel to the orientation of the elements. The functional significance of the observed effects on the integration of motion information for coding object speed and direction is discussed.

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[3P106] Size of motion display affects precision of motion perception

**Yoshiaki Tsushima, Yuichi Sakano, Hiroshi Ando**

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We enjoy visual images in different sizes of display such as a laptop and a theatre screen. How are our perceptual experiences altered by the size of display? Here, we conducted several motion perception experiments to investigate how perceptual experiences are influenced by size of visual images. Participants viewed the motion dots display for 500 msec in different size of perceptual field, 80 (large), 50 (middle), and 20 (small) degrees of visual angle. There were two types of coherently moving dots, expanding and contracting dots. The ratios of expanding to contracting (or contracting to expanding) dots were 10, 30, 40, 50, 60, 70, and 90 %. The size of a dot and dots density were fixed at all size of motion display. They were asked to report the global motion direction at each ratio of motion display, expansion or contraction. As a result, precision of motion perception at the larger display was higher than that at the smaller display. In addition, the variability of behavioral performances among participants decreased at the larger

motion display. This might indicate that visual images at larger display provide us with not only more precise information but also more unified perceptual experiences.

[3P107] The effect of temporal duration on the integration of local motion in the discrimination of global speed, in the absence of visual awareness.

**Charles Y Chung, Sieu Khuu, Kirsten Challinor**

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We examined the contribution of visual awareness to the spatial and temporal integration of local motion for the discrimination of global speed. Speed discrimination thresholds to rotational motion were measured using an annulus of moving Gabor in which the number of elements (2-8) and their temporal duration were varied. Experiment 1 showed that at brief stimulus durations (< 0.8s), speed discrimination improved with the number of elements, but not at longer durations. This demonstrated that spatial summation is more effective at brief stimulus-presentations. In Experiment 2, we investigated the minimum temporal duration required for local motion to be integrated to discriminate global speed. A subset of Gabor elements was presented asynchronously in which they appeared/disappeared at different temporal intervals. We find that transient Gabors were integrated over a temporal-window of 150ms to influence speed discrimination. In Experiment 3, to investigate the role of visual awareness we repeated Experiment 2 and used Continuous Flash Suppression (CFS) to suppress transient Gabors from awareness. We find that suppressed transient-Gabors contributed to global-speed discrimination, but needed to be presented earlier to influence performance. This suggests that motion integration can occur without visual awareness, but this process is slower than under conscious vision.

[3P108] Second-order apparent motion perception traversing horizontal and vertical meridians

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We reported that, when classical apparent motion stimuli consisting of two discs were successively presented within or across hemifields (right/left or upper/lower), the motion perception rate markedly declined at shorter ISIs in cross-hemifield conditions relative to within-hemifield conditions (Sato, Kanaya, & Fujita, VSS2013). These results suggest classical apparent motion is partially mediated by a lower-level motion mechanism, e.g., a first-order motion mechanism. To further clarify this point, we examined the effect of second-order motion on within/cross-hemifield classical apparent motion. The first-order motion mechanism is thought to be unable to detect second-order motion (Cavanagh & Mather, 1989). Two rectangular objects defined by the first-order attribute (luminance) or one of the second-order attributes (contrast or dotsize) were successively presented within or across hemifields. ISI was varied in seven steps between 0 and 533.3 msec. Four observers' task was to judge whether motion was perceived or not. Results showed that apparent motion perception was much the same in first- and second-order motions, and had a tendency similar to those of Sato et al. (2013). These results suggest that other motion mechanisms different from first-order motion mechanism that can detect second-order motion, e.g., long-range process (Braddick, 1974, 1980), mediate classical apparent motion.

[3P109] Effects of different electrical brain stimulations over V5/MT on global motion processing.

**Filippo Ghin, George Mather, Andrea Pavan**

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Transcranial electrical stimulation (tES) is a well-established neuromodulatory technique. To date the behavioural effects of tES on global motion processing are particularly fragmentary since previous studies employed different stimuli, stimulation regimes, stimulation sites and behavioural tasks. The aim of this study was to investigate the effect of different stimulation regimes (anodal tDCS, cathodal tDCS, high-frequency tRNS, and Sham) on global motion processing by stimulating the left V5/MT. Participants performed a motion direction discrimination task (8AFC). The stimuli consisted of global moving dots inside a circular window, and were displayed either to the right visual hemi-field (i.e., contralateral to the stimulation site) or to the left visual hemi-field (i.e., ipsilateral to the stimulation site). Results showed a significantly lower normalized coherence threshold for the contralateral than the ipsilateral visual hemi-field only when stimulating with anodal tDCS ( $M=1.27$  [SEM=0.2] vs.  $M=0.9$  [SEM=0.14], respectively). These results provide an additional confirmation of V5/MT as a crucial area for global motion processing and further evidence that anodal tDCS can lead to an excitatory effect at the behavioural level. The results suggest that anodal

tDCS may increase the signal-to-noise ratio for global moving patterns.

[3P110] The window of simultaneity widens around the time of an active or passive action

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Research has shown distortions for the perceived timing of voluntary actions and their consequences, mostly focusing on unimodal action consequences. However, voluntary actions mostly have multisensory consequences. In two studies we investigated simultaneity perception for stimuli triggered by self-generated actions by assessing window of subjective simultaneity (WSS) for audiovisual stimulus pairs triggered by button presses. We manipulated the temporal predictability for the action-consequences by introducing delays between the button press and the AV pair. We found widened WSS when the action-effect relationship was as predicted. Introducing a delay led to a tightening of the WSS. In a second experiment, we included a passive condition using a passively-depressed button. We replicated widened WSS around the action time, for both active and passive movements. Delays led to a tightening of the WSS for both active and passive movements. We also found that the psychometric slopes of the active condition were steeper than slopes for the passive condition. Our results suggest that; 1. changes in the WSS may be explained by shifts or compressions in perceived timing, 2. causality seems to be crucial in perceiving simultaneity between actions and consequences, 3. movement intentionality seems to aid in achieving more precise perception of simultaneity.

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[3P111] The influence of effector movement on the spatial coding of somatosensory reach targets: From gaze-independent to gaze-dependent coding

**Stefanie Mueller, Katja Fiehler**

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Previous research consistently showed that visual stimuli for reaching are coded in a gaze-dependent reference frame but the coding scheme of proprioceptive stimuli is less clear. Some studies suggest that proprioceptive reach targets are coded with respect to gaze, similar to visual targets, while others found gaze-independent coding. In study 1, we investigated whether an effector movement intervening between the presentation of the proprioceptive target and reaching towards it, accounts for the inconsistent results. Subjects reached to somatosensory targets while the gaze direction was varied. Additionally, we manipulated the presence of an effector movement (eyes or arm) between the target presentation and reaching. Reach errors only varied with gaze direction when the eyes or the arm were moved before reaching, thus indicating gaze-dependent coding. In study 2, we examined whether such a gaze-dependent representation after an effector movement replaced a gaze-independent one or whether a gaze-dependent representation was used in addition to gaze-independent, presumably body-centered representation. Hence, we used a similar paradigm as in study 1 but now varied the movement vector (start to target location) relative to the gaze direction and to the body midline. Results suggest mixed body- and gaze-centered coding when an effector movement intervened before reaching.

Funding: Fi 1567/4-2

[3P112] Turning down the noise in interceptive timing

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Humans show higher temporal precision if they generate faster movements when intercepting moving targets (Tresilian & Plooy, 2006; Brenner & Smeets, 2015). We systematically added noise to participant trajectories to determine whether this would cause participants to alter their movement speed. Participants used a 1-DoF manipulandum to launch a virtual puck at a moving target travelling at a constant speed. Initial baseline trials (n=100) had no added noise, with the puck moving at the strike speed. Participants then completed a block of trials (n=200) where the puck moved at the strike speed plus noise taken from a Gaussian distribution of a specified standard deviation (SD). There were three groups: i) no noise group (SD = 0 mm/sec); low noise group (SD = 100 mm/sec) and high noise group (SD = 200 mm/sec). The presence of noise increased temporal errors but participants responded to the presence of noise by increasing their movement speeds: the high noise group hit the puck at higher velocities than the low noise group, and the low noise group hit the puck at higher velocities than the no noise group. These results suggest that people naturally

offset changes in motor noise by systematically changing their movement speed.

[3P113] The lack of effect of a visual size illusion on grip aperture is independent of object size

**Jeroen Smeets, Eli Brenner**

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There is an extensive literature debating whether visual size illusions influence the peak grip aperture in grasping. We found no effect for 7cm diameter disks on a Ponzo illusion (Brenner & Smeets, EBR, 1996). We interpreted this as evidence that grasping is not based on a visual estimate of size. Most studies that did find an influence of illusions used approximately 3cm diameter disks embedded in an Ebbinghaus illusion. Could it be that people do use size information for smaller objects because they combine information to maximise precision, and for smaller objects size judgments are no longer less precise than judgments of position (Smeets & Brenner, Current Biology, 2008). In order to avoid any possibility of parts of the illusion being interpreted as obstacles, we tested this possibility using a modified diagonal illusion. Participants grasped both small (1.5-2.5 cm) and slightly larger (4-5 cm) objects. The illusion had an effect of more than 10% on perceptual judgements, irrespective of object size. For the peak aperture during grasping movements, the effect of the illusion was negligible (< 0.5%), again independent of object size. We conclude that the reported disagreement on the effect of illusion is not due to using differently sized objects.

[3P114] Repeated Search with Arm and Body Movements

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When we search the same display repeatedly for different targets with covert attention (i.e., without eye movements), search does not benefit from repetition. Here, we investigated whether increasing the cost of the search would result in a repetition benefit. In two experiments participants searched repeatedly for different target letters among distractor letters. In Experiment 1 participants searched circular arrays of film canisters that were arranged on a board. Participants had to reach out and turn over the canisters to make the search letters visible. In the repeated search condition the array did not change between searches; in the unrepeated search condition there was a new array for each search. In Experiment 2 participants searched in a room amidst circular arrays of computer monitors. Participants had to walk from one monitor to the next and to press a button to make the search letters appear. We found that search rates (based on search times and the number of search steps necessary to find the target) improved dramatically in the repeated compared to the unrepeated search condition in both experiments. This suggests that participants used memory to improve search in the same environment if the cost of searching made memory usage worthwhile.

[3P115] Gaze when grasping a glass of milk or water

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Most studies agree that people look close to where their index finger will touch an object when reaching to grasp it. Various factors modulate this tendency, but the only clear exception is for objects at eye height. To examine whether this is because objects at eye height occlude the whole last part of the index finger's trajectory, we compared gaze patterns when grasping a glass of milk or water. When the objects were at eye height, people could see their finger move behind the glass of water, but could not see anything through the milk. When the objects were below eye height, people could see both digits approach the glass. To encourage a precise grasp, the glass was placed on a small surface and people were to lift it and pour the liquid into another glass. Surprisingly, most participants looked closer to their thumb's endpoint while reaching for a glass that was below eye height, and looked below the endpoints altogether when the glass was at eye height, irrespective of the kind of liquid in the glass. This suggests that where people look when reaching for an object depends on more than only the requirements of the reaching movement.

[3P116] Tactile enhancement in reaching

**Dimitris Voudouris, Katja Fiehler**

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The perception of tactile stimuli on a moving limb is generally suppressed. This is paradoxical, as somatosensory signals are essential when moving. In order to examine whether tactile perception depends on the relevancy of the

expected somatosensory information, participants reached with their unseen right hand either to a visual or a somatosensory (digits of unseen left hand) target. Two vibrotactile stimuli were simultaneously presented: a reference either to the little finger of the left static hand or to the sternum, and a comparison to the index finger of the right moving hand. Participants discriminated which stimulus felt stronger. We determined the point-of-subjective-equality (PSE), which was higher during somatosensory than visual reaching, but only when the reference was at the target hand, suggesting enhanced tactile perception at the task-relevant location. We then examined whether tactile enhancement is target-specific. Participants reached to their left thumb or little finger and discriminated the intensity of a stimulus presented to one of these target-digits from another stimulus presented to the sternum. Stimuli on the target-digits were perceived stronger during reaching compared to a baseline (no-movement) suggesting that somatosensory perception is enhanced at the target hand. However, this enhancement was not specific to the movement goal. Funding: This work was supported by the German Research Foundation (DFG) TRR 135.

### [3P117] Sensory-based versus memory-based selection in well-practiced sensorimotor sequences

**Rebecca M Foerster, Werner X. Schneider**

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When performing an object-based sensorimotor sequence, humans attend to sensory environmental information that specifies the next manual action step – sensory-based selection. In well-practiced sequential actions, long-term memory (LTM) can directly control for the sequence of attention, gaze, and manual movements (Foerster et al., 2012) – memory-based selection. We revealed that individuals differ in the usage of sensory-based versus memory-based manual selection after training. Participants practiced a computerized version of the number-connection test, while eye movements were measured (Foerster et al., 2015). They clicked in ascending order on spatially distributed numbers 0-8 on the screen. LTM was build-up in 65 trials with constant visuospatial arrangement. In 20 consecutive change-trials, numbers 3-8 switched to 4-9 introducing a change on the sequence-defining visual features. The required spatial-motor sequence remained the same. In 15 reversion-trials, the original numbers appeared. During the first change trials, about half of the participants clicked slower, performed more errors and fixations, and exhibited longer cursor- and scan-paths. The remaining participants were hardly affected by the trajectory-irrelevant number change. The different gaze and hand patterns did not correlate with performance measures prior to the change. Thus, the applied selection mode was independent from the level of expertise.

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### [3P118] How do people steer a car to intercept a moving target: Flexibility in the visual control of locomotor interception

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Numerous studies have found evidence that humans use the constant bearing angle (CBA) strategy in locomotor interception. However, participants in these studies controlled only locomotion speed while moving along a fixed straight path. With such a task constraint, any change in bearing angle is equivalent to a change in target-heading angle. Therefore, these studies cannot discriminate between the CBA strategy and a constant target-heading angle strategy. To examine the strategy used in locomotor interception, we asked participants (N = 12) to steer a car to intercept a moving target in two virtual environments: one with only a textured ground-plane and the other containing textured objects. The car moved at a constant speed of 7 m/s and participants steered while the target had different but constant direction (left or right) and speeds (4, 5, or 6 m/s) across trials. Our results indicate that the bearing angle continuously changed during interception, inconsistent with the CBA strategy. In contrast, the target-heading angle initially diverged, and then remained constant until interception. This flexible constant target-heading angle strategy is consistent with a hybrid account of visual control of action that combines off-line strategy with information-based control, reflecting the flexibility in visual control of locomotor interception.

### [3P119] Exploring the role of actions in calibrating audio-visual events in time

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Perception in multi-sensory environments requires both grouping and segregation processes across modalities. Temporal coincidence is often considered as a cue to help resolve multisensory perception. However, differences in physical transmission time and neural processing time amongst modalities complicate this picture. This is illustrated by cross-modal recalibration, whereby adaptation to audio-visual asynchrony produces shifts in perceived simultaneity. Here, we examined whether actions might serve as anchors to calibrate audio-visual events in time. Participants were tested on an audio-visual simultaneity judgment task following an adaptation phase where they were asked to synchronize actions with audio-visual pairs presented at a fixed asynchrony (either flash leading or lagging). Our analysis focused on the magnitude of the cross-modal recalibration as a function of the nature of the actions; fostering either grouping or segregation. Greater temporal adjustments were found when actions promoted cross-modal grouping. A control experiment suggested that cognitive load and action demands could reasonably explain the obtained effect, above and beyond sensory-motor grouping/segregation. Contrary to the view that cross-modal time adaptation is only driven by stimulus parameters, we speculate perceptual adjustments strongly depend on the observer's inner state, such as motor and cognitive demands.

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[3P120] Effects of visual feedback of virtual hand on proprioceptive drift

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As proprioceptive drift has been investigated mainly with rubber hand illusion, little is known about the effect of visual feedback on the drift with fake hand which is slightly shifted from real hand. In this study, virtual fake hand was presented on the 3D display which was placed over the self-hand. This experimental setup enabled to manipulate the visual factors which may influence the drift. In experiment 1, the effects of (1) congruence of depth position between fake- and self-hand, (2) synchronized active motion, and (3) the temporal change of the amount of the drift were examined with horizontal movement of self-hand. In experiment 2, with vertical movement of self-hand, the effects of (1) congruence of visual size cue and (2) the temporal change of the drift were examined. As a result, when horizontal or vertical motion of the virtual fake hand was presented synchronized with the self-hand, the drift was significantly much larger than no-movement condition irrespective of the congruence of depth position and visual size cue. Although the drift persisted at least for 25 s induced by horizontal movement, the drift by vertical movement significantly decreased in 0-25 s range, suggesting the anisotropy in the proprioceptive drift.

[3P121] Motor activity associated with perceived objects depends on its location in space and previous interactions: an EEG study

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Previous studies have revealed the existence of a motor neural network that is activated during the perception of objects in particular when it is at a reachable distance. Yet, it is unclear whether the neural activity of this network is modulated by previous association between objects and specific motor responses. The aim of this study was to address this issue. Participants had to learn a new association between an object and a motor response (left or right hand grasping). Then, we recorded their cerebral response with an electroencephalogram while they judged the reachability of the object (with the right hand) when presented at different distances. EEG signals analysis showed that early components reflecting sensory processing were sensitive to the incongruence of the hand-object relationship (i.e. seeing an object associated with the left hand), and late components were sensitive to the distance of the object. This study reveals that motor related brain activation in the presence of a visual object depends on its position in space but also on the specificity of the effector-object relationship gained from previous experience.

[3P123] Foreperiod beta-power correlates with the degree of temporal adaptation

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When exposed to sensorimotor visual delays, people learn to intercept targets successfully. We hypothesize that adaptation should be related to the processing of some kind of execution error. If so, we should be able to reveal neural

correlates between degree of adaptation and beta-power activity before movement onset (foreperiod) which has been related to error processing in spatial visuo-motor adaptation. We measured EEG (32 channels) while subjects performed an interception task. The behavioral experiment was divided in 4 phases: full-vision (FV), no-vision (NV), adaptation (A), and NV. In the adaptation phase, we incrementally increased (1msec/trial) the temporal difference between the hand and the cursor movements. For the analysis, the adaptation phase was divided in early adaptation (EA) and late adaptation (LA). We examined beta-band (15-25 Hz) during the preparation of the interceptive timing task given the conditions FV, EA and LA. Interestingly, only LA showed a foreperiod beta-activity pattern that was parametrically modulated by the size of temporal adaptation to the temporal delays. This modulation was a positive correlation between adaptation and beta-power. This suggests that the foreperiod beta-power is related to temporal adjustments leading to adaptation in a similar way as in spatial errors.

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[3P124] The nature of error signals in adaptation

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People are able to predict the sensory consequences of their motor commands, such that they can compensate for delays in sensorimotor loops. This prediction is driven by the difference between the predicted outcome and the perceived error on a trial. To see if people can use cross-modal information to drive adaptation, we used different types of sensory error information in an adaptation task. A target on a screen moved from left to right towards a reference line (at different speeds/distances). In the bi-modal condition, subjects were instructed to match a high-pitched tone with the ball crossing the reference line. In the uni-modal condition, subjects were instructed to match the high-pitched tone with a low-pitched tone that was presented when the ball crossed the line. In both conditions, the consequence of this action was delayed with 1 ms/trial. The results show that subjects were unable to adapt to the delay in the bi-modal condition, but did adapt somewhat in the uni-modal condition. It shows that subjects are unable to integrate the auditory consequence with a visual reference (the reference line), and thus suggests that uni-modal error signals need to be present to adapt to sensory delays.

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[3P125] Motor learning that demands novel dynamic control and perceptual-motor integration: An fMRI study of training voluntary smooth circular eye movements

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Despite a large number of studies, the promise of fMRI methods to produce valuable insights into motor skill learning has been restricted to sequence learning, or manual training paradigms where a relatively advanced capacity for sensory-motor integration and effector coordination already exists. We therefore obtained fMRIs from 16 subjects trained in a new paradigm that demanded voluntary smooth circular eye movements without a moving target. This aimed to monitor neural activation during two possible motor learning processes: (a) the smooth pursuit control system develops a new perceptual-motor relationship and successfully becomes involved in voluntary action in which it is not normally involved; (b) or the saccadic system normally used for voluntary eye motion develops new dynamic coordinative control capable of smooth circular movement. Participants were able to improve the number of correction saccades within half an hour. Activity in the inferior premotor cortex was significantly modulated and decreased during the progress of learning. In contrast, activations in dorsal premotor and parietal cortex along the intraparietal sulcus, the supplementary eye field and the anterior cerebellum did not change during training. Thus, the decrease of activity in inferior premotor cortex was critically related to the learning progress in visuospatial eye movement control.

[3P126] Optic flow speed modulates guidance level control: new insights into two-level steering

**Jac Billington, Callum Mole, Georgios Kountouriotis, Richard Wilkie**

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Responding to changes in the road ahead is essential for successful driving. Steering control can be modelled using two complementary mechanisms: guidance control (to anticipate future steering requirements) and compensatory control

(to stabilise position-in-lane). Influential models of steering capture many steering behaviours using just 'far' and 'near' road regions to inform guidance and compensatory control respectively (Salvucci & Gray, 2004). However, optic flow can influence steering even when road-edges are visible (Kountouriotis et al., 2013). Two experiments assessed whether flow selectively interacted with compensatory and/or guidance levels of steering control. Optic flow speed was manipulated independent of the veridical road-edges so that use of flow would lead to predictable understeering or oversteering. Steering was found to systematically vary according to flow speed, but crucially the Flow-Induced Steering Bias (FISB) magnitude depended on which road-edge components were visible. The presence of a guidance signal increased the influence of flow, with the largest FISB in 'Far' and 'Complete' road conditions, whereas the smallest FISB was observed when only 'Near' road-edges were visible. Overall the experiments demonstrate that optic flow can act indirectly upon steering control by modulating the guidance signal provided by a demarcated path. Funding: Remedi.org, PhD studentship.

[3P127] Predicting the trajectory of a ball from the kinematics of a throwing action

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In several competitive sports, as often in everyday life, humans get engaged in catching objects thrown by a confederate or a competitor. When information about the ball trajectory is limited –because of sparse visibility or short duration of the ball trajectory- the catcher may rely on the throwing kinematics for predicting the outgoing ball's trajectory and improving performance. In this study, we explored the information content about the outgoing ball trajectory present in the whole-body kinematics of the throwing action. We collected data from twenty subjects throwing at four different targets. We then collected kinematics from two subjects simultaneously, adding the presence of a second subject whose task was to catch the ball. Applying a combination of decomposition and classification techniques, we used throwing data (i) to characterize different throwing styles across subjects, (ii) to characterize the target-dependent intra-individual variability in the throwing kinematics, and (iii) to quantify the discriminability of the outgoing ball trajectory as a function of the time percentage of the action. This analysis is functional for assessing, in a successive step, to what extent humans are able to extract useful information from the view of a throwing action and exploit it for improving catching performances.

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[3P128] Simultaneous density contrast

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Simultaneous density contrast (SDC) is the phenomenon in which the perceived density of a textured region is altered by a surround of different density (Mackay, 1973). However SDC has never been systematically examined. Here we measured dot texture SDC using surround densities varying from very sparse to very dense (0-76.8 dots/deg<sup>2</sup>), using a 2AFC staircase procedure in which observers compared the perceived density of a test-plus-surround texture with that of a comparison texture with no surround. Psychometric functions were fitted to obtain the point of subjective equality (PSE). Unexpectedly we found that 4 of 5 observers showed a bidirectional SDC; not only does a denser surround make the test region appear less dense than otherwise (as expected), but a sparser surround makes the test appear more dense than does no surround. The latter result runs contrary to reports that with the density aftereffect (in which the perceived density of a region is altered by adaptation to a different density) adaptation only ever reduces perceived density (Durgin & Huk, 1997). Additional experiments/analyses ruled out mediation of SDC by contrast or spatial frequency. Our results are consistent with the presence of multiple channels that are selective for texture density.

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[3P129] The neural response to visual symmetry in each hemisphere

**Damien Wright, Alexis Makin, Marco Bertamini**

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The human visual system is specially tuned to processing reflection symmetry. Electrophysiological work on symmetry perception has identified an ERP component termed the Sustained Posterior Negativity (SPN): Amplitude is more negative for symmetrical than random patterns from around 200ms after stimulus onset (Bertamini & Makin, 2014).

Presentation in central vision produces activity in both hemispheres. To examine activity in the two hemispheres separately and their interaction, we presented patterns in the left and right hemifields. In Experiment 1, a reflection and a random dot pattern were presented either side of fixation. In Experiment 2, just one hemifield contained a pattern whilst the opposite hemifield remained empty. In Experiment 3, both hemifields contained matching patterns. For each experiment, participants had to choose whether the patterns were light or dark red in colour (thus there was no need to classify the symmetry of the patterns). The SPN was found independently in each hemisphere, and it was unaffected by the stimuli presented in the opposite hemifield. We conclude that symmetry processing does not require activation of both hemispheres; instead each hemisphere has its own symmetry sensitive network.

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### [3P130] Identifying Semantic Attributes for Procedural Textures

**Qitao Wu<sup>1</sup>, Jun Liu<sup>2</sup>, Lina Wang<sup>1</sup>, Ying Gao<sup>1</sup>, Junyu Dong<sup>1</sup>**

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Perceptual attributes of visual textures are important for texture generation, annotation and retrieval. However, it has been verified that perceptual attributes are not sufficient in discriminating a variety of textures except for near-regular ones. Recently, semantic attributes have raised significant interest in object recognition and scene understanding. This work focuses on identifying semantic attributes of procedural textures and discusses whether they can provide deeper insight into texture perception. We first generated 450 textures by 23 procedural models. Then, twenty observers were asked to group these textures, and describe textures in each group using semantic terms. We analyzed these terms and merged similar ones. Finally, we identified 43 semantic attributes from 98 semantic terms introduced by [Bhusan, 1997]. We applied Hierarchical Cluster Analysis (HCA) to the similarity matrix of the procedural models, and clustered these models into 10 classes. We tested the classification performance with semantic attributes as features. The accuracies of cross validation for all classes was 83.66% and for near-regular ones was 99.43%, which outperformed the 12 perceptual features defined in literature by more than 20% and 10% respectively. These results demonstrated that semantic attributes were more effective in discriminating procedural textures and more consistent with human perception.

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### [3P131] The role of motion in mirror-symmetry perception

**Rebecca J Sharman, Elena Gheorghiu**

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The human visual system has specialised mechanisms for encoding mirror-symmetry (Gheorghiu, Bell & Kingdom, 2014, *Journal of Vision*, 14(10):63). Here we investigate the role of motion in symmetry detection and whether symmetrical motion is processed differently to translational motion. Stimuli were random-dot patterns with different amounts of mirror-symmetry about the vertical axis or no symmetry. In the ‘symmetry and motion’ conditions, patterns contained both position and motion-symmetry and the matched pairs moved inwards, outwards, in random directions or were static. We manipulated the amount of positional symmetry by varying the proportion of symmetrical dots and measured symmetry detection thresholds using a 2IFC procedure. In the ‘motion only’ condition, the dots moved either symmetrically (inwards/outwards) or horizontally (left/right). We varied the proportion of coherently moving dots and measured both direction discrimination and motion coherence thresholds. We found that symmetry detection thresholds were higher for static patterns compared to moving patterns, but were comparable for all moving conditions. Motion coherence thresholds were higher for symmetrical than horizontal motion. Direction discrimination thresholds were higher for outwards motion than inwards, left or right motion. Motion does contribute to mirror-symmetry perception, by reducing thresholds, although this is not influenced by motion direction.

Funding: The Wellcome Trust Research Grant

### [3P132] Dynamically adjusted surround contrast enhances boundary detection

**Arash Akbarinia, Alejandro Parraga**

Centre de Visió per Computador, Universitat Autònoma de Barcelona, Catalonia

It has been shown that edges contribute significantly to visual perception and object recognition. In the visual cortex, orientation selective receptive fields can capture intensity discontinuities at local level (Hubel & Wiesel, 1962), and neurophysiological studies reveal that the output of a receptive field is highly influenced by its surrounding regions. In this work, we propose a boundary detection model based on the first derivative of the Gaussian kernel resembling the double-opponent cells in V1 known to respond to colour edges (Shapely & Hawken, 2011). We account for four different types of surround stimulation (Loffler, 2008): (i) full, with a broad isotropic Gaussian, (ii) far, through different image scales weighted according to the distance, (iii) iso- and (iv) orthogonal-orientation, via orientation specific narrow long Gaussians. We dynamically adjust the surround weight of facilitation or inhibition according to the contrast of the receptive field. These signals are filtered at V2 with a centre-surround kernel orthogonal to the V1 orientations (Poirier & Wilson, 2006). Furthermore, we introduce a feedback connection from higher level areas (V4) to the lower ones (V1). Our preliminary results on two benchmark datasets show a large improvement compared to the state-of-the-art (non-learning) computational algorithms.

[3P133] From grouping to coupling: A new perceptual organization beyond Gestalt grouping

**Katia Deiana, Baingio Pinna**

Department of Humanities and Social Sciences, University of Sassari, Italy

In this work, the perceptual organization has been studied through new conditions that cannot be explained in terms of classical grouping principles. The perceptual grouping represents the way through which the visual system builds integrated elements on the basis of the maximal homogeneity among the components of the stimulus pattern. Our results demonstrated through experimental phenomenology the inconsistency of the organization by grouping, and more particularly, the inconsistency of the similarity principle. On the contrary, they suggested the unique role played by the dissimilarity among elements that behaves like an accent or a visual emphasis within a whole. The accentuation principle was here considered as imparting a directional structure to the elements and to the whole object thus creating new phenomena. The salience of the resulting phenomena reveals the supremacy of the dissimilarity in relation to the similarity and the fact that it belongs to a further perceptual organization dynamics that we called “coupling”.

Funding: perceptual organization, segmentation and grouping

[3P134] Probing Attentional Deployment to Foreground and Background regions

**Adel Ferrari, Marco Bertamini**

School of Psychology, University of Liverpool

Attention is allocated to locations in space. Previous studies (e.g., Nelson & Palmer, 2007) reported a foreground advantage, however how this depends on figure-ground organisation and boundary ownership is not clear. Observers were shown a scene of rectangular surfaces using Random Dot Stereograms (RDS). There was a central (target) rectangle and four surrounding rectangles. In one condition (Foreground) the surrounding rectangles were behind the target, in another condition (Background) the surrounding rectangles were in front of it. Figure-ground stratification was given solely by disparity of surrounding regions, not of the target. This stratification was always task-irrelevant. Parameters were adjusted for each individual using an adaptive procedure. Observers performed four tasks: (a) whether the target surface was horizontal/vertical (Aspect-Ratio), (b) which direction a Landolt-C gap was facing (Acuity), (c) whether a darker patch of the target surface was positioned in the upper/lower half of the surface (Displacement), (d) whether the surround was closer/farther compared to the target (Control task). Only in the Aspect-Ratio task (a) there was a figural advantage in terms of speed and accuracy. We take this as evidence that contour assignment is critical to generate a foreground advantage.

Funding: ECV2015

[3P135] Perception of the Kanizsa illusion by pigeons when using different inducers

**Tomokazu Ushitani, Mochizuki Shiori**

Faculty of Letters, Chiba University

One problem in investigating animal perception of illusory modal figures, such as the Kanizsa illusion, is that results often cannot be determined in terms of discriminative cues, because the animal might discriminate specific local features formed by real contours of the inducers, but not the illusory contours that are assumed to be perceived. Therefore, the current study examined whether pigeons could perceive the Kanizsa illusion by using a variety of

inducers to inhibit them using specific features. More specifically, we trained pigeons to search for an illusory triangle, or square, among illusory squares, or triangles. Both figures were formed on 15 textures consisting of a distribution of many small figures. Pigeons successfully learned to search for the target, suggesting that they perceived the illusion. To rule out the possibility that they merely rote learned numerous cues, we newly introduced five more textures as inducers. Results indicated that the search behavior of pigeons transferred to these novel inducers without any difficulty, which strongly supported the perception of illusory figures by pigeons. We have discussed how these results contribute to studies on the Kanizsa illusion in humans.

[3P136] Depth perception affects figure-ground organization by symmetry under inattention

**Einat Rashal<sup>1</sup>, Ruth Kimchi<sup>2</sup>, Johan Wagemans<sup>1</sup>**

<sup>1</sup>Brain and Cognition, KU Leuven, Belgium; <sup>2</sup>University of Haifa Israel

Figure-ground organizations entail depth relations: the figure is what lies in front of the ground, and the ground consequently continues behind the figure. Symmetrical regions are frequently perceived as figures. However, symmetry is considered a relatively weak figural cue, since it has been shown to be overpowered by other cues when in competition. In this study we tested whether symmetry can be an effective figural cue when attention is not available. Specifically, we examined the relationship between symmetry and depth information through shading, in the process of figure-ground organization, using an inattention paradigm. The results showed that when symmetrical and asymmetrical areas were defined by line borders, figure-ground organization could not be achieved under inattention. However, when depth by shading was added, figure-ground organization was accomplished under inattention when symmetry and shading were compatible (i.e., both leading to the same figure-ground organization), but not when they were incompatible (i.e., both factors leading to competing figure-ground organizations). These results suggest that figure-ground organization due to symmetry can be achieved without focused attention when depth information is available.

[3P137] Measuring Plaid-Selective Responses Across Contrast Using the Intermodulation Response

**Darren G Cunningham, Jonathan Peirce**

School of Psychology, University of Nottingham, UK

Relatively little is known about the signal combinations carried out by mid-level neural mechanisms to encode conjunctions of low-level visual features. We studied these using frequency-tagging in steady-state EEG recordings. These allow us to measure responses to the components as well as the “intermodulation” responses, which indicate nonlinearities at or after the point of signal combination. This provides a rich dataset with which to examine cross-orientation suppression and other nonlinearities, such as super-additive summation. Two grating components (1cpd and 3cpd, respectively) were orthogonally combined to form spatial frequency-matched (‘coherent’) and non-matched (‘non-coherent’) plaids. In particular, we explored the contrasts at which nonlinear responses occurred. At the fundamental component frequencies significant responses were found from Michelson contrasts of 0.02-0.08 upwards. When grating components formed a non-coherent plaid, there was no significant intermodulation response at any contrast. For coherent plaids, however, there was a significant intermodulation response at a Michelson contrast of 0.32 but not at 0.16 and below. This difference between coherent and non-coherent plaids did not appear to be accounted for by cross-orientation suppression, as component suppression was greater in the non-coherent plaid condition, suggesting that an additional selective nonlinearity was occurring for the coherent combination.

Funding: EPSRC

[3P138] Different mechanisms mediating interpolation of illusory and partly-occluded contours

**Bat-Sheva Hadad**

Edmond J. Safra Brain Research Center, University of Haifa

Continuous objects often project disparate fragments on the retina. Yet, in most cases, humans perceive continuous and coherent objects. A set of experiments was carried out to determine the spatial factors limiting interpolation, their developmental, and whether the same process underlies interpolation in different cases of fragmentation. Experiment 1 examined the effects of contour geometry, specifically, the effect of scale-dependent (i.e., retinal size) and scale-independent factors (i.e., support-ratio; SR). For both illusory and occluded-contours, interpolation was affected more

by SR than size. However, illusory-contours were less precisely interpolated and were affected more by SR. Experiment 2 traced the development of interpolation demonstrating a general improvement with age, with the two types of contours equally affected by spatial constraints during childhood. However, while interpolated occluded-contours became more precise with age and less dependent on SR, illusory-contours were less improved and more tied to SR by adulthood. Experiment 3 presented two parts of each display to the same or to different eyes. Superior performance in the monocular over binocular presentation was found more for the illusory-contours, indicating the involvement of relatively lower, prestriate portions of the visual system. Consistent with their different appearances, different mechanisms underlie interpolation of illusory and occluded contours.

Funding: Israel Science Foundation (ISF) #967/14

[3P139] The time compression induced by visual masking

**Riku Asaoka, Jiro Gyoba**

Department of Psychology, Graduate School of Arts and Letters, Tohoku University, Japan

The present study examined the effect of visual masking on the perceived duration of visual stimuli using the time reproduction task. Black and white checkerboards were presented for 50 ms as mask stimuli. A black unfilled circle or triangle was presented for 300, 500, 700, or 900 ms as target stimuli. Both types of stimuli were presented at the center of the display on a gray background. Participants were asked to reproduce the perceived duration of the target stimuli by pressing a key. In Experiment 1, the checkerboards were presented before and after the target stimuli with several inter-stimulus intervals. The reproduced duration was shorter in the 0 ms inter-stimulus interval condition than in the target-only condition, indicating that the visual masking compressed the perceived duration. Experiment 2 tested the effects of the forward or backward mask alone on the reproduced duration; this showed that the time compression was not observed in the forward or backward masking condition. Experiment 3 demonstrated that the time compression did not occur when the mask and target appeared in the different position. These results indicate that spatial and temporal factors modulate the visual masking effect on visual time perception.

[3P140] Emotions evoked by viewing pictures may affect perceived duration and temporal resolution of visual processing

**Makoto Ichikawa, Misa Kobayashi**

Department of Psychology, Chiba University

We investigated how impressions evoked by viewing a picture affects temporal resolution of the visual processing and perceived picture duration. In Experiment 1, as an index of temporal resolution of the visual processing, we measured the noticeable duration of a monochrome picture after presenting a color picture by the use of methods of constant stimuli. In addition, in Experiment 2, we measured the duration of the picture presentation. We found that the minimum duration with which observer could notice the monochrome image in viewing a dangerous picture was shorter than that in viewing safe pictures. We also found that the observers overestimated the duration of the picture presentation in viewing dangerous pictures. There was no significant correlation between the results of the two experiments. These results suggest that the basis for improvement of the temporal resolution in visual processing differs from that for the elongation of the perceived duration. Results of the present study suggest that enhancement of temporal resolution in the visual processing requires strong emotional arousal whereas elongation of perceived duration is achieved not only by emotional arousal, but also by emotional valence and salient impression in dangerous and unpleasant dimensions.

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[3P141] The effects of spatial attention on temporal integration

**Ilanit Hochmitz<sup>1</sup>, Marc M. Lauffs<sup>2</sup>, Michael H. Herzog<sup>2</sup>, Yaffa Yeshurun<sup>1</sup>**

<sup>1</sup>Psychology, University of Haifa; <sup>2</sup>EPFL Lausanne Switzerland

Feature fusion reflects temporal integration. Previous studies mostly employed foveal presentations with no attention manipulation. In this study we examined the effects of sustained spatial attention on temporal integration using feature-fusion with peripheral presentation. We used a typical feature fusion display. A vernier and anti-vernier stimuli (vernier with offset in the opposite direction than the first vernier) were presented in rapid succession in one of 2 possible locations, at 2° of eccentricity. The attended condition involved endogenous attention manipulation achieved through

holding the location of the stimuli constant for the whole block (i.e., the stimuli were always presented to the right of the fixation). Thus, in this condition there was no spatial uncertainty. In the unattended condition, the stimuli could appear either to the right or left of the fixation with equal probability, generating spatial uncertainty. We found considerable feature fusion in the attended condition, suggesting that feature fusion can also occur with peripheral presentation. However, no feature fusion was found without attention (i.e., when there was uncertainty regarding the stimuli location), suggesting that spatial attention improves temporal integration. We are currently conducting similar experiments using different attentional cues to manipulate transient attention.

[3P142] Cinematic cuts and temporal continuity

**Elena A Parozzi<sup>1</sup>, Luca Tommasi<sup>2</sup>, Rossana Actis-Grosso<sup>1</sup>**

<sup>1</sup>Department of Psychology, University of Milano-Bicocca; <sup>2</sup>University of Chieti-Pescara

Cuts between different focal lengths (such as transitions from long-shot to close-up) are widely used in video editing. The question is still open whether and how cuts alter the perception of temporal continuity. To investigate this issue, two experiments were carried out, with animations representing Michotte-type launch and entraining effects as prototypical events: two colliding squares underwent a sudden change in size (as from a close up to a long shot or vice versa, with 1.5 and 3 as two possible Degrees of Magnification, DM); the temporal continuity of the displayed event could also be altered, from a flashback to a flash-forward. In Experiment 1 participants (n=15) rated the perceived temporal continuity of the displayed events; the experimental setting of Experiment 2 was aimed at resembling a movie theatre, with small groups of participants (i.e. 3 groups of 5 persons each) watching the animations projected onto a white wall 3 m from the audience. Interestingly, results show, among other things, an effect of DM ( $p < 0.001$ ), indicating a general preference for cuts from long-shot to close-up and, more in general, that a temporally discontinuous edit can be made to appear continuous.

[3P143] Unpacking the prediction-motion literature

**Alexis D Makin**

Psychological Sciences, University of Liverpool

In a Prediction Motion (PM) task, participants observe a moving target disappear behind an occluder, and press when it reaches a goal. I have attempted to review and consolidate the fragmented PM literature by elucidating four theoretical dichotomies, and answering them with new data. Dichotomy 1) Do people track the occluded target with spatial attention (tracking strategy), or estimate time-to-contact before occlusion, then delay a motor response (clocking strategy)? Answer: Tracking and clocking are both viable strategies. Dichotomy 2) Is PM mediated by mental imagery, or the oculomotor system? Answer: Neither. Dichotomy 3) People can do PM tasks in physical space and feature space. They may thus update mental representations, both without sensory input, and at the right speed. Do we have a common rate controller in the brain, which can be functionally coupled to different sensory maps, or does each map have its own local rate control circuitry? Answer: common rate controller. Dichotomy 4) Do people run a rate controlled simulation of the occluded process, or do they use a clocking strategy? Answer: common rate controller. This synthesis helps unpack the PM literature, but also offers a new way of understanding fundamental mechanisms involved in controlling thought and action.

Funding: Leverhulme Trust Early Career Fellowship (ECF 721-2012)

[3P144] Effect of stimulus placement and presentation on duration discrimination

**Charlotte Harrison<sup>1</sup>, Nicola Binetti<sup>1</sup>, Isabelle Mareschal<sup>2</sup>, Alan Johnston<sup>3</sup>**

<sup>1</sup>Department of Experimental Psychology, University College London; <sup>2</sup>Queen Mary University of London; <sup>3</sup>University of Nottingham

Discrimination performance in psychophysical tasks is better when the reference stimulus is presented in the first interval of two-interval trials (Nachmias, 2006). We investigate the spatial dependence of this effect. In the current experiment, two circular sinusoidal gratings (reference and test) were shown sequentially and participants judged which was presented for a longer duration. The reference lasted 600ms, and the test had one of seven values (300-900ms). Stimulus-order was randomised between trials. The second stimulus could appear in the same retinotopic, spatiotopic, or 'combined' region of the screen. There were control conditions for each trial in which equivalent eye movements were made. While there were no observed effects of visuospatial memory type, stimulus-order effects were stronger in the 'spatiotopic control', compared to other control conditions. In this condition, the test duration was

overestimated by a significantly larger amount when the reference stimulus was presented second. Participants were also less sensitive to differences in duration overall when the reference stimulus was second. While the findings suggest that stimulus-order biases duration discrimination, there is less evidence for a spatial component to the effect. Funding: Leverhulme Trust

[3P145] The effect of awareness of temporal lag on motor-visual temporal recalibration varies with judgment tasks

**Masaki Tsujita, Koichiro Yamada, Makoto Ichikawa**

Faculty of Letters, Chiba University

Subjective judgment about temporal relationship between a voluntary action and a perceived visual event is adaptively recalibrated after repeated exposure to a temporal lag between a voluntary action and its visual feedback. A recent study demonstrated that motor-visual temporal recalibration in temporal order judgment depends upon awareness of a motor-visual temporal lag during adaptation (Tsujita & Ichikawa, 2016, *Frontiers in Integrative Neuroscience*). In this study, we examined whether awareness of the temporal lag is required for motor-visual temporal recalibration in simultaneity judgment. We allocated observers either of two conditions. In the unaware of lag condition, we first introduced a slight temporal lag and gradually increased it during adaptation. In the aware of lag condition, we introduced a substantial temporal lag throughout adaptation, and instructed observers about the introduction of the temporal lag before the adaptation. We found significant recalibration in both the unaware and aware of lag conditions. These results suggest that motor-visual temporal recalibration in simultaneity judgment is independent of awareness of motor-visual temporal lag, and based upon automatic, and unaware processing. We will discuss differences in the basis of motor-visual temporal recalibration between temporal order judgment and simultaneity judgment.

[3P146] Illusion and reality: the case of apparent duration

**David Rose**

School of Psychology, University of Surrey

What are 'illusions' and how ubiquitous are they? A common definition states that they are deviations of our percepts from veridical representation of physical reality. But to know if an illusion is occurring we have to have access to that reality independently of our percepts, which phenomenologists regard as impossible. Here, I show how realist science defends its belief in objective reality, and I give one example of a clear illusion: the 'stopped-clock' effect. In our experiments, the first flash of a series of four (each of physically equal duration 667 ms) appears longer than the second, whereas the second and third appear 'veridically' to have the same duration. By varying the physical duration of the first flash it can be made to appear the same duration as the second, which occurs when their 'real' durations are in the ratio 2:3 (Rose & Summers, *Perception* 24, 1177-1187, 1995). Several different controls were used to verify that the physical durations were as specified. The general relevance of such manipulations will be explained, illustrating how science can establish with high plausibility the objective reality of any stimulus, by searching for convergence between the results obtained with highly diverse methods.

### ***Wednesday August 31st Symposia presentations***

[31S101] The Continuity Field (CF): a mechanism for perceptual stability via serial dependence

**David Whitney, Wesley Chaney, Jason Fischer, Alina Liberman, Mauro Manassi, Ye Xia**

Psychology, UC Berkeley, USA

A critical function of vision is to stabilize perception, so objects look the same from moment to moment. This is a challenge because visual input is noisy and discontinuous. Though a classic question, the mechanism that links the perceived identity and properties of an object from moment to moment is unknown. We recently discovered the Continuity Field (CF), a mechanism of object constancy built on serial dependence; an object's present appearance is captured by what was perceived over the last several seconds. Serial dependence occurs in the perception of orientation, facial expression and identity, biological motion, object attractiveness, and perceived object position. This perceptual attraction extends over several seconds, and displays clear tuning to the difference (in orientation, facial expression, etc) between the sequential stimuli. It is spatially specific and selective to the attended object within a

scene, even if that object passes behind an occluder. Perceptual serial dependence cannot be explained by effects of priming, known hysteresis effects, or visual short-term memory. Our results reveal a novel mechanism—the Continuity Field—a spatiotemporally tuned operator that helps maintain stable object and scene representations in the face of a dynamic and noisy environment.

Funding: NIH

### [31S102] Humans exploit optimally serial dependencies

**Guido Marco Cicchini, David Burr**

Institute of Neuroscience, National Research Council; Department of Neuroscience, Psychology, Pharmacology and Child Health (NEUROFARBA), University of Florence, Florence, Italy

Natural scenes contain strong serial correlations as the world tends to be stable from moment to moment. Similar stimuli often require similar behavioral responses, so it is highly likely that the brain has developed strategies to leverage these regularities. On the other hand, we often need to be sensitive to change, for which opposite strategies (adaptation) are more appropriate. In this talk we will review some of our recent research on these issues, showing that: 1- Strong serial dependencies occur for many stimulus attributes, including numerosity, leading to an apparent logarithm encoding of number. 2- Serial dependencies occur both at the perceptual and response stages. The weight of current or past information depends on the reliability of both stimuli, as well as their similarity, well modeled by a Kalman filter that predicts the current state of the world, depending on the quality of information and the occurrence of novel events. 3- For attributes that change slowly over time (such as gender), serial correlations are positive and strong; but for changeable features, like expression, where the change is important, negative after-effects occur. Both processes operate at the same time, in the same stimuli.

Funding: ERC-FP7 ECSPLAIN (Grant No. 338866), Italian Ministry of Research FIRB (RBFR1332DJ)

### [31S103] Choice-induced aftereffects in visual perception

**Alan A Stocker**

Department of Psychology, University of Pennsylvania

Adaptation aftereffects are striking examples of how perception depends on stimulus history. Here, I present evidence that suggests that perception also depends on the observer's interpretation of the previous stimuli (i.e. a subjective stimulus history). More specifically, I present results of some recent psychophysical experiments in which subjects had to perform sequential discrimination tasks about the relative orientations of serially presented visual stimuli. The results indicate that subjects' decisions were biased by their previous judgements in the task sequence in a way that is orthogonal to the influence of the actual stimulus sequence. These findings cannot be explained by current models of perceptual adaptation. However, the data are well described with a probabilistic observer model that is constrained to remain self-consistent with regard to its interpretation of sensory evidence over time. I discuss the degree to which this novel observer model can account for other aspects of perceptual and cognitive behavior, and how it might help us to better understand the intricate computational principles underlying adaptive sensory processing in the brain.

Funding: NSF

### [31S104] Sequential integration in color identification

**Qasim Zaidi, Zhehao Huang**

Graduate Center for Vision Research, State University of New York

Sequential dependencies in visual perception have been attributed to observers integrating current input with past information, based on the prior assumption that constancy of object properties is generic in the physical world, so that integration can discount environmental transitions. We show that temporal color integration is an inherent aspect of estimating surface colors when illumination change is easily discernable, but controls are needed for adaptation and induction effects. When the illumination is obviously constant, but the surface color is changing in a similar fashion as above, integration is not needed. The results show a lack of integration and adaptation, but indicate that color memory is accurate for these tasks. A second control uses an illumination change condition that penalizes temporal integration and controls for induction effects, but observers still use temporal integration to estimate surface colors. We also compare color integration for directional shifts between natural lights (Sunlight-Skylight), between frequently encountered artificial lights (Tungsten-Fluorescent), and between unusual artificial lights (Kodak Red CC50R – Cyan

CC50C). There are differences between magnitudes of temporal integration depending on the nature of the illumination shift. These may be related to the familiarity of the final illuminant's color, suggesting complexities in the control of sequential integration.

Funding: EY007556 & EY013312

[31S105] Varieties of serial dependency in perceptual state variables

**Mark Wexler**

Laboratoire Psychologie de la Perception CNRS, Université Paris Descartes

We have recently shown that the perception of certain families of visual stimuli is governed by strong biases that vastly differ from one observer to the next. For example, with optic flow that can be perceived as a depth-slanted surface having one of two opposite tilts (because of depth reversals), perceptual decisions for different tilts are not independent: observers nearly always perceive tilts lying within 90 degrees of a preferred tilt direction--but the preferred tilt varies widely among observers (demos: [goo.gl/4cukhq](http://goo.gl/4cukhq) and [goo.gl/YaytLF](http://goo.gl/YaytLF)). These bias directions--which we call perceptual state variables--have population distributions that are non-uniform and that are different and independent for different stimulus families. The state variables vary not only between observers, but also over time. When measured in the same observer in long time series over minutes, hours, or months, the variables exhibit a variety of dynamical behaviors. In nearly all observers, the time series have autocorrelations, demonstrating a non-trivial form of perceptual memory. Part of their dynamics can be described by a simple random-walk model. Comparison of series sampled at different time scales suggests the existence of an additional internal variable, analogous to a temperature: more frequent presentations lead to higher volatility in the state variables.

[31S106] Change-related weighting of statistical information in visual sequential decision making

**József Fiser<sup>1</sup>, József Arató<sup>1</sup>, Abbas Khani<sup>2</sup>, Gregor Rainer<sup>2</sup>**

<sup>1</sup>Department of Cognitive Science, Central European University, Budapest; <sup>2</sup>Department of Physiology/Medicine University of Fribourg Fribourg Switzerland

There is a complex interaction between short- and long-term statistics of earlier percepts in modulating perceptual decisions, yet this interaction is not well understood. We conducted experiments, in which we independently manipulated the appearance probabilities (APs) of abstract shapes over short and long time ranges, and also tested the effect of dynamically changing these probabilities. We found that, instead of simply being primed by earlier APs, subject made decisions so that they reduced the discrepancy between recent and earlier APs. Paradoxically, this leads to favor the less frequent recent event if it was more frequent in the long past. Moreover, this compensatory mechanism did not take effect when the difference in APs between long past and recent times was introduced gradually rather than abruptly. This leads to a paradox false and lasting negative compensation with uniform APs after a momentary abrupt shift followed by a gradual return. We replicated our key human finding with behaving rats, demonstrating that these effects do not rely on explicit reasoning. Thus instead simply following the rule of gradually collected event statistics, perceptual decision making is influenced by a complex process in which statistics are weighted by significance due to detected changes in the environment.

### ***Wednesday August 31th Oral presentations***

[31T201] Differential attenuation of auditory and visual evoked potentials for sensations generated by hand and eye movements

**Nathan Mifsud, Tom Beesley, Thomas Whitford**

School of Psychology, UNSW Australia

Our ability to distinguish sensations caused by our own actions from those caused by the external world is reflected at a neurophysiological level by the reduction of event-related potentials (ERPs) to self-initiated stimuli. These ERP differences have been taken as evidence for a predictive model in which motor command copies suppress sensory representations of incoming stimuli, but they could also be attributed to learned associations. We tested the cross-modal generalizability of the predictive account by comparing auditory and visual responses in the same cohort, and tested the associative account with a novel task in which eye motor output produced auditory sensory input, an action-

sensation contingency which no participant could have previously experienced. We measured the electroencephalogram (EEG) of 33 participants as they produced auditory (pure tone) and visual (unstructured flash) stimuli with either button-presses or volitional saccades. We found that attenuation of self-initiated sensations, indexed by auditory and visual N1-components, significantly differed by sensory domain and motor area, and was strongest for natural associations between action and sensation (i.e., hand-auditory and eye-visual). Our results suggest that predictive and associative mechanisms interact to dampen self-initiated stimuli, serving to facilitate self-awareness and efficient sensory processing.

[31T202] Action video game play improves eye-hand coordination in visuomotor control

**Li Li, Rongrong Chen**

Department of Psychology, The University of Hong Kong

We recently found that action video game play improves visuomotor control in driving. Here we examined whether action video game play improves eye-hand coordination in visuomotor control. We tested 13 action gamers and 13 gender-matched non-gamers with a classic closed-loop visuomotor control task consisted of two conditions. In the eye-hand condition, the display (40°H×30°V) presented a cyan Gaussian target ( $\sigma=0.6^\circ$ ) that appeared to move randomly along the horizontal axis. Participants tracked the target motion with their eyes while using their dominant hand to move a high-precision mouse to vertically align a red Gaussian cursor (8° below) with the cyan target. In the eye-alone condition, the display replayed the target and cursor positions recorded in the eye-hand condition and participants were instructed to only track the target with their eyes. Action gamers and non-gamers did not differ in their eye-tracking performance in the eye-alone condition. However, in the eye-hand condition, action gamers showed better tracking precision, larger response amplitude, and shorter response lag for both eye and hand tracking than did non-gamers. Our findings provide the first empirical evidence suggesting that action video game play improves eye-hand coordination in visuomotor control such as driving.

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[31T203] Depth cues for allocentric coding of objects for reaching in virtual reality

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Previous research demonstrated that humans use allocentric information when reaching to visual targets; but most of the studies are limited to 2D space. In two virtual reality experiments, we investigated the use of allocentric information for reaching in depth and the role of different depth cues (vergence/retinal disparity, object size) for coding object locations in 3D space. We presented participants a scene with virtual objects on a table which were located at different distances from the observer and served as reach targets or allocentric cues. After visual exploration and a short delay the scene reappeared, but with one object missing (= reach target). In addition, the remaining objects were shifted horizontally or in depth. When objects were shifted in depth, we also independently manipulated object size by either magnifying or reducing their size. After the scene vanished, participants reached to the remembered target location on the blank table. Reaching endpoints deviated systematically in the direction of object shifts indicating the use of allocentric information. This was independent of observer-object-distance and dependent on object size suggesting that both vergence/retinal disparity and object size provide reliable depth cues when coding reach targets in an allocentric reference frame in reachable 3D space.

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[31T204] Different usage of visual information for cursor and target in a target-tracking task

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When tracking a moving target with a cursor, we need to know the target's current position and predict where it is going next. This means the visual system needs to collect target position and movement information over time. The same could be said for the cursor, despite having direct control over its movement. Thus, we hypothesized that visual target and cursor information would both be integrated over time. Two tasks were performed. In the target-judgement task, a target moved horizontally for variable durations. Participants judged whether the last target position was left or

right of a comparison stimulus shown after target disappearance. In the cursor-judgement task, the target was shown only briefly. Participants followed the target using the cursor and kept moving with the same speed after target disappearance. In this case, participants judged the last cursor position. Results show that for target-judgements, participants integrated position information over time, leading to a perceived lag of the target and increased perceptual precision over time. For cursor-judgements no lag or increase in perceptual precision was observed, suggesting that only the current cursor position was taken into account. We conclude that visual information is processed in fundamentally different ways for target and cursor.

Funding: This work was carried out at Bielefeld University and funded by the DFG Cluster of Excellence: Cognitive Interaction Technology ‘CITEC’ (EXC 277)

[31T205] Relative timing of visual and haptic information determines the size-weight illusion

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Although weight is perceived through the haptic modality, it can be influenced by visual information. This is demonstrated by the size-weight illusion: the effect that small objects feel heavier than larger ones of the same mass. It has been suggested that this illusion is caused by a mismatch between the expected and actual masses of objects. If so, we predict that size information needs to be available before lifting in the size-weight illusion. We investigated this in an experiment in which size could only be perceived through vision. In each trial, we made vision available for a 200 ms interval starting at various times from lift onset ranging from 200 ms prior to lift onset until when the maximum lifting height was reached. As predicted the size-weight illusion was strongly reduced when visual information became available later, but this decrease only occurred when vision was available about 300 ms after lift-off. This shows that the relative timing of visual size and haptic weight information is crucial, but that size information does not need to be available prior to the onset of the lifting action.

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[31T206] A shared numerical representation for action and perception

**Irene Togoli, Giovanni Anobile, Roberto Arrighi, David Burr**

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Much evidence has accumulated to suggest that in many animals, including young human infants, there exists a neural mechanism dedicated to estimating approximate quantity: a sense of number. Most research has concentrated on spatial arrays of objects, but there is also good evidence that temporal sequences of number are encoded by similar mechanisms (Arrighi et al, Proc. Roy. Soc., 2014). Processing of numerical information is also fundamental for the motor system to program sequences of self-movement. Here we use an adaptation technique to show a clear interaction between the number of self-produced actions and the perceived numerosity of subsequent visual stimuli, both spatial arrays and temporal sequences. A short period of rapid finger-tapping (without sensory feedback) caused subjects to under-estimate the number of visual stimuli presented around the tapping region; and a period of slow tapping caused over-estimation. The distortions occurred both for stimuli presented sequentially, and for simultaneous clouds of dots. Our results sit well with neurophysiological studies showing links between number perception and action. We extend these findings by demonstrating that vision and action share mechanisms that encode numbers, and that the ‘number sense’ serves to estimate both self-generated and external events.

[31T207] Revealing nudging effects of floor patterns on walking trajectories in the real world

**Ute Leonards, Hazel Doughty, Dima Damen**

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Recently, we have shown that floor patterns such as tiling orientation can influence our sense for walking “straight-ahead” in laboratory settings (Leonards et al., 2015). Here, we investigated whether similar pattern-induced lateral veering can occur in the real world. Developing an automatic tracking algorithm that allows extraction of walking trajectories from CCTV footage, rescaling it to the given environment, we recorded the walking trajectories of usual passers-by walking down a main corridor in a large university building. Seven different floor patterns were presented twice in random order, for 2-3 working days at a time, covering a section of 14.2x2.8m. Patterns consisted of stripes of different orientations (horizontal, diagonal left or diagonal right), and spatial frequencies (frequent, infrequent). The

corridor without stripes acted as control. Both direction and extent of lateral veering directly depended on the orientation and spatial frequency of the patterns. Oblique as compared to horizontal patterns/no-pattern control, induced veering of up to 1m over the analysed travel distance of 12 meters. The study will be discussed both with regard to the possible impact of patterns in man-made environments on everyday walking, and new technologies allowing us to transfer lab-based experimental settings into the real world.

[31T208] How your actions are coupled with mine: Adaptation aftereffects indicate shared representation of complementary actions

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Previous research has shown that humans share numerous cognitive processes when they interact, such as representations of tasks, goals, intentions, and space. However, little is known about the perceptual representation of complementary actions, in particular actions in an interaction that are often observed together. We examined behavioral correlates of potentially shared neural representations for human actions that are visually dissimilar, but contingent from accumulated previous observations in spatiotemporal proximity. Namely, we measured visual adaptation aftereffects in 25 participants for perceiving the actions Throwing and Giving after prolonged exposure to the actions Catching and Taking, and vice versa, in a completely crossed design. We found significant adaptation aftereffects for all tested actions ( $p < 0.001$ ) as well as for the complementary actions. For the complementary actions, the overall adaptation aftereffect for the disambiguation of Catching from Taking was significant after prolonged exposure (adaptation) to Throwing and Giving ( $p < 0.001$ ), as well as for the disambiguation of Throwing from Giving when Catching and Taking were used as adaptors ( $p = 0.002$ ). These results support the hypothesis that processes involved in the recognition of complementary actions might employ a shared neural representation.

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[32T101] Serial dependence of multisensory relative timing judgements is not sensory adaptation.

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Recent sensory experience affects subsequent experience. For example, following repeated exposure to audio events leading visual by  $\sim 200$  ms, smaller audio-leading-visual offsets are more likely to be reported as synchronous - consistent with classic negative sensory aftereffects. Recent studies have reported that a single such exposure can alter audiovisual synchrony judgements (SJ), producing aftereffects similar to extended exposure. These results are interpreted as evidence for rapid adaptation of audiovisual timing. If this were true, similar negative aftereffects for relative timing should be detectable in tasks other than SJ. We examined the influence of a single audiovisual relative timing presentation on subsequent judgements – serial dependence of relative timing – for SJ, temporal order judgements (TOJ), and magnitude estimation (ME). We found serial dependence for SJ consistent with previous results, producing apparently negative aftereffects for subjective synchrony, but the opposite direction of dependency for apparent timing estimates derived from TOJ and ME. To reconcile these conflicting results, we propose that serial dependence for SJ is dependence of synchrony decision criteria, not relative timing. This interpretation is consistent with Bayesian descriptions of the influence of recent experience on decisions and inconsistent with serial dependence for relative timing being equivalent to sensory adaptation.

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[32T102] What smell? Loading visual attention can induce inattentive anosmia

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The human sense of smell can provide important information, alerting us to potential dangers (e.g. the smell of smoke) or rewards (e.g. food) in our environment. Nevertheless, people often fail to attend to olfactory stimuli. Within the visual attention literature it is well established that high perceptual task load reduces processing of task-irrelevant stimuli, leading to phenomena such as “inattentive blindness”, whereby a clearly visible stimulus is apparently not

perceived when attention is engaged in a visually demanding task. The present study sought to establish whether the extent to which visual attention is loaded is also an important determinant of the ability to notice odors. Participants were exposed to an olfactory stimulus (coffee beans) while performing a computerized visual search task with either a high or low level of perceptual load. Across two experiments, the olfactory stimulus was subsequently reported by the majority of participants in the low load condition, but only approximately 25% of those in the high load condition. This study establishes the phenomenon of inattentional anosmia, an olfactory analogue of inattentional blindness. The findings demonstrate that the effects of loading visual attention extend to the olfactory sense, and have important applied implications.

[32T103] Rapid recalibration to audiovisual asynchronies occurs unconsciously

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In natural scenes, audiovisual events deriving from the same source are synchronized at origin. However, from the perspective of the observer, there are likely to be significant multisensory delays due to physical and neurological differences. Fortunately, our brain appears to compensate for the resulting latency differences by rapidly adapting to the asynchronous audiovisual events. Here, we examine whether rapid recalibration to asynchronous signals occurs unconsciously. On every trial, a brief tone pip and flash were presented across a range of stimulus onset asynchronies (SOAs). Participants were required to perform two tasks in alternating order. On adapter trials, participants judged the order of the audiovisual events. Here, audition either lead or lagged vision with a fixed SOA (150 ms). On test trials the SOA as well as the modality order varied randomly, and participants judged whether the events were synchronized or not. For test trials, we show that the point of subjective simultaneity (PSS) follows the physical rather than the perceived (reported) modality order of the preceding trial. These results suggest that rapid temporal recalibration occurs unconsciously.

[32T104] Integration of visual and tactile information during interval timing: Implications for internal clocks

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With two sources of independent information, people often do better. For example, dual depth cues (within vision) and size cues (between vision and touch) can enhance the precision of perceptual judgements. Because this enhancement most likely rests on the independence of noise affecting contributing estimates, it can speak to the underlying neurocognitive architecture. Humans may possess a single (amodal) internal clock, or multiple clocks tied to different sensory modalities. Statistical enhancement for duration would suggest the existence of multiple clocks, but evidence from visual and auditory modalities is mixed. Here, we assessed the integration of visual and tactile intervals. In a first experiment, 12 musicians and 12 non-musicians judged durations of 300 and 600 ms compared to test values that spanned these standards. Bimodal precision increased relative to unimodal conditions, but not as much as optimal integration models predict. In a second experiment, a smaller sample judged six standards ranging from 100 to 600 ms in duration. While musicians showed evidence of near optimal integration at longer durations, non-musicians did not, and there was no evidence of integration at the shortest intervals for either group. These data provide partial support for the existence of separate visual and tactile clocks.

[32T105] Effect of blue light on audiovisual integration

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A subset of retinal ganglion cells expresses melanopsin, a photo-pigment with absorption spectrum peaking at 480 nm (i.e., blue light). These cells can directly respond to light even without classic photoreceptor rods and cones, and are named intrinsically photosensitive retinal ganglion cells (ipRGCs). Past animal research revealed that Superior Colliculus (SC), a locus where multisensory signals are preliminarily integrated, receives inputs from ipRGCs as well. We therefore aimed to evaluate the potential influence of blue-light-elicited ipRGC signals as compared to other color lights on human multisensory perception. We examined blue light's effect using the audiovisual simultaneity judgements task that a flash and beep were presented at various SOAs, and participants were asked to judge whether the visual and auditory stimuli were presented simultaneously under blue- or red-light background. Results showed that

participants' audiovisual simultaneity perception was more precise, especially in the visual-leading conditions, in the blue-light than in the red-light background. Our results suggest that ipRGCs may project to SC (or other cortical areas involving audiovisual integration) in humans as well. This is the first attempt to directly explore the impacts of blue light on multisensory perception, which sheds light on how modern technology impacts human perception.

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[32T106] Spatiotemporal dynamics of visual and auditory attention revealed by combined representational similarity analysis of EEG and fMRI

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The cortical attention networks have been extensively studied with functional magnetic resonance imaging (fMRI), but the temporal dynamics of these networks are not well understood. In order to bypass the low temporal resolution of fMRI, we used multivariate pattern analysis to combine fMRI data and event-related potentials (ERPs) from electroencephalogram (EEG) of identical experiments in which participants performed grating orientation and/or tone pitch discrimination tasks in multiple conditions. We varied target modality (visual or auditory), attention mode (selective or divided attention, or control), and distractor type (intra-modal, cross-modal or no distractor). Using representational similarity analysis (RSA), we parsed time-averaged fMRI pattern activity into distinct spatial maps that each corresponded, in representational structure, a short temporal segment of ERPs. Multidimensional scaling of temporal profiles of cortical regions suggested eight clusters. Discriminant analysis based on the eight clusters revealed four attention components that were spatially distributed and had multiple temporal phases. The spatiotemporal attention components were related to stimulus and distractor triggered activation, top-down attentional control, motor responses and shifting between brain states. The results suggest that time-averaged fMRI activation patterns may contain recoverable information from multiple time points, and demonstrate complex spatiotemporal dynamics of visual-auditory attentional control in cortical networks.

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[32T201] Neural model for adaptation effects in shape-selective neurons in area IT

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Neurons in higher-level visual cortex show adaptation effects, which likely influence repetition suppression in fMRI studies, and the formation of high-level after-effects. A variety of theoretical explanations has been discussed that are difficult to distinguish without detailed electrophysiological data. Recent electrophysiological experiments on adaptation of shape-selective neurons in inferotemporal cortex (area IT) provide constraints that narrow down possible computational mechanisms. We propose a biophysically plausible neurodynamical model that reproduces these results. METHODS: Our model consists of a neural field of shape-selective neurons that is augmented by the following adaptive: (i) spike-rate adaptation; (ii) input fatigue adaptation, modeling adaptation in earlier hierarchy levels or afferent synapses; (iii) firing-rate fatigue, depending on the output firing rates of the neurons. RESULTS: The model reproduces the following experimental results: (i) Shape of typical PSTHs of IT neurons; (ii) temporal decay of adaptation with number of stimulus repetitions; (iii) dependence of adaptation on efficient and ineffective adaptor stimuli, which stimulate the neuron strongly or only moderately; (iv) dependence of the strength of the adaptation effect on the duration of the adaptor. Conclusions: A mean field model including several adaptive processes provides a unifying account for the observed experimental effects.

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[32T202] How the Brain Represents Statistical Properties

**Shaul Hochstein**

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Intensive research uncovered diverse dimensions of summary statistic perception, including simple and complex

dimensions (circle size and Gabor orientation to face emotion and attractiveness), the type of statistics acquired (mean, variance, range), and our ability to summarize elements presented simultaneously or sequentially and divide displays into groups, detecting statistics of each. How does the brain compute scene summary statistics without first attaining knowledge of each scene element? One possible solution is that the brain uses implicit individual element information to compute summary statistics, which become consciously accessible first. I show that this added step is superfluous. Direct acquisition of summary statistics is unsurprising; novel computational principles aren't required. A simple population code, as found for single elements, may be scaled up for group mean values. With a broader range of neurons, the computation is identical for sets as for one element. Population codes add power, determining elements to be included or excluded as outliers triggering pop-out attention, and naturally dividing between sets. As suggested by Reverse Hierarchy Theory, conscious perception may begin with summary statistics and only later focus attention to individual elements. A similar population code representation may underlie categorization, including both category prototype and its boundaries

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[32T203] Inhibitory function and its contribution to cortical hyperexcitability and visual discomfort as assessed by a computation model of cortical function

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Irrespective of what they represent, some visual stimuli are consistently reported as uncomfortable to look at. Recent evidence from brain imaging suggests that uncomfortable stimuli are responsible for abnormal, excessive cortical activity, especially in clinical populations. A long-standing hypothesis is that reduced inhibition, potentially caused by a lowered availability of gamma-aminobutyric acid (GABA) neurotransmitter, may drive susceptibility to visual discomfort. We have shown in previous work that the sparsity of the network response of a computational model of the visual cortex based on Gabor-like receptive fields and both excitatory and inhibitory lateral connections is a good predictor of observers' judgments of discomfort [Penacchio, et al, (2015) *Perception*, 44, 67-68]. To test the former hypothesis we assessed computationally how the distribution of firing rates evolves when the strength of inhibition is modified. We found that, as inhibitory strength is progressively reduced, the sparsity of the population response decreases. A winner-take-all process emerges whereby the spatial distribution of excitation in the network becomes similar to the response to typically aversive stimuli such as stripes. These findings back up recent suggestions that abnormal inhibitory activity is involved in the generation of visual discomfort, an abnormality that may be extreme in clinical populations.

[32T204] Contextual interactions in grating plaid configurations are explained by natural image statistics and neural modeling

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The processing and analysis of natural scenes requires the visual system to integrate localized, distributed image features into global, coherent percepts. A central hypothesis states that our brain hereby uses statistical dependencies in visual scenes: when represented in neural interactions between elementary feature detectors, they will enhance the processing of certain feature conjunctions, while suppressing others. By combining psychophysical experiments with computational modeling and image analysis, we investigated which interaction structures underlie feature integration in visual cortex, and how perception and neural interactions relate to natural scene statistics. As stimuli we used grating patch configurations (plaids) comprising four patches with varying orientations, spatial frequencies, and inter-patch distances. Human detection thresholds for plaids were strongly modulated by inter-patch distance, number of orientation- and frequency-aligned patches and spatial frequency content (low, high, mixed). For large inter-patch distances, detection thresholds for the plaids were inversely related to their likelihood of occurrence in natural images. Using a structurally simplistic cortical model comprising orientation columns connected by horizontal axons, we were able to reproduce detection thresholds for all configurations quantitatively. In addition to medium-range inhibition and long-range, orientation-specific excitation, model and experiment predict a novel form of strong orientation-specific, inhibitory interactions between different spatial frequencies.

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### [32T205] Reinforcement learning: the effect of environment

**He Xu, Michael Herzog**

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Reinforcement learning is a type of supervised learning, where reward is sparse and delayed. For example in chess, a series of moves is made until a sparse reward (win, loss) is issued, which makes it impossible to evaluate the value of a single move. Still, there are powerful algorithms, which can learn from delayed and sparse feedback. In order to investigate how visual reinforcement learning is determined by the structure of the RL-problem, we designed a new paradigm, in which we presented an image and asked human observers to choose an action (pushing one out of a number of buttons). The chosen action leads to the next image until observers achieve a goal image. Different learning situations are determined by the image-action matrix, which creates a so-called environment. We first tested whether humans can utilize information learned from a simple environment to solve more complex ones. Results showed no evidence supporting this hypothesis. We then tested our paradigm on several environments with different graph theoretical features, such as regular vs. irregular environments. We found that humans performed better in environments which contain less image-action pairs to the goal. We tested various RL-algorithms and found them to perform inferior to humans.

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### [32T206] Combining sensory and top-down effects in a cortical model of lightness computation

**Michael E Rudd**

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Recently, there has been an interest in differentiating high-level, interpretative effects on lightness judgments from sensory effects (Blakeslee & McCourt, 2015). For some time, I have been modeling data from simple lightness matching paradigms to discover what perceptual factors are required to fully account for them. That task has proved surprisingly complex. A successful model requires the correct quantitative amalgam of sensory, midlevel, and top-down factors. One important factor is likely sensory: incremental luminance steps are weighted only 1/3 as much as decremental steps by the visual system (Rudd, 2013). Another is midlevel: cortical mechanisms integrate luminance steps in object-centered coordinates. Two other factors are high-level. One is the observer's propensity to classify ambiguous edges as resulting from either reflectance change or an illumination change (Rudd, 2010, 2014). The other is the size of an adjustable attentional window over which the observer evaluates the effects of spatial context. Here, I explain how these factors combine to account for lightness in these simple paradigms. My findings are consistent with other recent results demonstrating strategic effects in lightness (Economou, ECVF 2011) and color (Radonjić & Brainard, 2016) judgments and against strictly data-driven computational approaches (e.g. ODOG, Retinex, Anchoring Theory).

### [33T101] Evidence for automatic generative learning in humans

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It is commonly assumed that humans learn generative or discriminative representations of the sensory input depending on task context (e.g. Hsu & Griffiths, 2010). Following our earlier findings (Orban et al. 2008), we propose that humans always form generative models based on the statistics of the input. To test this proposal, we investigated whether a learned internal model of the visual input would automatically incorporate task-irrelevant dimensions, and whether a generative model is formed even when the task requires only a simpler, discriminative representation. Participants (N = 30) were presented with circle ensembles of varying mean size and standard deviation (SD). Their task was to estimate one of these parameters throughout the experiment, making the other dimension task-irrelevant. Unbeknown to the participants, the input formed two implicit categories across trials, one with small means and large SDs, and the second with large means and small SDs. Participants showed the same significant regression to the mean bias in either dimension both during the estimation task and after a categorization along the task-irrelevant dimension. Thus, even in a restricted or discriminative context, humans implicitly form a generative model of the distribution of the data, which model automatically influences their subsequent decisions.

### [33T102] Transcranial Random Noise Stimulation (tRNS) boosts Perceptual Learning in reducing critical

space of crowding

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Crowding, the difficulty in discriminating a target when surrounded by similar items, negatively affects letter discrimination and reading in the peripheral vision. While not disadvantageous in the healthy population, crowding represents a major difficulty for patients suffering from central vision loss (Age-related Macular Degeneration, AMD). Perceptual Learning (PL) has been used to reduce critical space of crowding; however, PL requires a large amount of sessions to be effective and this represents a practical difficulty for clinical patients that are not autonomous. Recently, combined use of transcranial random noise stimulation (tRNS) and PL has been proven to boost learning in foveal vision in both healthy and clinical populations. In this study, we investigated whether tRNS can effectively boost PL on a peripheral crowding task (8° eccentricity) over a short number of training sessions (4). Additionally, we tested whether learning transferred to untrained spatial location and orientation. Results showed greater learning rate within and between sessions for the PL+tRNS group respect to the sham (PL alone). Moreover, PL+tRNS group showed higher amount of transfer to untrained conditions. In conclusion, combining PL and tRNS improves peripheral visual abilities over a small number of sessions, opening new possibilities in clinical application for AMD subjects.

Funding: Erasmus+ Grant

[33T103] Perceptual learning with minimal roles of early cortical plasticity and neuron-specific response reweighting

**Cong Yu, Xin-Yu Xie**

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Two theories explain visual perceptual learning (VPL): Early cortical plasticity and neuron-specific response reweighting, as motivated by observed learning specificities. However, with double training VPL often shows complete transfer to untrained conditions, indicating that VPL is primarily a rule-based cognitive process. Here we demonstrate that VPL is equally effective with the minimal roles of early cortical plasticity and neuron-specific response reweighting. In a peripheral orientation-discrimination learning task, training took places in 12 rotating locations and 4 rotating orientations 90-deg apart. Each condition received 12 trials per session for 5 sessions. A staircase controlled the orientation difference from condition to condition. The pre/post condition was never practiced. The results showed significant orientation learning, which transferred to the untrained pre/post condition, so that learning was comparable to that in a control group that practiced the pre/post condition for equal number of trials. Similar results were seen in a motion-direction learning task with 6 rotating locations and 8 rotating directions 45-deg apart, but without direction/location specificities in the control group. Supporting our rule-based VPL theory, these results indicate that early cortical plasticity and neuron-specific input reweighting are unnecessary. Instead sensory inputs can be reweighted at a later stage in a neuron unspecific manner.

[33T104] A novel method for studying internal representations of statistical distributions in feature space

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The visual world does not consist of isolated objects or features but rather of visual ensembles united by common properties. Studies on “summary statistics” demonstrate that humans utilize such common properties to guide behavior. However, studying internal representations of ensembles is difficult because different underlying representations can result in similar summary statistics. We present a new approach based on priming of pop-out that allows estimating these internal representation. Observers searched for an odd line among 36 lines differing in orientation. Trials were organized in streaks with distractors drawn randomly from the same distribution on each trial. Each streak was followed by one or more test trials with different target and distractors. We analyzed RT on test trials as function of the distance between target and the mean of preceding distractors distribution. Response times followed the shape of preceding distractor distributions Gaussian distributions yielded monotonically decreasing functions; uniform distributions - two-segment functions; bimodal distributions - two-peak functions; and skewed distributions yielded correspondingly skewed RT functions. We show for the first time that observers can encode relatively complex

statistical distributions of features. Our new approach is a powerful tool for understanding internal representations of stimulus ensembles.

Funding: Supported by Russian Foundation for Humanities (#15-36-01358A2) and Icelandic Research Fund (IRF #152427)

[33T105] Face Training in Developmental Prosopagnosia

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Several attempts have been made to improve face recognition in developmental prosopagnosia. These efforts have often resulted in training effects that are either not long lasting, or do not generalize to novel viewpoints, expressions, or identities. We used a perceptual learning approach to train face recognition in a group of 7 participants with developmental prosopagnosia. Four completed the 11-week training program first, followed by an 11-week non-training period and three completed the reverse order. During the training program, participants selected which of two test faces appeared most similar to a target face. A staircase procedure was used to ensure that each participant was training at an individually appropriate level. With each week of training, variation across viewpoint and expression were gradually introduced. Performance on post-tests improved significantly more during the training period than non-training period for both trained faces ( $p < 0.001$ ) and untrained faces ( $p < 0.05$ ), suggesting that the program produced effects that generalized across novel viewpoints, expressions, and identities. At the individual level, some participants reported improvements in their everyday experiences as well. In sum, perceptually learning may be an effective approach for improving face recognition in developmental prosopagnosia.

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[33T201] Combined fMRI and eye-tracking based decoding of a bistable plaid motion perception

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The phenomenon of bistable perception has been particularly useful in probing the neural bases of conscious perception. Study of bistability requires access to the observer's perceptual dynamics which is usually achieved via active report. Validity of active-report paradigms, however, is questioned due to issues such as response bias or confounding of report and perception. To enhance usability of paradigms independent of active report, we optimized decoding procedure employing a combination of two biological measures of perception, namely brain activity patterns and eye movements. Twenty participants continuously observed a bistable visual plaid motion stimulus in 11 runs. Multivariate pattern analysis (MVPA) using support-vector machine was adapted to decode participants' perceptual time courses from functional magnetic resonance imaging (fMRI) data and from eye-movement patterns reflecting optokinetic nystagmus. Results revealed that both measures can individually offer high decoding accuracies ( $M=81$ ,  $SD=7\%$  and  $M=79$ ,  $SD=11\%$  for fMRI and eye-tracking, respectively). Additionally, classification based on the two measures together further improved the accuracy significantly ( $p < 0.001$ ,  $M=85$ ,  $SD=7\%$ ). These findings show that combined MVPA of fMRI and eye movement data can be used to decode bistable plaid motion perception with high accuracy, thus offering a useful tool for the study of conscious perception in no-report paradigms.

Funding: This work was supported by the German Research Foundation (DFG, grant numbers STE 1430/2-1 and STE 1430/7-1).

[33T202] Sequential dependencies in suppression durations in continuous flash suppression

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In perceptual bi-stability the content of visual awareness continuously alternates over time even with constant retinal input. Despite the seemingly random nature of the alternation process, research on perceptual bi-stability has demonstrated that consecutive dominance durations are serially dependent. This implies that the underlying alternation mechanism includes a memory component. Here we asked whether serial dependence is also observed in continuous flash suppression (CFS), a variant of binocular rivalry in which a dynamic, flashing mask is presented to one eye while a static stimulus is presented to the other. We analyzed a large data set ( $n = 393$  observers) of time series of

suppression durations obtained in a set of so-called ‘breaking CFS’ experiments. Across experimental manipulations, stimuli, and observers, we found that suppression durations showed sequential dependence. Moreover, this dependence was predominantly monocular. Thus, the underlying competition mechanism of CFS also includes a memory component that is primarily monocular. We suggest that the temporal dependency structure of suppression durations in CFS is akin to that observed in binocular rivalry, which might imply that both phenomena tap into similar rather than distinct mechanisms.

[33T203] Using binocular rivalry to tag competing tone sequences: towards a no-report paradigm for auditory multistability.

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Studies of perceptual multistability typically rely on subjective report. For visual rivalry, however, several “no-report” paradigms have been suggested recently, which use reflexive behaviours to measure the observer’s current perceptual state. For auditory multistability, no such paradigms are available yet. We used binocular-rivalry stimuli to tag individual streams of an auditory multistable stimulus. Specifically, we presented two tone sequences concurrently. Sequences differed by their frequency (low, high) and the interval between the tones (forming an ABA\_ pattern). To each eye, a horizontally-drifting grating was presented; to induce binocular rivalry, gratings were distinct in colour and motion direction. To associate each grating with one tone sequence, a pattern on the grating jumped vertically in temporal synchrony with the respective tones. Participants continuously reported which sequence they perceived in the foreground (high pitch, low pitch, both, none). We find that the direction of the slow phase of the optokinetic nystagmus – induced by the visually dominant grating – discriminates whether participants perceive the high or low tone. In our naïve observers, this discriminability emerged after about 20 minutes of task performance. These results demonstrate interactions between multistable stimuli in separate modalities, and they pave the way towards no-report paradigms for auditory multistability.

[33T204] Triggered reversals of perceptual dominance can occur without a corresponding change in visual awareness

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When viewing displays that are compatible with several comparably plausible interpretations our perception oscillates between these alternatives. As multi-stable perception is widely used to study visual awareness, we asked whether changes in perceptual dominance can occur without being reflected in visual awareness. To this end, we triggered perceptual reversals in an ambiguously rotating sphere and systematically varied the post-trigger presentation duration (0-320 ms), while collecting observers’ reports about the initial and final directions of illusory rotation. In a separate condition, we used an additional probe sphere, which followed the target after a 50 ms blank interval, to determine which post-trigger presentation duration is sufficient to reliably initiate a perceptual reversal. We found that although very brief post-trigger intervals (10-20 ms) are sufficient to initiate perceptual reversals, observers become aware of them only if post-trigger presentation continued for at least 80 ms. The lack of awareness following brief post-trigger intervals (10-20 ms) was confirmed also by response time measure and reports on unclear perception. Our results show that exogenously triggered perceptual reversal can occur in the absence of visual awareness and extend earlier work on spontaneous reversals that indicated that neither awareness, nor attention may be required for multi-stable perception.

[33T205] Regulating the dynamics of visual perception through entraining brain rhythms

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What determines the dynamics of perception? To what extent could it be regulated by the temporal characteristics of sensory information? To pursue these questions, we employed perceptual alternations, a phenomenon widely applied for characterizing the inherent fluctuation of conscious perception, where competing percepts of an ambiguous stimulus gain access to awareness alternately. Imposing rhythmicity on ambiguous visual stimuli, we demonstrated a robust regulatory effect on the dynamics of perception: The perceptual alternation rate increased with the frequency of

stimulus rhythms, especially when rhythmic signals arose from regular rather than random changes of visual cues. Critically, such perceptual regulatory effect was significantly mediated by the cortical entrainment process – the synchronization between neural oscillations and external rhythms. These findings suggest that brain rhythms play an essential role in sustaining the dynamics of visual perception, and they can trace and exploit temporal regularities in visual information to regulate our perception. Exposure to visual rhythms, similar to listening to speech and music, can attune our brain to sensory information flow, thereby helping our senses adapt to the ebb and flow of the dynamic environment.

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### ***Thursday September 1st Poster presentations***

[4P001] Age-related changes in saccadic adaptation

**Jing Huang, Jutta Billino, Sabine Margolf-Hackl, Karl Gegenfurtner**

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Saccadic eye movements provide an opportunity to study closely interwoven perceptual, motor, and cognitive changes during ageing. We aimed to study how age affects the ability of the oculomotor system to compensate for systematic foveal endpoint errors. We investigated adaptation in a double step paradigm. Subjects had to make saccades to a target at 10 deg eccentricity which was displaced to 7.5 deg after saccade onset. Adaptation was embedded in a baseline and a post-adaptation epoch without manipulation of target position. We compared performance in young (N=12, mean age=28.0 years) and senior (N=11, mean age=66.5) subjects. We determined rate of adaptation by fitting an exponential function to the saccadic gain data. All observers showed saccadic adaptation. At the end of the adaptation period, the average saccade gain was reduced to 0.86 relative to 1.00 during the baseline period. The overall amount of adaptation differed between the two age groups, being stronger for the young group (16% versus 10%,  $t(21)=2.9$ ,  $p<.01$ ). Age groups did not differ in the rate of adaptation, 65 vs. 85 trials to reach 67% decay ( $t(21)=-1.2$ ,  $p>.25$ ). Differences seem to emerge from fast adaptation phase processes at the beginning of the adaptation, possibly due to strategic effects.

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[4P002] Gender differences in visual perception

**Albulena Shagiri<sup>1</sup>, Andreas Brand<sup>2</sup>, Maya Roinishvili<sup>3</sup>, Marina Kunchulia<sup>3</sup>, Guillaume Sierro<sup>4</sup>, Julie Willemin<sup>4</sup>, Eka Chkonia<sup>5</sup>, Luisa Iannantuoni<sup>4</sup>, Karin Pilz<sup>6</sup>, Christine Mohr<sup>4</sup>, Michael Herzog<sup>1</sup>**

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Gender differences are well established in cognition and somato-sensation, but there are almost no studies on gender differences in visual perception. One reason is that sample size is often small because effect sizes are large. Small samples are not well suited to test for gender differences. Here, we tested 887 participants from 14 to 90 years old. We tested participants in visual and vernier acuity, visual backward masking and the Wisconsin Card Sorting Test (WCST). We found no gender differences in any of the four tests for younger participants ( $n=358$ ; 14-30 years old). Even in a subgroup of schizophrenia patients ( $n=260$ ), we did not find gender differences, but large performance deficits in patients compared to controls. For middle-aged participants ( $n=170$ ; 31-59 years old), men performed significantly better than women in all perceptual tests, even when we controlled for age. We also found better performance of men compared to women in vernier duration in older participants ( $n=99$ ; 60-90 years old) and trends in the same direction for the other tests. Hence, it may be that women's performance deteriorates with age more strongly than men's performance. We did not find any difference in WCST, indicating no gender differences for executive functions.

Funding: National Centre of Competence in Research (NCCR) SYNAPSY

[4P003] Biological Motion and Attention in Healthy Ageing.

**Hannah C Agnew, Karin S Pilz**

Previous studies have shown a direct link between attentional abilities and performance on biological motion tasks, both of which deteriorate with age. Here, we investigated whether age-related decline in biological motion perception is mediated by impaired attentional abilities. In a first task, we assessed baseline biological motion performance, and asked 27 younger (M = 23 years) and 22 older adults (M = 68 years) to indicate the facing direction of point-light actions. Overall, older adults performed worse than younger adults. In a second task, we assessed selective visual attention using a conjunctive visual search task. Finally, in a third task, we combined both and assessed attentional demands related to biological motion perception. Younger and older adults were asked to indicate the presence of the target point-light walker among a varied number of distracters. Overall, reaction times were slower for older adults. Interestingly, younger adults displayed steeper search slopes than older adults on the conjunctive visual search, which indicates a less efficient search. However, search efficiency did not differ between age groups on the biological motion search task. Correlations between the search two tasks were only found for younger adults suggesting that older adults use different search strategies on each task.

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[4P004] Manipulation and function knowledge in a lifespan perspective: evidence from a semantic priming study

**Cynthia Collette, Isabelle Bonnotte, Charlotte Jacquemont, Solène Kalénine, Angela Bartolo**

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Recent studies suggest a distinction between object manipulation (i.e. how an object is used) and function knowledge (i.e. what an object is for). The aim of the present study is to determine the lifespan development of the two types of knowledge. Three groups of children (8, 9 and 10 years old) and a group of young (19-28 years old) and old (62-80 years old) adults participated in a semantic priming paradigm. They had to name target objects that were preceded by objects related in terms of function or manipulation, or by non-related objects. In the manipulation condition, results showed facilitative priming effects in children that decreased with age. Facilitation transformed into interference at 10 years of age, which persisted in young adults. In the function condition, facilitative priming effects were solely registered in young adults. In old adults, no priming effects were observed in both function and manipulation conditions. In summary, object conceptual processing was more embodied in children than in adults, in line with embodied cognition theories. Reversely, function knowledge was only processed in young adults, in line with a more amodal approach. The processing speed of the primed objects might explain the lack of effects in old adults.

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[4P005] Age-related differences in preferential attention to, but not interference from, affective images

**Janice E Murray, Mark Madill**

Psychology, University of Otago

Studies of age-related differences in attention have shown that older adults are more likely to preferentially attend to positive than negative affect faces (Mather & Carstensen, 2005). Additionally, in contrast to young adults, older adults experience greater interference from happy than angry background faces (Ebner & Johnston, 2010), suggesting that older adults are also less able to ignore or disengage from positive stimuli. To test whether this valence-dependent interference effect in older adults generalizes to non-face affective stimuli, a flanker task using positive, negative and neutral images from the International Affective Picture System was used. In two directed attention experiments, young (19-29 years) and older (63-95 years) adults made speeded valence responses to a positive or negative target image that was flanked by identical distractor images. Distractor valence was either congruent or incongruent with target valence, or was neutral. Consistent with a general attentional bias towards positive stimuli, older but not young adults responded faster to positive than to negative target images. Both age groups, however, showed no difference in the observed facilitation and interference effects as a function of distractor valence. The results suggest that age-group differences in interference from affective information may depend on stimulus class.

[4P006] Quantifying the Effect of Healthy Ageing on Features of Face Perception

**Andrew J Logan<sup>1</sup>, Gael E Gordon<sup>2</sup>, Gunter Loffler<sup>2</sup>**

<sup>1</sup>School of Optometry and Vision Science, University of Bradford; <sup>2</sup>Glasgow Caledonian University

The ability to recognise differences between faces is important for social functioning. We aimed to quantify the effect of healthy ageing on different processes underlying face discrimination. Synthetic face discrimination thresholds were measured using a memory-free “odd-one-out” task for 15 younger (19.7±0.83 years) and 15 older (73.1±7.91 years) adults. Thresholds were measured for full-faces, external features (head-shape, hairline), internal features (eyes, nose, mouth, eyebrows) and shapes. Full-face discrimination thresholds were significantly higher (1.24X; < 0.05) for older, relative to younger, adults. A similar age deficit was found for external and internal features (1.41X and 1.30X respectively). Comparable thresholds for external features and full-faces suggest that both younger and older adults rely on the external features when discriminating unfamiliar faces. While older adults performed poorer in every aspect of face perception, there was no effect of age for shape discrimination in an otherwise identical test protocol. Healthy ageing causes a similar reduction in sensitivity to full-faces and component features. This deficit cannot be explained by a general decline of visual or cognitive functioning. Older observers engage the same strategy as younger observers, albeit less efficiently, in extracting salient features from faces. Face discrimination may be particularly vulnerable to the effects of ageing.

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[4P007] Alpha7 subunit of the nicotinic acetylcholine receptor gene (CHRNA7) and perception of coherent motion in aging

**Marina Kunchulia<sup>1</sup>, Nato Kotaria<sup>2</sup>, Karin Pilz<sup>3</sup>, Adam Kotorashvili<sup>2</sup>, Michael Herzog<sup>4</sup>**

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Genetic variations of the alpha7 subunit of the nicotinic acetylcholine receptor gene (CHRNA7) are linked to cognitive deficits in aging and schizophrenia. However, little is known about associations of the CHRNA7 gene with aged-related decline in visual perception. In the present study, we tested whether variations in the alpha7 subunit of the nicotinic acetylcholine receptor gene (CHRNA7) interact with the perception of coherent motion in healthy aging. We assessed motion coherence for twenty-five older participants (60-73 years) and twenty-six younger participants (20-27 years) for a left/right motion direction discrimination task. A single nucleotide polymorphism (SNP) [rs2337980] of the CHRNA7 was genotyped. Overall, 25 participants were classified as T/C allele carriers (11 older), and 22 participants were classified as C/C (11 older). Only 3 participants were T/T and therefore, this group was excluded from further analysis. Overall, older adults had higher motion coherence thresholds than younger adults. We did not find any age-related associations of motion direction discrimination with the CHRNA7. However, regardless of age group, participants carrying the T/C genotype performed the task significantly better than C/C carriers. Our results therefore, indicate a strong relationship between the nicotinic system and motion perception.

[4P008] Age related differences in perception of a situation and eye-witness identification

**Helen Kaye**

Psychology, The Open University

Understanding the factors that affect accurate eyewitness identification is practically as well as theoretically important. Groups of younger (aged under 40) and older (aged over 40) adults viewed a film of a staged incident involving two men that was deliberately ambiguous and could be interpreted as involving a (mildly) violent crime. Subsequently participants were asked to describe the incident, and later to identify the men, one in a target present (TP) line up and the other in a target absent (TA) line up. The results confirmed previous findings that older participants make more false identifications than younger participants and analysis of the descriptions given of the incident revealed that older participants were significantly more likely than younger to use words associated with violence or crime, such as “aggressive” “assault” and “victim”. Non-violent descriptors included “argument” and “dispute”. The tendency to describe the incident as violent was more pronounced for older participants who subsequently made a false identification than for those who subsequently made a correct rejection in the TA line-up. No such difference was found for the younger participants. These findings are consistent with age related differences in identification reflecting social and motivational factors.

[4P009] Effects of aging in cognitive and anticipated properties of the moving object

**Masaru Takeichi<sup>1</sup>, Takeyuki Arai<sup>2</sup>, Kinya Fujita<sup>3</sup>**

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The purpose of this study was to discuss anticipate and cognitive property of elderly persons. 8 young (19-38 y.) and 8 elderly (64-81y.) persons participated in the experiment. Participants were required to answer the position of a moving object at the moment of a visual trigger stimulus, which is presented after the occlusion of the object with five levels of delay (200-1000ms) by changing the color of the occluding board. The similar tasks were performed without occlusion. The object moved from left to right at a visual speed of 10deg s<sup>-1</sup> on display. Anticipated velocity in occluded task and cognitive velocity in visible task were calculated from the answered position and the trigger delay. Anticipated velocity of the elderly group was much less than the actual object velocity and no significant difference with that of the young group. Cognitive velocity of the elderly group was significantly smaller than the young one. Cognitive velocity showed a correlation with age. From the results, it suggested that the aging might have more effects on the visual and cognitive function than the attention that affected anticipated velocity.

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[4P010] Spatial attention measures in healthy aging

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Young adults typically display a processing advantage for the left side of space (“pseudoneglect”), whereas older adults display no strongly lateralised bias, or indeed a preference towards the right (Benwell et al., 2014; Schmitz & Peigneux, 2011). For young adults, we have recently reported that 5 commonly-used spatial attention tasks (line bisection, landmark, greyscales, gratingscales and lateralised visual detection) all provide stable intra-task measures of bias over time, however no strong inter-task correlations were found (Learmonth et al., 2015). At present there is no systematic evidence for intra- and inter-task consistency in older adults. To investigate this, we tested 22 older adults (mean age=70.44) on these five tasks, on two different days. Preliminary results show that three of the five tasks (line bisection, landmark and greyscales) seem to provide stable measures over testing sessions, indicating that they measure a consistent property of the spatial attention network. However, as per our previous finding in young adults, there seem to be no significant between-task correlations. Moreover, in contrast to the leftward biases reported in young adults, this elderly age group showed no significant lateral biases on any of the tasks.

[4P011] Compensation mechanism of chromatic adaptation in elderly person

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Although elderly people show yellowing optics in their eyes, they do not see the world in yellow. The locus of an achromatic point after long-term yellow light adaptation was measured in order to explore the colour compensation mechanism in elderly people. After adaptation to yellow light through an optical sharp cut filter (Fuji film SC-52) using an integrating sphere, the transition of the achromatic point in 10 elderly and 10 younger subjects was measured at 10-min intervals over a 110-min period using the staircase technique. The elderly subjects showed minimal transition in chromatic adaptation, which suggested that their daily yellow adaptation had progressed. In contrast, the achromatic point in young subjects showed notable changes initially, but returned to the locus of the normal white point at the end of the trial. The average distance to the achromatic point transition and the average duration to return to the pre-adaptation achromatic point showed significant differences between the two groups. These results indicate the presence of a visual compensatory mechanism for long-term chromatic adaptation and suggest that elderly people usually compensate colours by this mechanism.

[4P012] Dual task performances in pathological and physiological aging.

**Martina Conti<sup>1</sup>, Maria Gabriella Donato<sup>1</sup>, Simona Cintoli<sup>1</sup>, Nicoletta Berardi<sup>1</sup>, Gloria Tognoni<sup>2</sup>, Maria Michela Del Viva<sup>1</sup>**

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Recently, it has been shown that SCI (Subjective Cognitive Impairment) individuals have greater probability to develop dementia, causing a growing interest in the neurological research. These individuals are characterized by

subjective complaints about a certain degree of deterioration of their cognitive level, particularly regarding their memory, although they exhibit normal performances in classical neuropsychological tests for the assessment of dementia. SCI individuals also exhibit early functional (fMRI) changes during divided attention tasks, probably due to compensatory strategies. The aim of this study is to differentiate memory and attention performances of SCI individuals from that of healthy aging subjects, by using psychophysical tasks. We tested healthy aging, SCI individuals with two dual visual tasks, where the interfering stimulus could be either presented simultaneously or right after the test stimulus, hence during test-stimulus retention. This is to probe its effect respectively on attention or working memory abilities. Preliminary results show that SCI individuals have lower performances than controls when two visual stimuli are presented simultaneously, suggesting lower abilities to sustain a large attentional load.

[4P013] Visually evoked potentials gained by new mobile device can detect CNS fatigue

**Zuzana Kubova, Karolina Kubova, Miroslav Kuba, Jan Kremlacek, Frantisek Vit, Jana Szanyi, Jana Langrova**

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A new mobile device for visual evoked potentials (VEPs) acquisition developed in our lab was tested in 25 students (17 – 19 years). Repeated examination E2 was performed about 1 month after E1. Additionally, VEPs were also recorded under the influence of increased fatigue (sleep deprivation) - examination E3. Visual stimulus (centrifugal motion) consisted of sequential lightning up of 15 LEDs from the center to periphery of a golf cap peak. The stimulus was located either in the center of the visual field (C) (visual fixation of the central LED) or in periphery (P) (fixation in the lower part of the visual field). Reliable VEPs were gained in 19 out of 25 subjects and there was no significant difference in VEPs to E1-C/P and E2-C/P stimuli. Under the influence of fatigue (E3), the P2 latencies were significantly prolonged (by 30 ms on average). In this study we have shown that our device is suitable for VEP monitoring outside specialized electrophysiological labs. Moreover, the possibility of a prolonged monitoring of VEPs could bring new applications - e.g. to display objectively signs of CNS fatigue.

Funding: Supported by Charles University in Prague, project PRVOUK P37/07.

[4P014] Effects of indirect screen vision and tool-use on the time and precision of object positioning on real-world targets

**Anil Ufuk Batmaz, Michel de Mathelin, Birgitta Dresch-Langley**

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A current approach for surgical imaging is to employ a single camera with a fisheye lens, the latter providing a hemispherical focus of vision with poor off-axis resolution and aberrant shape contrast effects at the edges of objects viewed on the screen. We built an experimental platform for testing effects of fisheye screen representations of a Gestural Action Field (GAF) on the effectiveness of tool-mediated object positioning on predefined target locations within the GAF. Six men and six women had to place a small object on the centre of five successive target positions, using a tool or not (control), in successive trials while viewing the GAF 1) directly in front of them 2) on a 2D screen in fisheye or 3) in corrected 2D view. Results show that fisheye viewing and corrected 2D viewing have significantly detrimental effect on time (seconds) and precision (pixels) of the positioning task. The effects significantly depend on whether a tool is used or not to displace the object.

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[4P015] The relationship between the direction of attention and evaluation content while observing products

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When people observe products, they turn their eyes to them (i.e., attend to their interested parts). This attention with eye movement is called “overt attention.” When they evaluate different types of impressions for many products, it is unclear whether they change the observing parts for each impression (i.e., evaluation content). In this study, the relationship between the direction of the visual line and observed parts during evaluation was clarified using eye movement measurements and impression words (i.e., evaluation words). As participants observed the experimental

stimuli, they evaluated each impression of the stimulus and reported the observed parts for each of their evaluations after the experiments. Heat maps were produced and the direction of the attention was identified. This study clarified that the parts attended to during the observation of the products do not change for each evaluation. However, differences existed between the direction of attention and the reports after the experiments for some participants. Therefore, using the direction of attention potentially explains the property of the evaluation words (i.e., the analytical words for stimuli), subjective words according to their integrated judgments, and participants' preferences.

[4P016] Assessing visual processing capabilities using the virtual reality device Oculus Rift

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The neuropsychological assessment of visual processing capabilities strongly depends on visual testing conditions including room lighting, stimulus size, and viewing-distance. This limits standardization, threatens reliability, and, in practice, prevents the assessment of core visual functions such as visual processing speed. Increasingly available virtual reality devices allow to address these problems. One such device is the portable, light-weight, and easy-to-use Oculus Rift. It is head-mounted and covers the entire visual field, thereby shielding and standardizing the visual stimulation. A fundamental prerequisite to use Oculus Rift for neuropsychological assessment is sufficient test-retest reliability. Here, we compare the test-retest reliabilities of Bundesen's (1990) visual processing components as measured with the Oculus Rift and with a standard CRT computer screen. We found that the reliability of the temporal threshold of conscious perception and the capacity of visual working memory was comparable between Oculus Rift and the CRT. Visual processing speed was measured more reliably with Oculus Rift than with the CRT. These findings reveal that the Oculus Rift is applicable for the standardized and reliable assessment of elementary visual cognitive functions outside psychophysical laboratories. As such, they may pave the way for assessing these functions in motorically impaired or immobile patients.

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[4P017] Brain games: Extensive action video game experience enhances globally-directed visual-attention

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Increasing data suggest that extensive action video gaming experience may lead to long-lasting benefits including improvements in visual acuity, contrast sensitivity, and visual attention. Here, we asked if the visual-attentional benefits of video-gaming experience holds when observers are asked to ignore (sometimes conflicting) local information, and selectively attend to global information. We tested twenty participants (10 video-game players; 10 non-video-game players) on an RSVP task and a letter identification task. In both tasks, stimuli were Navon figures that were congruent or incongruent. In the RSVP task, observers were asked to selectively attend to the global configuration of the stimuli, identify the initial target, and detect the presence of a second target that was present in 50% of the trials. We found that attentional blink, as quantified by impairments in detection of the second target in the RSVP stream, was significantly weaker for action video gamers than for non-gamers, in particular for the incongruent stimuli. Results from the control task indicated both groups could identify the targets (under non-RSVP conditions) comparably. These findings suggest an enhanced selective, global visual-attention capacity in video-game players, perhaps manifesting from a quicker M-pathway that has been proposed to underlie globally-directed attention processing.

[4P018] Blur Unblurred, for the Vision Scientist

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Optical blur is often considered as equivalent to low-pass filtering. Yet that belief, although not entirely wrong, is clearly inaccurate. Here we wish to disentangle dioptric blur, caused by myopia or mis-accommodation, from blur by low-pass filtering and by convolution with a Gaussian kernel. Perhaps surprisingly – if well known in optometry – the blur kernel (or point-spread function) for dioptric blur is, to a good approximation and disregarding diffraction, simply a cylindrical disk. Its projection onto the retina is classically referred to as a blur circle, the diameter of which can easily be deduced from a light-ray model. We further give the derivation of the relationship between the blur disk's

diameter and the extent of blur in diopters, as well as the diameter's relation to the near or far point, and finally its relationship to visual acuity.

[4P019] Mobile device for visually evoked potentials recorded from prefrontal cortex

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With the use of our own patent (CZ 304 882) a new mobile device for visual evoked potentials (VEPs) examination was developed in our lab. It is based on new principles of visual stimulation using LEDs placed in the upper peripheral part of the visual field (built in a special headset carrier). VEP recording from the prefrontal cortex (via dry electrodes located in the carrier on the non-hairy part of the forehead) simplifies examination which can be done as a self-service. Amplified VEPs are transmitted via USB or blue-tooth to a laptop for on-line evaluation. We will demonstrate the use of this mobile device and basic characteristics of VEPs from healthy subjects. Although there is a larger inter-individual variability of this type of VEPs compared to the standard VEPs from striate cortex, reproducible robust reactions to flash or moving visual stimuli seem to be promising information for evaluation (long term monitoring) of CNS disorders (testing of selected diagnoses is in process). Our low-cost mobile VEP device might enlarge diagnostic applications of VEPs and enable a home monitoring of some CNS disorders. Acknowledgements: This research was supported by Charles University in Prague, Czech Republic, project PRVOUK P37/07. Funding: Charles University in Prague, Czech Republic, project PRVOUK P37/07

[4P020] From brain oscillations to new technological applications: Proof of concept

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Converging evidence from various approaches highlights the relevance of ongoing neural oscillations in low frequencies (6-14 Hz) for subsequent behavioural performance in visual perception, multisensory processing, spatial attention or working memory tasks. However, evidence mainly comes from inference based on group statistics and correlative approaches. This limits knowledge to a descriptive level explanation, and complicates transfer to applications, which require explanatory variables that predict performance reliably at single subject level, on a trial to trial basis. Here, we sought proof for the validity of the dependency between low frequency fluctuations and perception on an individual, trial to trial basis. We measured EEG in a spatial attention paradigm (e.g., Posner), concentrating on the individual alpha frequency (IAF) during the cue-target, pre-stimulus period. We analyzed whether performance (hit/miss) was phase-dependent in the IAF band at posterior electrodes. In particular, our analysis was directed to access the relevance of alpha phase at exact time of stimulus presentation. Our results demonstrate the feasibility of reproducing known principles regarding brain oscillations and behaviour on single individuals with non invasive recordings. This provides an innovative platform for the exploiting brain signal in applied technologies, such as BCI. Funding: SGR2014-856 (AGAUR), ERC-2010-StG -263145 (ERC), PSI2013-42626-P (MINECO)

[4P021] Visual-motor integration in dyslexia

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Developmental dyslexia is a common disorder characterized by difficulties with reading despite adequate intelligence and education. Phonological deficits are often indicated as the primary features of dyslexia. Many individuals with dyslexia, however, also or only have problems integrating visual information over space and time, and /or motor control. These problems have been, to some extent, explained by the magnocellular and dorsal stream dysfunction. We used a novel, computer-based “dot-to-dot” (DtD) task to explore visual-motor integration in 472 children (aged 4 – 11 yrs, m=6.18; 229 females) from three primary schools in Edinburgh, UK, and its relationship with phonological and cognitive skills known to be compromised in dyslexia. We found that: (1) children deemed at “high” risk of dyslexia according to existing screening tools (e.g. LUCID-Rapid) performed significantly less accurately than those deemed at “low” risk. (2) DtD accuracy was significantly correlated with motor control task; weak correlations were found between the DtD task and phonological deficits which may indicate that that DtD task may tap only into visuo-motor

deficits. Follow-up testing of the youngest, pre-reading, children was conducted using visual psychophysical tests to explore the relationship between the DtD task and visual deficits.

[4P022] Inattentional Blindness: the role of target-congruency in a multiple object tracking paradigm

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Inattentional blindness (IB) is the inability to detect unexpected events when visual attention is engaged in an attentionally demanding task. Our study aimed to investigate the magnitude of inattentional blindness in relationship to the similarity between the unexpected item and other items occurring on the screen. We employed multiple object tracking task in which the unexpected event congruency, the distinguishing feature (color, shape, orientation, or size), and attentional load (the number of targets to be tracked) were manipulated. After ~9 trials, an unexpected event, either a) target-congruent, b) distractor-congruent, or c) entirely novel, entered the visual scene. The incidence of IB was affected by both attentional load and the congruency of the unexpected item. Participants showed less inattentional blindness under low attentional load and when the extra item was novel vis-à-vis target congruent and distractor-congruent items. Interestingly, the detection of the target-congruent extra item was contingent on the attentional load. However, the novel items were more likely to be noticed regardless of the attentional load and were least susceptible to inattentional blindness. We conclude that when attentional system is overloaded, the detection of unexpected items is driven by bottom-up saliency of the stimulus.

[4P023] Collaborative multiple object tracking: How many objects can you track and which ones did you pick?

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When humans collaborate, they often distribute task demands in order to reach a higher joint performance compared to performing the same task alone (i.e., a collective benefit). Here, we tested to what extent exchanging information about how to distribute task demands and performance feedback contribute to the collective benefit in a collaborative multiple object tracking task. Specifically, pairs jointly tracked a subset of target objects among several moving distractor objects on a computer screen and at the end of a trial either received performance feedback, or the co-actor's target selections, or both. In all conditions, pairs' performances exceeded the individual performances and a hypothetical performance that would be reached if co-actors would act independently. Comparing conditions, pairs reached a higher performance and divided task demands more efficiently when receiving both information in comparison to receiving the performance feedback or the co-actor's selections. However, over time, performances converged to similar levels in all conditions, suggesting that pairs' coordination strategies become equally effective. Overall, pairs in a spatial collaborative task benefit from information about how to distribute task demands among co-actors as well as performance feedback and the most from having both information available.

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[4P024] Multiple identity tracking: evidence that location tracking and identity tracking suffer similarly from spatial interactions

**Katie M McLeod, Leili Soo, Soren K Andersen**

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Many everyday activities, such as team sports, driving, or observing your children at the playground require us to keep track of multiple moving objects. In the lab, this ability is commonly investigated using the multiple object tracking (MOT) paradigm, in which participants track a set of identical target stimuli moving among distractors and indicate their locations at the end of the trial. Variations of this task using the multiple identity tracking (MIT) paradigm, in which non-identical targets with different identities are tracked, have revealed that participants may often know the locations of targets despite not knowing which of them is which. These findings suggest at least partially separate mechanisms for tracking locations and identities of moving objects. To test this claim, we investigated whether spatial separation of objects, which is known to critically influence location tracking, has a similar effect on identity tracking. Participants tracked 4 out of 8 circles (4 pairs of different colours) for a few seconds, after which they reported the

positions of specific targets. Location and identity tracking accuracy decreased in parallel for smaller spatial separations. This suggests that the mechanisms for tracking locations and identities share the same spatial resolution.

[4P025] Attentional (an-)isotropy: differential effects of covert and overt object tracking

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There has been some debate about the anticipatory nature of attention during object tracking but most studies agree that for a relatively low tracking load, motion paths do appear to be taken into account. We investigated the relative contributions of overt and covert attention on the apparent anticipatory nature of attention at a low tracking load using a single-object tracking (SOT) task (1 target, 1 distractor) and a relatively higher tracking load using a multiple-object tracking (MOT) task (2 targets, 2 distractors), both combined with probe detection. We found that probes that are presented at likely future object locations are detected more often than probes presented at other locations surrounding the object. This effect occurs for both overtly and covertly tracked targets in SOT, but only for covertly tracked targets in MOT (controlling for eye movements). That is, in our SOT/MOT setup, covert attention always leads to an anisotropical spread of attention, whereas overt attention leads to anisotropy only when the attentional load is relatively low (SOT). We discuss our results in the context of previous results on anticipatory attention.

[4P026] Age and gender effects in attentional tracking

**Eugenie Roudaia, Jocelyn Faubert**

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Multifocal tracking ability declines with ageing when the number of tracked targets or the speed increase (Sekuler et al., Perception, 2008; Legault et al., Front. Psychol., 2013). Holcombe & Chen (JOV, 2013) reported that attentional tracking has a temporal frequency limit of ~7 Hz when tracking one target and reduces to ~4Hz, ~2.6Hz when tracking 2, 3 targets, respectively. We adapted this paradigm to test whether ageing affects the temporal frequency limit for one target, the efficiency of splitting attention across multiple targets, or both. Younger (M = 22.8 y.) and older (M = 68.2 y.) participants tracked one, two or three targets moving along concentric circular trajectories each containing either 5 or 10 objects per ring. Speed was varied across trials to determine the speed threshold for identifying one of the targets chosen at random. Younger participants showed an effect of target number, with temporal frequency thresholds of 5.2 Hz, 3Hz, and 1.9 Hz for one, two, and three targets. Interestingly, while older men only differed from younger participants when tracking three targets (1.3 Hz), older women showed poorer thresholds starting with one target (3.3Hz). Thus, age-related declines in tracking moving targets appear to affect women more than men.

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[4P027] Infant's Perception of Biological Motion – a Neurobiological study using Functional Near-Infrared Spectroscopy

**Isabel C Lisboa, Helga Miguel, Alfredo F. Pereira, Adriana Sampaio, Sandra Mouta, Jorge A. Santos**

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Understanding how specialized is the infant's cortex to process biological motion is still an open question. Studies indicate that the right temporal sulcus (RTS) is activated on the infant's perception of face motion, which is not the case when non-biological motion, such as inverted face motions are presented (Otsuka, Y., et al, 2007). However, face motion has a sharp social content and, although adults show a strong unilateral response on the RSTS when viewing the classical Point-Light-Walkers (PLW), the neurodevelopmental path of such cortical specialization is still unknown. In this study, we recorded the hemodynamic response in the RTS of 7month-old infants (N=6) when presented with approaching PLW, using Functional Near-Infrared Spectroscopy. We implemented a block design where infants viewed three PLW:(1) an intact biological motion, (2) the same motion but inverted (3) the same stimuli but animated only with the translational component, without the opponent movements of the limbs. Results showed a tendency for an increase in the HbO concentration ( $\mu\text{M}$ ) on the RTS in the biological motion condition, whereas this activation pattern was not present in the other conditions. These results confirm behavioral data and show that biological motion is processed differently in the RTS since early on.

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[4P028] Dissociating global and local biological motion processing in the human brain

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It has long been assumed that the human brain contains dedicated machinery for processing biological motion. Behaviourally, biological motion perception has been shown to implicate mechanisms that are distinct: one that governs the retrieval of global structure (body form) and another purported to process "local" information that is particularly sensitive to the gravity-defined acceleration pattern conveyed by the feet. Here, we used fMRI to dissociate the neural underpinnings of these two mechanisms. We measured responses (N=16 participants) to point-light stimuli containing solely structural information (local horizontal directionality neutralized but global structure intact), solely local information (global structure destroyed, but local information intact), and perturbed local information, presented vertically- upright and inverted. Observers were asked to judge walking direction. Results from SVM (MVPA) analyses indicate widespread sensitivity to global structure from early cortex (V1-V3) extending to the inferior and superior parietal lobule, in contrast to comparatively weak sensitivity to local information in cortex. Strikingly, we found significant sensitivity to local information in subcortical ventral lateral nucleus, VLN, an area not sensitive to global structure. These data suggest that distinct networks are engaged for biological structure versus local motion processing, the latter of which may rely primarily on earlier, subcortical systems.

[4P029] Response priming with dynamic, spatially varied, and biologically moving stimuli

**David Eckert, Christina Bermeitinger**

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How do dynamic and spatial information of a prime stimulus influence the response to a subsequent target stimulus in a modified response priming paradigm? In response priming, a prime stimulus influences the responses to a target stimulus that follows the prime after a short temporal delay. When both stimuli evoke the same response tendency, reactions are typically faster. In the current experiments, we used dynamic prime stimuli (moving dot rows), included elements of spatial cuing, that is, we varied the position of the prime stimuli, and implemented biological movements as primes. Hence, compatibility effects of both motion and position were possible. For dot rows, with a stimulus onset asynchrony (SOA) of 150 ms, we found positive compatibility effects of both prime position and movement. However, with a longer SOA, of 300 ms, negative compatibility effects for both factors were found: faster responses to targets that moved in the opposite direction, or were presented in the opposite location, as the primes. With biological movements as primes, always positive effects were found. Results are discussed in relation to previous findings from experiments utilizing response priming and cuing paradigms, as well as different theories on positive and negative compatibility effects.

[4P030] It's not human! - Neural correlates of agency violations

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Beliefs about the human origin of observed movements have been shown to modulate sensorimotor processes on both the behavioral and neurophysiological level. In this fMRI study we examined how the neural correlates of oculomotor tracking are modulated by top-down (human vs. computer instructed agency) and bottom-up cues (biological vs. nonbiological stimulus velocity profile). Our results show a preference for biological over nonbiological motion in a right-hemisphere occipito-temporal cluster comprising the motion-sensitive area V5. Importantly, a mismatch between instructed human agency and a nonbiological velocity profile primarily activated medial-frontal areas comprising the frontal pole, the paracingulate gyrus, and the anterior cingulate gyrus, as well as the cerebellum and the supplementary eye field. This mismatch effect was specific to the instructed human agency and did not occur for a mismatch between instructed computer agency and a biological velocity profile. Our results indicate that violating expectations based on a predictive model specific for biological movements requires a correction of the movement in accordance with (nonbiological) sensory information which is reflected by medial-frontal activations.

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[4P031] When your movements betray your feelings: Reading emotional state through body kinematics

## **Yannick Wamain, Anaïs Demay, Yvonne Delevoeye-Turrell**

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While recent evidences argue that motor and social intention could be decoded from simple observation of motor behaviour, the issue of reading emotional states through body kinematics is still debated. This question was investigated by conducting two complementary experiments using action production and action observation paradigms. In the action experiment, we used a music emotional induction paradigm to elicit 4 different emotions: sadness, happiness, fear and peacefulness. Body motion kinematics and emotional states of the participants were continuously measured through the experiment. Analysis of pattern of movement revealed differences in both the postural and the dynamic aspects of body movement. These movement trials were then used as stimuli in an observation experiment using Full-light and Point-light displays (FLD or PLD). These stimuli were viewed by 20 naïve observers who were required to perform both Emotion Recognition and Movement Evaluation tasks. Results revealed that observers could categorise emotion states significantly above chance level, on the basis of movement tempo and fluency. Together, these findings argue in favor of the hypothesis that emotion and action are deeply interconnected, giving exciting perspectives in the ability to use body language to recognize threat from fear, without error.

[4P032] The face of actions: Evidence for neural action recognition processes being sensitive for facial identity

### **Stephan de la Rosa, Ylva Ferstl, Heinrich H Bülthoff**

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Accurately associating an action with its actor's identity is fundamental for many – if not all- social cognitive functions. What are the visual processes supporting this ability? Previous research suggest separate neural substrates are supporting the recognition of facial identity and actions. Here we revisited this widely held assumption and examined the sensitivity of neural action recognition processes to facial identity using behavioral adaptation. We reasoned that if action recognition and facial identity were mediated by independent visual processes then action adaptation effects should not be modulated by the actor's facial identity. We used action morphing and an augmented reality setup to examine the neural correlates of action recognition processes within an action adaptation paradigm under close-to-natural conditions. Contrary to the hypothesis that action recognition and facial identity are processed independently, we showed in three experiments that action adaptation effects in an action categorization tasks are modulated by facial identity and not by clothing. These findings strongly suggest that action recognition processes are sensitive to facial identity and thereby indicate a close link between actions and facial identity. Such identity sensitive action recognition mechanisms might support the fundamental social cognitive skill of associating an action with the actor's identity.

[4P033] Biological motion presented with upright and inverted display orientation: Human ultra high field 9.4 T fMRI

### **Marina A Pavlova, Michael Erb, Gisela Hagberg, Alexander Sokolov, Klaus Scheffler**

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Body motion (BM) is a rich source of information for social cognition and interaction. Yet display inversion severely impedes BM processing. It is still unclear how brain networks underpinning BM processing are affected by display inversion. To address this issue, we used ultra-high field functional magnetic resonance imaging (fMRI) at 9.4T. Participants performed a two-alternative-forced-choice task, indicating whether an upright point-light walker or control displays (the same movie inverted 180 deg) were presented. An upright walker elicits most pronounced clusters of fMRI activity in the bilateral superior occipital cortices and the right middle temporal cortex, whereas the inverted display results in bilateral activity of lower occipital cortices, primarily, the lingual cortices. The BOLD response in these areas exhibited specific temporal dynamics during stimulus duration: a decrease in activation in the second 5 s of stimulus duration, with a recurrent increase afterwards. Perceivers who did not recognize upside-down display as a walker exhibit activity in the distributed network with hubs in the right hemisphere including the lingual and postcentral cortices, and the pars operculum. The outcome provides novel insights on the brain networks underlying body motion processing and its functional neuroanatomy.

[4P034] Processing of emotional body language within the visual social cognition network

### **Arseny A Sokolov<sup>1</sup>, Michael Erb<sup>2</sup>, Frank Pollick<sup>3</sup>, Richard SJ Frackowiak<sup>4</sup>, Karl J Friston<sup>4</sup>, Marina A**

## Pavlova<sup>2</sup>

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Despite the significance of the brain networks for visual perception of emotions and intentions are indispensable in our everyday life, their architecture remains little understood. Here, we performed functional MRI (fMRI) and diffusion tensor imaging (DTI) in healthy subjects who had to recognize emotions (happy, neutral and angry) conveyed by a point-light arm seen knocking on an invisible door. Data pre-processing, fMRI data and dynamic causal modelling (DCM) analysis were performed with SPM12, and probabilistic tractography on the DTI data by using FSL. The data reveal higher activations in the right superior temporal sulcus (STS) and caudate nucleus for happy as compared to neutral knocking. Angry versus neutral knocking activate the inferior insula, perigenual anterior cingulate cortex (ACC) and posterior midcingulate cortex (MCC) in the left hemisphere. The cerebellar vermis (lobule IX) and right amygdala respond most strongly to neutral knocking. Structural and effective connectivity analysis reveals how emotional content of visually perceived stimuli is extracted and processed within this network. In summary, processing of emotional body motion appears to be lateralized depending on the emotional content. Combining information on function and structure may help to better understand neuropsychiatric conditions with impaired visual social cognition. Funding: Bourse de relève académique pour jeunes chercheurs, Faculty of Biology and Medicine, University of Lausanne

[4P035] Impaired visual competition in patients with homonymous visual field defects.

### **Anna Geuzebroek, A.V. Van den Berg**

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Intensive visual training can partially recover visual field defects resulting from stroke. Standard visual detection tasks (perimetries), used to assess this progress, do not provide information about visual competition. Competition is however essential for natural search tasks and detecting unexpected events. In this study, we investigated the potential of a recovered visual field to compete for attention with the 'intact' visual field. Ten patients with visual field defects that had received intense visual training were compared to healthy, age-matched controls using a saccade target selection paradigm. Our paradigm asks subjects to choose the brightest of two flashed targets that reverse their intensity difference during the flash (Kalisvaart et al. *Journal of Neuroscience*). Surprisingly, choice behaviour even in patients' supposedly intact visual field was significantly different from the control group for all but one. In the latter patient, competition involving her recovered visual field was also similar to the control group. Other patients' decisions were mostly based on guessing, as revealed by choice-reaction time analysis. They had a larger amount of early responses, which indicates that patients might compensate for their defect by emphasizing speed instead of accuracy during decision-making.

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[4P036] Neural correlates of visual backward masking: Compensation mechanism in relatives of schizophrenia patients

### **Janir Nuno da Cruz<sup>1,2</sup>, Maya Roinishvili<sup>3</sup>, Eka Chkonia<sup>4</sup>, Patrícia Figueiredo<sup>2</sup>, Michael Herzog<sup>1</sup>**

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Visual backward masking (VBM) is a very sensitive endophenotype of schizophrenia. Masking deficits are highly correlated with reduced EEG amplitudes. In VBM, a target stimulus is followed by a mask, which decreases performance on the target. Here, we investigated the neural correlates of VBM in relatives of schizophrenia patients. We had three conditions: target only and two VBM conditions, with long and short inter-stimulus intervals (ISI). Patients' performance was impaired, while the relatives performed at the same level as the controls. Interestingly, EEG N1 amplitudes were higher in relatives compared to controls, while they were lower in patients relative to controls as previously reported. For relatives, N1 amplitudes were at the same level in all conditions. For controls and patients, N1 amplitudes increased with task difficulty, e.g., amplitudes in the long ISI condition were lower than in short ISI condition. Our results suggest that relatives use a compensation mechanism tuning the brain to maximum performance in all conditions. Since relatives are already at the peak of their activations, increasing the task difficulty does not change brain processing.

[4P037] Evidence for a Face Inversion Effect in People with Parkinson's

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The ability of people with Parkinson's (PwP) to discriminate upright and inverted facial expressions is evaluated using a temporal two-interval forced-choice paradigm. Stimuli are black and white images of neutral, happy, angry, disgusted, fearful, sad and surprised expressions. Inverted stimuli are the two expressions that participants are most and least sensitive to. A range of intensities of expressions (0-100%) are created by morphing between neutral and expressive images. The neutral image (0%) is presented in one interval and the expressive image (varies 0 – 100%) in the other. Observers indicate the interval that contained the image that was most expressive. For all upright expressions and all participants, performance increases from chance to 100% correct as intensity of expression increases. Fitted functions describing performance of happy and disgust are shifted to the left of others. This suggests that PwP are most sensitive to expressions of happiness and disgust. PwP and control participants show a small reduction in sensitivity for the expression they are most sensitive to when it is inverted (Face Inversion Effect). For PwP there is a considerable Face Inversion Effect for the expression they are least sensitive to. This suggests that configural face processing is disrupted in Parkinson's disease.

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[4P038] The role of optical and morphological characteristics of the human eye in detection of objects in different visual tasks

**Olga Vakhrameeva, Galina Moiseenko, Aino Lamminpia, Dmitry Maltsev, Mikhail Sukhinin, Sergey Pronin, Sergey Koskin, Yuri Shelepin**

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It has been shown recently, that in addition to multiple cognitive impairments and specific changes in the brain, schizophrenia changes structure of the macula region in retina (S.M. Silverstein, 2015). The goal of the present study was to investigate the influence of foveal avascular zone diameter (FAZD) in healthy human on the contrast sensitivity and on the discrimination ability of the small objects in different tasks: detection, classification, and reading. Refraction and axial length of the eye were measured for all subjects; FAZD was measured using optical coherence tomography line scan. Corrected distance visual acuity (CDVA) and contrast sensitivity of all subjects were measured; visual event-related potential (ERP) were measured in classification task; eye movements were analyzed during the reading task. We found that CDVA and maximum of the contrast sensitivity both depend on FAZD. Investigated characteristics of the eye have an impact on recognition and decision-making process (as shown by ERP). Fixation durations were affected by FAZD in reading task. Thus, morphological characteristics of the fovea region are essential for perception of the small objects and together with psychophysiological tests can be used as a method for diagnostics and monitoring of treatment effectiveness in schizophrenia.

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[4P039] Transfer of induced preferred retinal locus of fixation among visual tasks

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Normally sighted subjects develop a preferred retinal locus of fixation (PRL) under simulation of central scotoma. The location of the PRL can be induced at any desired region when systematic relocations of a saccade stimulus are applied. This saccade stimulus presented during the inducement does not represent all daily visual tasks, therefore this study investigates whether induced PRLs can be transferred to other visual tasks such as reading and object following. Ten normally sighted subjects with an already developed PRL participated. Five subjects had a self-chosen PRL location and were used as control subjects. The other five had an induced PRL location. The already developed PRL location was used as baseline. Under simulation of central scotoma, subjects had to fulfill two new visual tasks. The first task was to follow a group of moving dots presented on the screen and report changes in color. The second task was to read a text and subsequently answer related questions. Results showed that the differences between the baseline PRL position and the PRL position for the object moving task were comparable. Additionally, the reading task results showed that 3 out of 5 subjects with an induced PRL selected the induced PRL for reading.

[4P040] The integration of gaze cues in faces for congenital prosopagnosia

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A considerable amount of research on identity and emotion perception with the composite design points to the holistic processing of these aspects in faces. In this field, less research has been dedicated to gaze. Nonetheless, gaze perception is a substantial component of face perception, and holds critical information for communication. Studies in the context of attentional allocation show interactions between gaze-cues in faces. However, holistic integration was never tested directly. Research on gaze perception with the composite design could (1) facilitate comparison with other face aspects that have been investigated using this design, and (2) help us to better understand gaze perception abilities in populations with face recognition problems. In the current research, the complete composite design is administered to assess the holistic integration of facial gaze-cues in a population with congenital prosopagnosia (CP), a condition characterized by face recognition difficulties. In Experiment 1, the effect of head-orientation on the perception of eye-orientation was evaluated, and vice versa for Experiment 2. Results indicate abnormal integration of head-orientation on the perception of eye-orientation in CP compared to matched controls, but normal integration of eye-orientation on the perception of head-orientation. Implications for a better understanding of face perception in CP are discussed.

[4P041] Structural insights into mutations of RDH12 causing Leber Congenital Amaurosis based on the *Drosophila Melanogaster* homolog, PDH

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Vision represents the most sophisticated and important sensory system in the human body. The universal retinylidene chromophore of visual pigments isomerizes upon interaction with a photon which induces a cascade of downstream signaling events. The conformational change from 11-cis- to all-trans-retinal and subsequent chromophore release produces cytotoxic all-trans-retinal. This photo product is a substrate for the visual cycle, through which it is converted back to 11-cis-retinal. The first and rate-limiting enzymatic reaction, the reduction of the cytotoxic all-trans-retinal to all-trans-retinol, is catalyzed by retinol dehydrogenases. Mutations in their corresponding genes encoding can cause severe impairment or loss of vision. Here, we solved the structure of the *Drosophila melanogaster* photoreceptor dehydrogenase that provided novel insights into the structure and function of retinol dehydrogenases. Also, we analyzed mutations causing Leber Congenital Amaurosis 13 in a homology model of human RDH12 based on the orthologue structure. Our findings revealed the molecular basis of disease-causing mutations in RDH12, including a novel substrate-induced conformational change of the NAD<sup>+</sup> cofactor within the family of short-chain dehydrogenases. Funding: Swiss National Science Foundation - SNF

[4P042] How does glaucoma affect visual categorization of objects?

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Glaucoma induces damage at various levels of the visual system from retina to cortex. The purpose of this study was to determine whether glaucoma without visual loss in central area of visual field affects the ability to categorize briefly presented objects. Methods: 14 people with glaucoma and 15 age-matched controls were measured in a visual categorisation task on accuracy and response times. Grey level photographs of objects were presented for 28 ms foveally. Perimetric thresholds were normal for all participants within the central 3 degrees. Two levels of contrasts were included: one medium level at 50% and one with high contrast at 100%. Results: On average, accuracy was significantly decreased for the medium contrast presentation in glaucoma patients compared to controls (87% vs 94%). Group average response times were significantly slower for the patients (712ms) relative to the control group (643ms). Performance was equivalent in the two groups when the contrast of the pictures was optimized to 100%. Conclusions: The impairment observed in the experiment supports previous work that demonstrates that people with glaucoma have greater difficulties with complex visual tasks than is predicted by their visual field loss. The performance was equivalent to age-matched controls when contrast was maximized.

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[4P043] The evaluation of dynamic stereotests in the screening of amblyopia – a clinical study

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Amblyopia is a common disorder, which if left untreated, could cause irreversible damage. From the lack of stereovision we can suspect the presence of amblyopia, or eye disorders potentially leading to amblyopia. The currently available stereotests are not suitable to detect anomalies leading to amblyopia. The aim of this research was to test the dynamic random dot stereotest (DRDS) in the clinical practice. We examined 122 children at the pediatric ophthalmology outpatient clinic. The patients were either healthy or were diagnosed with eye diseases such as strabism, hyperopia, anisometropia or amblyopia, etc. All of them went through a regular ophthalmology examination and were also tested with the DRDS. Sensitivity and specificity were determined individually in all pathologies that can cause amblyopia. The overall sensitivity of DRDS for these diseases was 79,2 %, and specificity proved to be 66,2 %, compared to the gold standard Lang test (33.3% sensitivity, 98.6% specificity). Hyperopia was the most common from these pathologies, so we examined that in depth. Our data suggests that the DRDS would be a sensitive and reliable method for the screening of amblyopia or other eye disorders potentially leading to amblyopia.

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[4P044] Alternation frequency ranges for stereopsis in patients with strabismus

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Earlier, we reported estimates of the minimal frequency ( $F_{min}$ ) of alternative left-right presentations of stereo pairs of images necessary to obtain stereopsis in normal subjects (Rychkova and Ninio, 2009, Perception 38, Suppl.,59). The purpose of the present study was to estimate the alternation frequency ranges for stereopsis in patients with strabismus. We used 20 different stereograms (created by J Ninio) displayed on a monitor or presented on a synoptophore. 30 out of 34 patients with strabismus were able to perceive depth with the simple linear stereoscopic images. However, these patients required a higher  $F_{min}$  than normal subjects and, in addition, had an upper limit of alternation frequency ( $F_{max}$ ), unlike the normal subjects. Thus, for each patient, the values of  $F_{min}$  and  $F_{max}$  limited the frequency range in which he/she was competent for stereopsis. The widest ranges ( $7.6 \pm 0.6$  Hz for  $F_{min}$  and  $32.6 \pm 0.9$  Hz for  $F_{max}$ ) were found for simple linear stereoscopic images. Smaller ranges ( $10.1 \pm 1.1$  Hz for  $F_{min}$  and  $22.9 \pm 0.9$  Hz for  $F_{max}$ ) were found for stimuli containing slanted elements. Only 10 patients achieved stereopsis with complex random-dot images, within a narrow range of high alternation frequencies ( $22.3 \pm 1.5$  Hz for  $F_{min}$  and  $30.4 \pm 1.5$  Hz for  $F_{max}$ ).

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[4P045] Peripheral eye optics, blind retina and potential extent of nasal and temporal visual fields

**Galina Rozhkova, Ekaterina Kruttsova**

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Eye optics is well-studied for paraxial light beams falling onto a central retina. There are also some data on moderate eccentricities. However, to study the utmost retinal periphery, we need information on peripheral eye optics which is rather specific. For the light beams entering human eye through peripheral optics, the cornea is not a spherical but a conic structure, and the pupil transforms into a narrow oval slit. In an effort to establish a correspondence between retinal anatomy and functional properties, on one side, and the results of psychophysical measuring visual fields, on the other side, we collected the necessary data on the living eye (geometry of the cornea, lens and eye chambers; refractive indexes of the cornea, aqueous humor, superficial and core layers of the lens, etc.) and calculated the runs of the light rays to the extreme periphery of the retina. Our calculations have shown that the extension of the temporal visual field can exceed  $120^\circ$  and that the posterior margin of the blind retina on the temporal meridian most likely corresponds to ca.  $70^\circ$  in the nasal visual field. These data are in a good agreement with our measurements of the nasal and temporal visual fields.

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[4P046] Assessment of the blind retina margins by means of perimetry

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The data on the blind retina available in literature are rather scanty. In an unpublished manuscript of Yarbus, there is a sketch depicting the blind retina as a circular area that extends from ora serrata (anterior margin) and has variable width along retinal meridians gradually decreasing from temporal to nasal side. Schouten and Ornstein (1939, JOSA, 29, 168-182) illuminated temporal sector of the retina through the sclera and found certain evidence of the blind zone at 8-12 mm from the limbus. However, later, Fry and Alpern (1953, JOSA, 43, 187-188) couldn't reproduce this result. We tried to determine the blind retina posterior margins in terms of the visual angles by means of a standard perimetry with varying positions of fixation point in 5 subjects. The mean values of the horizontal nasal margins (in relation to the visual axis of the viewing eye) for the fixation angles 0°, 15°, 20°, and 30° (increasing eye turn from the nose), appeared to be 65.4°, 71.0°, 70.6°, and 71.3°, respectively. Thus, after some initial increase, the nasal visual limit remained practically unchanged indicating that the posterior blind retina margin on the temporal side corresponded to the nasal light beam directions close to 71°.

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[4P047] Amblyopia treatment: Advantages of virtual occlusion based on a contemporary 3D technique

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The aim of this study was to compare the effectiveness of amblyopia treatment by means of training programs designed to employ either permanent traditional occlusion of one eye (PTO) or variable virtual occlusion realized by means of 3D technique (PVO). The subjects were 60 amblyopic patients (aged 6-15 yr) undergoing a special combined treatment of amblyopia that included various standard procedures and interactive computer programs. All patients took the same standard treatment procedures but, for each patient, the type of computer program - PVO or PTO - was chosen randomly. The computer treatment course consisted of 10 sessions by 10 minutes. During the observation period, 20 patients (group 1) underwent one course of PTO, 28 patients (group 2) - one course of PTO and then one course of PVO, and 12 patients (group 3) - one course of PVO only. The mean increase of visual acuity in decimal units after the PTO course appeared to be  $0.11 \pm 0.06$  in group 1 and  $0.10 \pm 0.07$  in group 2 whereas after the PVO, the increase was  $0.16 \pm 0.09$  in group 2 and  $0.17 \pm 0.09$  in group 3, i.e. was significantly higher ( $p < 0.005$ ) indicating the advantage of virtual occlusion. In addition, virtual occlusion produced less discomfort.

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[4P048] A quick method for quantifying depth and extent of interocular suppression in amblyopes

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During binocular viewing, amblyopic eye sensitivity is reduced and interocular suppression present. Recent research has targeted suppression to improve binocular and monocular vision in amblyopia. To accurately and extensively quantify suppression across 24 deg of visual field, a dichoptic modulation-matching task exists. An efficient new clinical method intended for paediatric application is now tested in adult amblyopes. A friendly 'alien' character was presented dichoptically to the amblyopic eye at different horizontal visual field locations. Participants increased or decreased 'alien' modulation using a 2AFC staircase procedure to 'hide the alien' in fixed modulation surrounding noise presented to the preferred eye. Suppression for luminance-modulated (LM) and contrast-modulated (CM) noise stimuli was compared, as CM stimuli previously revealed deeper deficits for interocular blur (JoV, 2015) and amblyopic suppression (VSS, 2015). With the new clinical method, suppression patterns do not differ between LM and CM stimuli [ $p > 0.1$ ] but suppression was deeper for CM than LM stimuli [ $p < 0.1$ ]. A quick, robust clinical assessment of amblyopic suppression is therefore nearing reality.

Funding: College of Optometrists Postdoctoral Research Award

[4P049] The relationship between spatial/motion perception and traits of visual vertigo

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Visually-induced vertigo ('visual vertigo') is a condition where certain visual environments trigger dizziness and nausea. It is often attributed to dysfunction in visual-vestibular interaction, but the exact cause is unknown. We were

interested in any linkage between visual vertigo and motion and spatial processing. In an initial study, we measured traits of visual vertigo and performance on a battery of visual tasks in a healthy population (n=37). The battery included measures of motion perception and the area over which information is integrated (motion coherence; flanker; surround suppression), and the impact of task-irrelevant motion (visual search). It also included contrast sensitivity, orientation and shape judgements as indexes of general visual ability. We found that individuals with more visual vertigo traits showed stronger spatial suppression and had lower contrast sensitivity thresholds. No other tasks correlated with vertigo traits. Reliability checks (two sessions, two weeks apart) showed good reliability for some tasks (spatial suppression, orientation/shape judgements) but average to poor for others (motion coherence, flanker, visual search), which could have affected our ability to find a relationship with vertigo traits. Future work will test whether patients with a diagnosis of visual vertigo also show differences in these tasks.

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#### [4P050] Visual Compensation Method using Stereo Vision System for People with Color Vision Deficiency

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People with color vision deficiency have difficulty distinguishing different colors. Moreover, they encounter various limitations in everyday life, such as in terms of career choices and automobile license acquisition. Numerous researchers have worked hard in conducting studies to improve the quality of life of such people; the development of a color conversion method is the most popular research topic. Although color discrimination becomes possible by changing a color, color vision-deficient users have to receive an unnatural impression. Thus, we propose a visual compensation method using stereo vision system for people with color vision deficiency. Instead of changing a color, color discrimination is made possible by making a specific color area pop out. An object that has a color similar to that of its background can be recognized if it differs in depth. In our proposed method, when the difference of the color computed by color vision deficiency simulator and original color exceeds a threshold, the depth of the color area is changed dynamically in creating a stereo image. A simple experiment showed that artificially changed depth plays a key role in discriminating two similar colors.

#### [4P051] Using MRI to assess visual function during treatment for wet age-related macular degeneration

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Emerging treatments for wet age-related macular degeneration (AMD), including anti-angiogenic ocular injections, aim to restore function in the eye. Clinical measures of treatment success are limited primarily to retinal imaging and visual acuity, reflecting changes in retinal anatomy and letter discrimination, respectively. For vision restoration to be successful, however, the entire visual pathway must function properly. This project addresses whether MRI can be used as an objective measure of changes in visual function in the brain over the course of treatment. Ten wet-AMD patients underwent structural and functional MRI along with standard clinical measures before and monthly after receiving antiangiogenic treatment. fMRI stimulation consisted of full-field luminance modulation delivered in a block design to the treated and untreated eye separately. Brain responses were assessed from a large area encompassing early visual cortex and from individual regions representing the lesioned and intact retina. Both positive and negative responses were assessed. The proportion of positively-responding voxels to negatively-responding voxels increased after the first treatment in 7 out of 10 patients. Moreover, changes in fMRI response often differed from changes in visual acuity, suggesting fMRI can provide additional objective, patient-specific information about visual function over the course of treatment, complementing standard clinical assessments.

#### [4P052] Can an fMRI signature of reorganisation of visual processing in patients with retinal lesions be found in normally-sighted individuals?

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Macular degeneration (MD) results in central vision loss, removing input to the corresponding representation in V1.

There is disagreement concerning whether the Lesion Projection Zone (LPZ) can be activated, whether activation is task-dependent, and whether it is evidence for cortical reorganisation or feedback from extrastriate areas. To emulate MD in controls, 10 normally-sighted participants viewed a bright central 12deg disc to 'bleach' the retina, creating a transient 'retinal lesion' (simulated or 'sLPZ'). An fMRI experiment followed, in which participants viewed blocks of faces, scrambled faces and uniform grey, either passively or while performing a one-back task. Stimuli were presented peripherally abutting the 'bleaching' zone, and 'bleaching' was topped up between each stimulus block. Activity within the sLPZ was present in a few individuals during the one-back task. However, individual variability was high, and most participants showed no evidence of stimulus-driven activation within the sLPZ, regardless of task. A participant with Juvenile MD completed the same paradigm (without 'bleaching'), and demonstrated increased LPZ activity during the one-back task compared to passive viewing. Evidence that peripheral stimulation can produce central responses in controls performing a task suggests that LPZ activation in MD patients may be driven by feedback from extrastriate cortex.

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[4P053] The evidence of impairment the processes of identification in schizophrenia

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The purpose of the study is to examine the mechanisms of global and local analysis, features of their interaction and the role of interaction to ensure the integrity of perception in the task of recognition using fragmented images on model of schizophrenia. Subjects were 24 mentally healthy persons and 54 patients with schizophrenia. We used Gollin test. It was found that patients with schizophrenia require more contour fragments to recognize the object than healthy subjects. Individuals with first-episode schizophrenia require fewer fragments for recognition of the object contour than the chronically ill, as well as patients with paroxysmal type of the disease compared with patients with a continuous type of the disease. The results of the study certify the dysfunction of mechanisms of recognition of fragmented figures in schizophrenia, that is, mechanisms for building a complete image. Based on the theory of spatial-frequency filtering in the visual system, these mechanisms are mechanisms of global and local analysis. Thus, we have demonstrated dysfunction of the mechanisms of global and local analysis at the highest levels of information processing, showed that the severity of these disorders depends on the clinical picture and the type of the disease.

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[4P054] Central Contrast Sensitivity of Individuals with Dyslexia does not differ from age-matched Controls

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Dyslexia is characterised by persistent reading difficulties despite ample educational opportunity and intelligence, in the absence of optometric, ophthalmological and neuropsychological impairments (Cornelissen et al., 1995; Jones et al., 2016). Prominent visual dysfunction theories suggested to underlay the condition include the magnocellular deficit hypothesis, enhanced crowding effects, hypersensitivity to colour and attentional impairments (Qian & Bi, 2015; Gori & Facoetti, 2015; Kusano et al., 2015; Berninger et al., 2016). These experiments were programmed on MATLAB using the PTB extensions (Brainard, 1997). They followed a 2-AFC procedure and integrated a 1-up 3-down adaptive staircase methodology to determine the contrast thresholds. The stimuli incorporated were Gabors, two-dimensional sinusoidal gratings enveloped by a Gaussian function. Central achromatic and chromatic (blue-yellow and red-green), spatial (0.3, 1, 3, 10 and 20 cpd), static and temporal contrast sensitivities of subjects with dyslexia and controls were discerned. Analysis of variance revealed no significant differences between group performances on the static ( $F[1, 7]=0.19$ ,  $p=0.893$ ) or temporal tasks ( $F[1, 7]=0.874$ ,  $p=0.381$ ). No significant interactions of group with spatial frequency, colour and/or temporal frequency were evident. Central contrast sensitivity appears comparable between individuals with dyslexia and controls. Peripheral deficits have been found in adults with dyslexia however (Panchagnula et al., 2013).

[4P055] Eye-tracking based technic for detection of deception

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In the current study we assessed perspective of eye-tracking technic for revealing concealed information. Healthy adult participants (N=28) were randomly divided into two groups: “guilty” group and “innocent” group. We devised a mock crime scenario: 3 high-priced objects were hidden in the experimental room and each participant from the “guilty” group made a mock crime by “stealing” one of them. The other group didn’t take part in any activities related with the crime. Eye tracking recording was performed in both groups. 6 stimuli contained written questions related with the crime and according to the standard polygraph guilty knowledge test were exposed to the participants. We found statistically significant differences in fixation duration and fixation dispersion between two groups: “innocent” participants were looking at the distractors more frequently and their fixations were more distributed. At the same time “guilty” participants had fixations in the areas which were related with the object of crime and/or had more fixations in the blank areas. Saccade velocity was higher and saccade amplitude was smaller in the “guilty” group. Their gaze was moving at smaller distances within saccades and did it significantly faster than in the “innocent” group.

[4P056] On the robustness of the measurement of eye dominance strength based on saccadic parameters  
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It is well known that the saccadic system presents multiple asymmetries. Notably, saccadic peak velocities are higher for temporal saccades, for centripetal saccades and for the abducting eye. However, we have shown that eye dominance strength influences the naso-temporal asymmetry (Vergilino-Perez et al., 2012): while participants with weak eye dominance exhibit the classical naso-temporal asymmetry, participants with strong eye dominance exhibit higher peak velocities for a given saccade direction whichever the recorded eye. The current study tests the robustness of this classification by varying eye departure position, involving centrifugal and centripetal saccades, and by comparing saccades made by the abducting eye and the adducting one. Preliminary analyses on saccadic peak velocities indicate that our classification of eye dominance strength is found whichever the eye departure position. More precisely, participants with weak eye dominance exhibit all the classical asymmetries whichever the eye departure position, in contrast to participants with strong eye dominance that exhibit only the centripetal-centrifugal asymmetry. These results show (1) the robustness of our classification of participants based on eye dominance strength with analyses of saccadic peak velocities and suggest (2) that a strong eye dominance overrides the classical naso-temporal and abducting-adducting asymmetries.

[4P057] GridFix: A Python toolbox to facilitate fixation analysis and evaluation of saliency algorithms using Generalized linear mixed models (GLMM)

**Immo Schütz, Wolfgang Einhäuser, Antje Nuthmann**

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Why do humans fixate some areas of a scene and not others? Typically, this question is addressed by comparing features at fixated locations to baseline locations. Baseline choice is critical and often needs post-hoc sampling of fixated locations from other scenes, observers and/or conditions. To overcome this issue, we proposed to combine a-priori parcellation of scenes with GLMM (Nuthmann & Einhäuser, 2015). This approach also automatically accounts for feature dependencies and quantifies the unique contribution of individual features and other predictors, such as spatial biases. Here we present an open-source Python implementation of this method. The toolbox computes standard image features, allows for importing custom-made feature and salience maps, and provides scene parcellations of arbitrary granularity. It outputs a predictor matrix and source code to run GLMMs with lme4 in R, which the user can then adapt further. To exemplify the typical workflow, we compare different salience algorithms and how well they predict fixations above and beyond the central bias. Recent models outperform the classical saliency model of Itti et al. (1998). However, the effect of central bias varies between algorithms, suggesting that some augment their performance by (explicitly or implicitly) incorporating the tendency to look at scene centres.

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[4P058] Detecting Diplopia through Eye Movements: A Machine Learning Approach

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Discovery of patterns in big data could be applied for automatic diagnosis in vision. Specifically, massive recording of eye-tracking data could reveal visual disorders if properly analyzed. However, it is necessary to check that automatic methods can actually predict subjective responses before blind application. For instance, a particular example is automatic diplopia detection: it is well known that fusional vergence responds to retinal image disparity, being saccades the most efficient way to bring the image of interest onto the fovea [Danchaivijitr-2004]. This additional disparity information changes the basic eye movement properties, leading to an increased number of fixations and shorter and faster saccades [Jansen-2009]. Therefore, identifying these patterns may allow us to detect when the subject is suffering diplopia. In this work we have used recordings of subjects undergoing induced-disparity tests to develop diplopia-detection algorithms. Our models are based on decision tree classifiers, since they show a great deal of potential in many pattern recognition problems [Breiman-1984]. Furthermore, computational simplicity of these classifiers allows dealing with large amounts of data and making accurate predictions in short time periods, fast enough to perform real-time detection of diplopia. This suggests that machine learning can be effectively used to accelerate and improve diagnostics.

[4P059] Effects of ADAS notifications on driver's visual attention under simulator driving conditions  
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Whenever making calls, using mobile apps to socialize, texting or taking selfies, drivers are not paying sufficient attention to the road environment in order to arrive safely to the destination. Recently, the automotive industry has shown huge interest towards Advanced Driver Assistance Systems (ADAS). This research focused on investigating the influence of ADAS notifications in a scenario with distracting conditions while driving in EF-X Eca-Faros simulator. The eye glance behavior was analyzed for a series of 17 subjects that were asked to take selfies while driving 20 minutes in the virtual environment (VE). The data obtained regarding the glance behaviour was compared with a reference set of data – the same drivers, VE and distraction, but without the ADAS notifications. The eye-tracking system Tobii XL 120 was used to calculate the total eye-off-road time, number and duration of glances to the phone while performing the selfies tasks. A smartphone based ADAS[Duguleana2015] was used to notify the user with audio signals in case of eye-off-road events. The eye glance measurements show that the drivers took many short glances to the smartphone (< 1.6 s) while performing this task. When the ADAS was used the eye-off-road time decreased by 22 %.

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[4P060] New methods for an eye-tracker based on multiple corneal reflections  
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DAVALOR RESEARCH CENTER, UNIVERSITAT POLITECNICA DE CATALUNYA

Pupil and corneal reflection technique is one of the most commonly used in video based eye tracking because of its adaptability and simplicity. Especially, interpolation based methods, which use polynomial expressions to estimate the user's point of regard from the positions of the pupil and the glint and a set of coefficients deduced during the calibration process, are widely used since they can be set up with ease and do not require hardware calibration. Recently, a new 3D virtual reality system to assess human visual function has been developed (Eye Vision Analyzer (EVA) DAVALOR, Spain). It contains a multiple-corneal reflections dark-pupil eye-tracker which offers an unprecedented high resolution imaging of the pupil and the cornea and twelve IR LED light sources for efficient corneal tracking. The objective of this work was to develop new algorithms to improve its accuracy. Different light sources configurations were tested and the best accuracy values were obtained when multiple glints were considered. Moreover, the new system aims to be reliable when corneal reflections are partially occluded by eyelashes or eyelid make-up by means of robust ellipse fitting to the glints, which represents a substantial improvement on current eye-trackers and an important requirement for EVA's application.

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[4P061] Influence of simulated blur on kinematic of eye movements

**Marta S Bernadí, Josselin Gautier, Garcia-Guerra Carlos-Enrique, Carles Otero, Jaume Pujol**

DAVALOR RESEARCH CENTER, UNIVERSITAT POLITECNICA DE CATALUNYA

The effect of perceived blur on human visual system and eye movements remains largely unknown. In particular, the eye movement reactions to uniformly blurred stimuli, such as those experienced during a subjective refraction test. The goal of this study was to assess the influence of visual blur (here defocus) on fixations and saccades, specifically of large ( $> 22^\circ$ ) and small amplitude ("microsaccades"  $< 1^\circ$ ). A database of eye movements recorded on 168 natural images at 3 different levels of blur on 64 persons was used. Data were obtained with the Eyetracker ETL 400 ISCAN. The defocus was simulated by applying homogeneous blur on images by steps of one quarter of diopter (0.25, 0.50 and 0.75 Diopter). Participants had normal vision and were asked to free-view only one level of blur per image during 3 sec. Results showed that on average, when the blur increase the number of fixations decrease but the number of large saccades and microsaccades events increase. Moreover, the average microsaccade amplitude also raised with the induced blur. These results suggests that the perceived visual blur participates in adjusting eye movements at both large and fine scale, which could have potential clinical applications in the evaluation of subjective refraction.

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[4P062] CHAP: An Open Source Software for Processing and Analyzing Pupillometry Data

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Pupil dilation is an effective indicator of cognitive load. There are many available eye tracker systems in the market that provide effective solutions for pupil dilation measurement, which can be used to assess different cognitive and affective processes. However, there is a lack of tools for processing and analyzing the data provided by these systems. For this reason, we developed CHAP - an open source software written in Matlab. This software provides a user-friendly interface (graphical user interface) for processing and analyzing pupillometry data. The software receives input of a standard output file of the Eyelink eye tracker (EDF file) and provides both pre-processing and initial analysis of the data. Our software creates uniform conventions for building and analyzing pupillometry experiments, and provides a quick and easy-to-implement solution for researchers interested in pupillometry.

[4P063] Classification of Expertise in Photoediting based on Eye Movements

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Can expert knowledge be modeled by machine-learning algorithms based on eye-movement data (EM) in the domain of photoediting? To investigate this question we recorded EM from 4 experts and 4 novices during two photoediting tasks: set the 1- contrast or 2-color of a given image to the most aesthetically pleasing one. The stimuli were images acquired from expert photographers that were degraded either in 1-contrast or 2-color along the blue-yellow axis. Clustering of adjusted-contrast and adjusted-color showed two distinct groups corresponding to the experts and novices. For the experts the adjusted-value was closer to that of the original-image. A support-vector machine was trained to classify EM-based features (luminance at fixation, luminance-variance in small (3x3px) or large (51x51px) region around fixation, color at fixation, color-variance in small/large region) into experts or novices. Classification-accuracy was significantly higher for the contrast (60 %) than in color (52 %) adjustment task. Luminance-features were significantly more discriminative during contrast than during color-adjustment, and vice-versa for color-features. Luminance-features were more discriminative (60% accuracy) than color-features (54 %). Based on EM-based classification of observer expertise we conclude that EM encode task-relevant information (increased discriminability of color-/luminance-features in color/luminance-based tasks respectively).

[4P064] The testing of motion sickness resistance in virtual reality using eye tracking

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Prolonged exposure to moving images in virtual reality systems can cause virtual reality induced motion sickness (VIMS). The ability to motion sickness resistance may be associated with the level of vestibular function development. The aim of the present research is to study oculomotor characteristics during the observation of moving virtual environments causing the VIMS effect. We supposed that people, who have a robust vestibular function as a result of their professional activity, are less susceptible towards VIMS compared with people who have no such professional abilities. 30 figure skaters, 30 football players, 30 wushu fighters and 20 non-trained people were tested. The CAVE virtual reality system was used to initiate the VIMS effect. Three virtual scenes were constructed consisting of many bright balls moving as a whole around the observer. The scenes differed in the width of the visual field: all balls subtended 45°, 90° or 180°. The results showed more active eye movements for athletes compared to non-trained people — an increase in blink, fixation and saccade counts. The decrease in saccadic amplitudes was revealed for figure skaters. These characteristics were considered as individual indicators of the motion sickness resistance of athletes.

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[4P065] Gaze behavior in real-world driving: cognitive and neurobiological foundations

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Driving is a ubiquitous visual task, and in many ways an attractive model system for studying skilled visuomotor actions in the real world. In curve driving, several steering models have been proposed to account for the way drivers invariably orient gaze towards the future path (FP) and/or the tangent point (TP). For twenty years "steering by the tangent point" (Land & Lee, *Nature*, 1994) has been the dominant hypothesis for interpreting driving gaze data, and the textbook account of vision in curve negotiation. However, using some novel methods for analyzing real world gaze data, a number of studies from our group have recently undermined the generality of the TP hypothesis, supporting instead the FP models (Lappi et al., *J Vis*, 2013; Lappi, Pekkanen & Itkonen, *PLOS ONE*, 2013; Itkonen, Pekkanen & Lappi, *PLOS ONE*, 2015; review: Lappi, *J Vis*, 2014). This presentation integrates the findings of these experiments, with some previously unpublished results, and presents on that basis a theoretical framework of oculomotor control in visually oriented locomotion. The neurobiologically grounded theory is consistent with current computational theories of spatial memory and visuomotor control and neuroimaging work on the neural substrates of driving (Lappi, *Front Hum Neurosci*, 2015).

Funding: Supported by Finnish Cultural Foundation grant 00150514.

[4P066] The Other Race Effect on contextual face recognition

**Fatima M Felisberti, James John**

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We are a social species and face recognition plays an important role in our cooperative exchanges. The level of exposure to faces of a given race can affect their recognition, as observers tend to recognize faces of their own race better than faces of other races—the Other Race Effect (ORE). This study investigated ORE in the recognition of briefly encoded unfamiliar faces. Participants ( $n = 80$ ; 47.5% Caucasians, 52.5% Afro-Caribbean) were asked to encode three groups of faces tagged with different moral reputations (trustworthy, untrustworthy or neutral; 50% Caucasians, 50% Afro-Caribbean). The recognition test used a two-alternative forced-choice paradigm (2AFC: "old-new"). The findings showed a significantly higher sensitivity ( $d'$ ) for trustworthy and neutral faces in comparison to untrustworthy faces. In addition, Caucasian participants were significantly more sensitive (and faster) at recognizing faces of their own race than Afro-Caribbean ones (and vice-versa, although the amplitude of the difference was smaller). The findings confirm previous studies and also extend them by showing that ORE modulation of face recognition is sensitive to the moral information associated with the encoded faces.

[4P067] Incidental learning of trust does not result in distorted memory for the physical features of faces

**James Strachan, Steven Tipper**

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People can use their eyes to direct others' attention towards objects and features in their environment. A person who consistently looks away from targets is later judged to be less trustworthy than one that consistently looks towards

targets, even when the person is a background distractor that viewers are instructed to ignore. This has been shown in many experiments using trustworthiness ratings, but one outstanding question is whether these systematic changes in trustworthiness reflect perceptual distortions in the stored memory representations of these faces, such that faces that provide valid cues are remembered as looking more trustworthy than they actually were, and vice versa for invalid faces. We test this in two experiments, one where we gave participants the opportunity to morph the faces along a continuum of trustworthiness and asked them to report the image they had seen during the experiment, and one where we presented the original face images morphed to appear more or less trustworthy and asked participants to select from the two. The results of these two experiments suggest that this incidental learning of gaze contingencies does not result in distorted memory for the faces, despite robust and reliable changes in trustworthiness ratings.

[4P068] Pupillary response reflects the effect of facial color on expression

**Satoshi Nakakoga, Yuji Nihei, Shigeki Nakauchi, Tetsuto Minami**

Department of Computer Science and Engineering, Toyohashi University of Technology

The change of facial color and expression reflects our physical condition. Previous behavioral studies indicated that there is an interaction between facial color and expression. However, it is not clear how facial color affects expression. Our study investigated the contribution of facial color to expression recognition in blur images with the measurement of behavior and pupillometry. In the experiment, the face stimuli of facial colors (natural color, and reddish) with different expressions (neutral, and anger) in 3 blur levels were presented. Participants performed expression identification task. Behavioral results showed that the accuracy of the reddish-colored face condition was higher than that of the neutral-colored face condition, and this effect significantly increased in proportion to the blur levels. The ratio of peak pupil size between the expression conditions was computed. The ratio in the natural-color condition significantly increased in proportion to the blur levels. However, the ratio in the reddish-color condition remained substantially constant regardless of the blur level. This result indicated that the reddish-color provided the information necessary to identify anger. These results showed the contribution of facial color increases as blur level increases in both psychophysics and pupillary experiment, which suggested facial color emphasizes the characteristics of specific expression.

[4P069] Learning faces from inverted television

**Robin S Kramer, Rob Jenkins, Andrew Young, Mike Burton**

Department of Psychology, University of York

We learn new faces throughout life, for example in everyday settings like watching TV. Recent research suggests that image variability is key to this ability: if we learn a new face over highly variable images, we are better able to recognise that person in novel pictures. Here we asked people to watch TV shows they had not seen before, and then tested their ability to recognise the actors. Some participants watched TV shows in the conventional manner, whereas others watched them upside down or contrast-reversed. Image variability is equivalent across these conditions, and yet we observed that viewers were unable to learn the faces upside down or contrast-reversed – even when tested in the same format as learning. We conclude that variability is a necessary, but not sufficient condition for face learning. Instead, mechanisms underlying this process are tuned to extract useful information from variability falling within a critical range.

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[4P070] Precise Representation of Personally, but not Visually, Familiar Faces

**Duangkamol Srismith, Mintao Zhao, Isabelle Bühlhoff**

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People are good at recognising faces, particularly familiar faces. However, little is known about how precisely familiar faces are represented and how increasing familiarity improves the precision of face representation. Here we investigated the precision of face representation for two types of familiar faces: personally familiar faces (i.e. faces of colleagues) and visually familiar faces (i.e. faces learned from viewing photographs). For each familiar face, participants were asked to select the original face among an array of faces, which varied from highly caricatured (+50%) to highly anti-caricatured (-50%) along the facial shape dimension. We found that for personally familiar faces, participants selected the original faces more often than any other faces. In contrast, for visually familiar faces, the highly anti-caricatured (-50%) faces were selected more often than others, including the original faces. Participants

also favoured anti-caricatured faces more than caricatured faces for both types of familiar faces. These results indicate that people form very precise representation for personally familiar faces, but not for visually familiar faces. Moreover, the more familiar a face is, the more its corresponding representation shifts from a region close to the average face (i.e. anti-caricatured) to its veridical location in the face space.  
Funding: Max Planck Society

[4P071] The effect of facial familiarity on the assessment of facial attractiveness

**Yuan Zhou**

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Both facial familiarity and facial physical attractiveness play important roles on human social communication. Here, we investigated whether the facial familiarity will influence the perception of face attractiveness in the Asian female faces. The 50 subjects were divided into two groups and we selected the familiar faces for the participants in one of two groups. The selected faces were morphed with the novel faces to create the artificial faces of different familiarity levels. The subjects in two groups were instructed to rate the facial attractiveness and facial naturalness using the method of paired comparison. The results indicate that the familiarity decreased the assessment of facial attractiveness for the high attractive faces, but no significant effect on the normal attractive faces. The results are inconsistent with halo effect to some extent, and indicates an complex interaction between the facial attractiveness and familiarity.  
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[4P072] Uncanny Valley: social distance and prosopagnosia

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People prefer humanlike characteristics, looks and motion in toys, robots and avatars, as long as the likeness is not too compelling. This sudden dip in preference is labeled uncanny valley. One way to understand this interesting phenomenon in face perception is to investigate people with prosopagnosia. Two groups of Psychology students, controls (18, age 19-21, 5 males) and prosopagnosiacs (6, age 21-24, 4 males), estimated faces for familiarity and social distance (using Bogardus inspired scale). In the first experiment, human and robot faces were morphed (8 levels). Controls demonstrated standard decrease in familiarity as more robot characteristics were added ( $F(9,733)=20.11$ ,  $p < 0.0001$ ), while this tendency was much smaller in prosopagnosiacs ( $F(9,230)=2.23$ ,  $p < 0.021$ ). However, this perceptual effect did not influence social distance in prosopagnosiacs ( $F(9,230)=11.58$ ,  $p < 0.0001$ ) vs. controls ( $F(9,733)=11.59$ ,  $p < 0.0001$ ). In the second experiment, human, robot and symmetrical human faces were compared. Controls demonstrated expected preference for unchanged human face ( $F(3,301)=33.559$ ,  $p < 0.0001$ ), while prosopagnosiacs made no distinction ( $F(3,92)=1.31$ ,  $p < 0.27$ ). Again the perceptual effect did not influence social distance in prosopagnosiacs ( $F(3,92)=5.933$ ,  $p < 0.0001$ ) vs. controls ( $F(3,301)=15.503$ ,  $p < 0.0001$ ). In this study we obtained uncanny valley effect measuring it through social distance and showed the exclusively perceptual side of phenomenon by investigating people with prosopagnosia.

[4P073] Trustworthiness judgement from facial images and its relationship to outcome of political contest in South Asia

**Garga Chatterjee, Avisek Gupta, Ishan Sahu**

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Humans use facial information to judge or infer various aspects about a person. Such inferences or judgements may or may not represent real information about those aspects. Studies have shown that personality trait judgement from facial images has predictive value in various scenarios like differentiating between candidates from different political parties (Rule & Ambady, 2010), prediction of corporation performance from the facial appearance of CEOs (Rule & Ambady, 2008), etc. In the present study, we investigated whether inferences of trustworthiness based solely on facial appearance of election candidates to political offices in South Asia has any relation with the actual outcome of the election. Candidates were selected from closely contested elections from various regions. The photographs of the winner and first runner-up of an election were presented simultaneously to the experiment participants, who had to indicate which of the two faces appeared more trustworthy. The results showed that for 60% of the candidate pairs the

face-based trustworthiness judgement was not related to success in election. In most political contests, facial appearance based trustworthiness does not seem to matter in electoral contest outcomes in South Asia.

[4P074] Changes of eyes expression of a model affect a perception of facial expression

**Elizaveta Luniakova, Jahan Ganizada**

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Recognition of facial expressions of emotions was studied applying eye tracking technology. Three types of stimuli were used: (A) a set of photos of 2 male and 2 female faces each displaying six basic facial expressions; and two sets of composite photos (B and C). To construct stimuli “B” the eyes on a photo displaying one of basic emotional expressions (anger, fear, disgust, happiness, or sadness) were replaced by the eyes from a photo of the same person posing neutrality. Stimuli “C” were composed in the same way from portraits displaying neutrality and eyes from photo of a person posing one of five emotional expressions. The results did not show significant differences between photos “A” and “B” in expression recognition and in proportion of fixations on the various internal parts of the faces, except fear expression. A fearful face with neutral eyes was not perceived as fearful; a number of fixations on the eyes, nose and mouth increased; fixation durations became shorter. Facial expressions on photos “C” were not recognised as the same basic emotions which were posed on the original photos and were described as “concentration”, “contempt”, “distrust” and rarely as “neutral expression”. Fixation time on eyes area increased.

[4P075] Pupillary response to face-like processing

**Yuji Nihei, Tetsuto Minami, Shigeki Nakauchi**

Computer science and engineering, Toyohashi University of Technology

Most people have experienced a phenomenon where they perceive faces in the various non-face objects. This phenomenon is called “face pareidolia”. Several studies for the face pareidolia have been investigated using brain activity. In the present study, we investigated face pareidolia using pupillary response. The pupillary response was suggested to be influenced by high-level cognition (e.g. preference and, interest). Therefore, we predicted that change of pupil diameter may be induced by face pareidolia. In our study, we measured that pupil diameter when stimuli were perceived as faces. The stimuli consisted of five circles including a big circle and four small circles. The big circle as a face outline was presented on the center of display with four small circles arranged at random inside. The subjects performed two tasks (face-like and symmetry) to the same stimuli in the block design. In the face-like block, they were asked to make a face-like/not judgment and in the symmetry block, they were asked to make a symmetry/not judgment as results, pupil dilation for face-like task showed differences depending on the behavioral responses. However, pupil dilation for symmetry task showed no differences. These results suggest that this pupillary effect is specific for the face-like processing.

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[4P076] Disruption of face detection and individuation in schizophrenia: links with deficits of visual perception and selective attention

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Previous evidence (Butler et al., 2008; Chen et al., 2009) points to a greater impairment of face detection than face recognition in schizophrenia. To further investigate this distinction, we employed a set of tasks derived from Or & Wilson (2010), which seek to target specific aspects of face perception with separate tasks for detection and identification of faces. The tasks were based on a 2AFC discrimination and categorisation design, with presentation times varying in intervals of 1 frame per second (FPS) between 16.7 – 3006 milliseconds (ms). Bayesian adaptive estimation was employed to estimate the threshold of mean presentation time needed to achieve 75% accuracy on each task. Following attentional evaluation, participants in the control and schizophrenia group completed both detection and individuation tasks. Subjects with schizophrenia required a significantly greater mean presentation time than controls to achieve 75% accuracy on the face detection task but not the face identification task. In addition, this increase in presentation time was significantly correlated with the individual scores of the schizophrenia group on the attentional evaluation. These results indicate a link between impaired face detection in schizophrenia and severity of

negative symptoms in schizophrenia including inattention and lack of inhibition.

[4P077] Face direction or image direction?

**Elena Nikitina**

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Peculiarities in perception of faces turn to the left or to the right are repeatedly studied in psychology and art. Some authors explain the observed effects by the general principles of perception (Gross & Bornstein; Hufschmidt), and some – by the objective differences between the right and left sides of faces (Kean; Schirillo). In this study we tested two hypotheses: Right-directed faces are perceived more masculine than left-directed faces. Demonstration of right or left side of a real face is not related to gender recognition but can be taken into account during the attribution of personal qualities. We used photos of right and left directed faces of 7-year olds, 20-year olds and elder people and their mirror images. We found that left direction of female faces images significantly improved their gender identification. No difference for original photos and mirror images was observed. But our participants demonstrated the tendency to attribute more courage and intelligence and less honesty for mirror photos turned right.

[4P078] The speed of continuous face detection in a gaze-contingent paradigm

**Jacob G Martin<sup>1</sup>, Maximilian Riesenhuber<sup>2</sup>, Simon J. Thorpe<sup>1</sup>**

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We report that the continuous detection of small faces with the human eye is incredibly fast and resistant to fatigue. Subjects detected 500 faces with no background in only 107 seconds on average (N=24). Moreover, only an average of 27 additional seconds were required to detect 500 faces hidden in cluttered background photos. The fastest subjects processed 500 faces in 100 secs with no background and only required an average of 114 sec with a background. Inverting the faces significantly decreased subjects' accuracy and speed; as would be expected if the visual hierarchy prioritized the detection of objects according to experience or utility. These inversion effects were present within eccentricities which ranged from 4 degrees to 20 degrees, both with and without hiding the faces in a background. Funding: Funded by ERC Advanced Grant N° 323711 (M4) and R01EY024161

[4P079] Stepwise dimensional discrimination of compound visual stimuli by pigeons

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To document the dynamics of discrimination learning involving increasingly complex visual stimuli, we trained six pigeons in a stagewise Multiple Necessary Cues (MNC) go/no-go task. The compound stimuli were composed from 4 dimensions, each of which could assume either of two extreme values or the intermediate value between them. Starting with a stimulus composed entirely from intermediate values, we replaced those values with each of the two extreme dimensional values in four successive stages, thereby increasing the discriminative stimulus set from 2 in Stage 1 to 16 in Stage 4. In each stage, only one combination of dimension values signaled the availability of food (S+), whereas the remaining combinations did not (S-s). In each stage, training continued until the response rate to each of the S-s was less than 20% of the response rate to the S+. All pigeons acquired the final MNC discrimination. Despite the novelty of this stagewise design, we successfully replicated the key results of prior MNC discrimination studies: (1) speed of learning was negatively related to compound complexity, (2) speed of learning was negatively related to the similarity between S+ and S- compounds, and (3) attentional tradeoffs between dimensions were observed, especially in later training stages.

[4P080] Perceptual learning for global motion is tuned for spatial frequency

**Jordi M Asher, Vincenzo Romei, Paul B Hibbard**

Psychology, University of Essex

Perceptual learning research routinely demonstrates that improvements exhibit a high degree of specificity to the trained stimulus. A recent study by Levi, Shaked, Tadin, & Huxlin (2015), observed an improvement in contrast

sensitivity as a result of training on global motion stimuli. This study sought to further investigate this generalisation of learning. Participants trained daily, for five continuous days, on one of three global motion tasks (broadband, low or high frequency random-dot Gabors) with auditory trial-by-trial feedback. Additionally participants completed a pre and post training assessment consisting of all three levels of global motion (without feedback) as well as high and low spatial frequency contrast sensitivity tasks. Perceptual learning, during the five days training, occurred for low, and to a lesser extent for broad frequency conditions, but no improvement was found in the high frequency condition. Comparisons of pre and post assessments found improvement exclusively in the low frequency global motion condition. Furthermore, there was no transfer of learning between global motion stimuli. Finally, there was no improvement in contrast sensitivity for any trained frequency. This suggests that global motion training may not improve contrast sensitivity, and improvements at the visual level occur only with low frequency global motion tasks. Funding: This research was financially supported by a grant from ESSEXLab

[4P081] tRNS over the parietal lobe inhibits perceptual learning of task irrelevant stimuli

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Attention helps selectively sensitize the brain towards important visual information. However, unattended information can influence learning; the brain can unconsciously adapt to visual features (Watanabe 2001). In our study, we measured whether transcranial random noise stimulation (tRNS) facilitates this sensitization, or whether distracting information can inhibit the process. Subjects were divided into the “training group (TG)” or “no training (NG)” group. Both groups completed an orientation discrimination (OD) task on Day 1 and Day 5. On Days 2-4, the TG was presented with the same stimuli, but performed a temporal order (TOJ) of the Gabors used in the OD task. We hypothesized that stimulation would help process the unattended orientation, and lead to increased performance on Day 5. The NG performed no task during Days 2-4. Subjects were stimulated over hMT+, parietal cortex (Par), sham, or behavioral only (8 groups, two per condition). tRNS was administered during days 2-4. The NG-Par subjects performed significantly better on the OD task on Day 5. Conversely, the TG-Par subjects that underwent training performed significantly worse on the OD task on Day 5. When subjects are stimulated while performing an irrelevant TOJ task, inhibition of cortical processes involved in task irrelevant learning occurs.

[4P082] Transcranial Random Noise Stimulation (tRNS) Modulates Cortical Excitability of the Visual Cortex in Healthy Adults

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tRNS can induce long term increases of the corticospinal excitability of the motor cortex (Terney et al., 2008). Moreover, tRNS over the parietal cortex can improve mathematical skills. However, it is unclear whether tRNS over other areas causes similar changes in excitability. Our aim was to investigate whether tRNS over the visual cortex leads to increases in excitability similar to the motor cortex. In Experiment 1 we tested 12 participants in a within-subject design. To quantify the magnitude of cortical excitability changes, we measured phosphene threshold using an objective staircase method. Single-pulse TMS was used to elicit phosphenes before, immediately after, and every 10 minutes up to 1 hour after the end of 20min tRNS or Sham. In Experiment 2, 8 subjects underwent the same procedure, but were followed up to 2 hours post-tRNS. We found a significant effect of stimulation immediately after and up to 60 minutes after the end of the stimulation in Experiment 1. We replicated and extended these findings in Experiment 2, by showing that phosphene threshold returns to baseline at 90 minutes post-tRNS. Our findings demonstrates that tRNS can modulate the excitability of the visual cortex, and the effect is sustained and long lasting.

[4P083] Perceiving novel objects: The effect of learning on repetition blindness

**Idy W Chou, Dorita H. F. Chang**

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Repetition blindness (RB) refers to the failure in detecting the second occurrence of a repeated stimulus when a series of stimuli are presented in rapid succession. For familiar objects, RB is observed even if stimuli differ across orientations, suggesting RB must involve some view-invariant source. Here, we probed the source of RB in object perception by testing changes in RB across orientations before and after training using novel objects. In the RB task, novel object streams were presented under a RSVP paradigm and contained either repeated or non-repeated objects with varying orientation differences. Observers were asked to judge whether they saw a repeated item in the stream or not. In a second object discrimination task, two different or identical objects were presented in separate intervals and observers were asked to discriminate whether the objects were the same or different. Participants (N = 14) were tested on both tasks before and after training. Results indicated significant RB for novel objects across orientations even before training. Training reduced the overall magnitude of RB uniformly across orientations. These findings support a view-invariant source of RB, which has a locus earlier than object recognition, perhaps at the stage of featural processing and organization.

[4P084] Dichoptic perceptual training in juvenile amblyopes with or without patching history

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Dichoptic training is a popular tool in amblyopia treatment. Here we investigated the effects of dichoptic training on juvenile amblyopia no longer responsive to patching treatment (PT group) or never patch treated (NPT group). Training consisted of three stages. (1) 10 PT and 10 NPT amblyopes (8-17 years) received dichoptic de-masking training for 40 hours. They used AEs to practice contrast discrimination of Gabors that were dichoptically masked by a band-filtered noise pattern simultaneously presented in NAEs. Training improved maximal tolerable noise contrast for AE contrast discrimination by 350% in PT and 480% in NPT, which translated to stereoacuity improvements by 4.6-lines in PT and 3.0-lines in NPT, and AE visual acuity improvements by 1.3-lines in PT and 2.1-lines in NPT. (2) The amblyopes further received stereopsis training for another 40 hours. Training improved stereoacuity by 2.4-lines in PT and 0.5-lines in NPT, and AE acuity by 0 line in PT and 0.5 lines in NPT. Seven PT amblyopes regained normal stereoacuity after two stages of training. (3) Extra monocular AE grating acuity training (30 hours) failed to improve VA and stereoacuity in both groups. Our study confirmed the effectiveness of dichoptic training approaches in the treatment of juvenile amblyopia.

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[4P085] Learning when (and when not) to integrate audiovisual signals

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To promote effective interaction with the environment, the brain combines information received from different sensory modalities. Integration of cues relating to a common source can improve the precision of sensory estimates, but these benefits must be tempered against the costs of integrating cues relating to independent sources. To balance these competing demands, the brain restricts multisensory integration to cues that are proximal in space and time. Rather than being fixed, recent research suggests that the tolerance of audiovisual integration to temporal discrepancies can be altered via training. However, little is known about the mechanisms underlying these changes. Here, we measure the temporal and spatial tolerance of the ventriloquist effect before and after training on an audiovisual temporal discrimination task. We show that training leads to two distinct effects on multisensory integration in the form of (i) a specific reduction in the tolerance to discrepancies in time but not space, and (ii) a general reduction in the magnitude of crossmodal interactions across all spatiotemporal disparities. These effects arise naturally from a Bayesian model of causal inference in which learning improves the precision of audiovisual timing estimates, whilst concomitantly decreasing the prior expectation that stimuli emanate from a common source.

[4P086] Visual perceptual learning of a task-irrelevant feature of the stimulus

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Awareness, focused attention, and task-relevance were thought to be necessary for perceptual learning (PL): a Feature of the Stimulus (FoS) on which participants perform a task is learned, while a task-irrelevant FoS is not learned. This

view has been challenged by the discovery of task-irrelevant PL, occurring for subthreshold task-irrelevant stimuli presented at an unattended, peripheral location. Here, we provide further evidence for task-irrelevant PL by showing that it can occur for subthreshold task-irrelevant FoS presented in the fovea (hence spatially attended). Our experiment was divided into 3 stages: pre-test, training, and post-test. During pre- and post-tests, participants performed a 3-dot Vernier task and a 3-dot bisection task. During training, participants performed an unrelated task (luminance discrimination) on the same stimulus. The task-irrelevant FoS, manipulated during training, was the position of the middle dot: either a subthreshold left/right offset (Experimental Group) or in perfect alignment with the outer dots (Control Group). The Experimental Group showed performance improvements in the Vernier task but not in the bisection task; while the Control Group showed no effect on performance in either task. We suggest that PL can occur as an effect of mere exposure to a subthreshold task-irrelevant FoS, which is spatially attended.

[4P087] Broad learning transfer in visual hierarchical processing

**Kenji C Lau, Dorita H. F. Chang**

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Kenji C. K. Lau, Dorita H. F. Chang The literature has yielded mixed conclusions as to whether there is hemispheric specialization for the perception of hierarchical stimuli (e.g., Navon-type figures), with some findings indicating enhanced processing of local configurations in the left hemisphere and enhanced global (holistic) processing in the right hemisphere. Here, we tested hierarchical processing of stimuli in the two visual fields (left/right) to probe hemispheric specialization with perceptual learning. Participants (N = 16) were presented with letter-based, congruent and incongruent Navon figures and asked to judge the identity of either the global or local structure. Participants were tested in four conditions consisting of all combinations of the two visual fields and two tasks (global/local), before and after training on one of the four conditions. Results showed no interaction between the two visual fields for the two tasks. More importantly, training improved performance and speed (RT) for all conditions, regardless of the trained task or visual field. The results suggest hierarchical stimuli are processed comparably well by both hemispheres for both tasks and demonstrate extensive learning transfer between trained locations and tasks.

[4P088] Training transfer: from augmented virtual reality to real task performance.

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The aim of this study was to investigate whether augmented cues in VR that have previously been shown to enhance performance and user satisfaction in VR training translate into performance improvements in real environments. Subjects were randomly allocated into 3 groups. Group 1 learned to perform real tyre changes, group 2 were trained in a conventional VR setting, while group 3 were trained in VR with augmented cues, such as colour, sound and vibration changes signalling task relevant events or states. After training participants were tested on a real tyre change task. Overall time to completion was recorded as objective measure; subjective ratings of presence, perceived workload and discomfort were recorded using questionnaires. Overall, participants who received VR training performed significantly faster on the real task than participants who completed real tyre change only. Participants who were trained with augmented cues performed real task with fewer errors than participants in minimal cue training group. Systematic differences in subjective ratings that reflected objective performance were also observed. Results suggest that the use of virtual reality as a training platform for real tasks should be encouraged and further evaluated.

Funding: ESRC CASE,

[4P089] The role of vestibular inputs in self-motion perception by cutaneous sensation (2): Does the active motion of the perceiver facilitate or inhibit perceived self-motion by cutaneous sensation?

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Perceived self-motion has been substantially investigated in vision. But, Murata et al. (2014) reported the wind for cutaneous sensation with vibration for vestibule also occurred perceived self-motion. They called “cutaneous vection”. The authors of this study have compared perceived self-motion on cutaneous vection with actual body transfer. This

study compared active motion and passive motion. This experiment prepared three factors (with or without wind, transfer or vibration, and active motion or passive motion). We used a bladeless fan for cutaneous stimulus to the participant face and an AC motor for vibration to the participant body. The participant sat astride an aerobike. The fan and the aerobike were installed on a platform. The platform itself could move to and fro. In active motion condition, the participant pedaled the bike. Onset latency, accumulative duration and rating of subjective strength were measured. The latency was longer in active motion than in passive motion regardless of other factors ( $F(1,14) = 11.29, p = .00$ ). There was not significantly difference in duration. The rating was higher in with wind condition than without wind condition regardless of other factors ( $F(1,14) = 9.43, p = .01$ ). In this experiment, the active motion of perceiver inhibited the occurrences of perceived self-motion by cutaneous sensation.

[4P090] Coordination of eye-head movements and the amount of twist of the body while jumping with turn  
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Gymnasts stabilize their gaze before/during landing in a jump with half/full turn while coordinating eye and head movements. The aim of this study was to compare the differences between eye and head movements during jumps with half turn and those during jumps with full turn. The participants were male skilled gymnasts. They performed jumps with half turn (180 degrees) and full turn (360 degrees). Horizontal eye movement during these jumps was measured using electrooculography. Head movement was simultaneously recorded by high-speed digital camera. Gaze was determined from the obtained eye and head movement data. We found two main results: 1) When jumping with half turn, the gymnasts started gaze stabilization earlier than when jumping with full turn; 2) There was a correlation between the initiation times of gaze stabilization during the two kinds of jump. These results indicate that the amount of twist of the body while jumping with turn would affect timing of gaze stabilization during landing. Furthermore, gymnasts who delay stabilize their gaze before landing during jumps with half turn tend to also delay it during jumps with full turn.

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[4P091] Construction of a model of vection

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In vection studies, three main indices are used to gauge the illusory experience of self-motion (latency, duration and magnitude). We sought to identify the combination of these indices that best describes vection. The vection indices were taken from seven of our previous experiments, using 317 data-sets from a total of 107 participants. All three indices were highly and significantly correlated. To understand the properties underlying the generation of vection, we conducted a new vection experiment in which 10-minute-trials were repeated three times. We modeled the magnitude of vection over time using two time-varying functions; one sinusoidally modulating magnitude and the other slowly varying curve in magnitude. Vection duration adhered to a Gamma distribution. Therefore, vection can be considered an example of alternation between two phases of perception (e.g., Rubin's vase), and our data support the assumptions of this two-wave model. We further simulated 10000-trials using our model and found that the distributions of latency, duration and magnitude data were similar to actual data obtained from human observers. We propose a novel index of vection based on a weighted linear combination of the three measurable vection parameters, which provides benefits that can be easily implemented in future vection studies.

[4P092] A New Bias in Repeated Serial Subjective Estimation - Vection in a Contest of Japanese Comedians

**Emi Setoguchi, Takeharu Seno**

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When we estimate something subjectively, the estimated values tend to be smaller in the early phase and larger in the late phase. We analyzed the results of 20 contests of Japanese comedians (R-1, M-1 and King of Conte) in which 8 comedians were repeatedly ranked by professional reviewers estimating their skills of comedy. These estimated

rankings clearly showed the tendency we assumed, i.e. the first presenter had a disadvantage and the last presenter had an advantage. A significant main effect of the order of appearance number was obtained ( $F(7,133) = 2.42, p = 0.022$ ). Secondly, we conducted a vection (visually induced illusory self-motion perception) experiment in which 12 naïve participants subjectively estimated vection strength 8 times. We presented an expanding-grating-optical-flow for 30 seconds. They estimated the vection strength from 0 (no-vection) to 100 (very-strong-vection). The estimated vection strength increased as the trial number increased. A significant main effect of the trial number was obtained ( $F(7,77) = 2.56, p = 0.019$ ). The two tendencies corresponded well. Thus we conclude that we have found a new bias in repeated serial subjective estimations.

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[4P093] No evidence for a locomotion-induced change in human surround suppression

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Electrophysiological studies in rodents have shown that visual processing is modulated by the locomotion of the animal. (Niell & Stryker, 2010). In 2013, Ayaz et al. reported a surprising reduction in surround suppression (SS) in mice running on an air-cushioned ball. Here we used psychophysics to ask whether a similar effect is evident in humans. We measured contrast discrimination thresholds for Gabor patches at 5 different pedestal levels and three surround conditions ('no surround', 'high contrast parallel grating', 'high contrast orthogonal grating'). Data were measured while subjects were a) standing still, or b) walking briskly (7km/h) on a treadmill. We measured orientation-tuned SS in both conditions. However, the magnitude of SS increased rather than decreased in the locomotion condition. A further experiment indicated that one potential explanation for this increase was image blurring due to head movements during locomotion. We explore the possibility that the reduction in SS measured with electrophysiology in head-fixed rodents reflects a general reduction in contrast masking during locomotion that might serve to maintain edge contrast in jittered visual scenes.

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[4P094] Does vection affect sensitivity of smell?

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In recent years, many trials on displaying scents with other media such as movies and games have been conducted. We sometimes feel self-motion illusion (vection) while viewing a screen displaying translating patterns. Since no studies on the association between feeling of self-motion and the sense of smell have been reported, the aim of this research is to investigate the effects of vection on the sensitivity of scents. The ink-jet olfactory display developed by our team provides users with a pulse of scent in a hundred milliseconds. In our experiment, the subjects wearing a head mount display were asked to sniff scents emitted from the olfactory display with auditory cue. We measured the discrimination threshold of scents using pair-wise comparison of two scent-pulses with five visual-conditions (i.e., no visual stimulus, in-out and up-down vection stimuli) and two scent-conditions (i.e., lavender and banana.) The result of statistical tests showed that the discrimination threshold in vection conditions is higher than in no stimulus condition whereas there were no differences within vection and within scent conditions. This result indicates that vection stimuli improve in sensitivity of smell.

[4P095] Representation of egomotion in non-human primate

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The aim of this study is to characterize the cortical network processing egomotion-compatible optic flow in non-human primate. Functional MRI recordings were performed in 3 awake behaving macaques. The experimental protocol was similar to the one of a previous human study: we used a block design paradigm where the stimuli alternated between a baseline (fixation point only), a single patch of egomotion-compatible optic flow ('EC') and an array of nine similar optic flow patches that was inconsistent with egomotion ('EI'). We characterized the cortical areas responding to egomotion-compatible optical flow through the contrast 'EC' > 'EI'. Consistent with human data and single-cell studies in macaque, significant activations were found in dorsal MST, in area VIP and in the visual posterior sylvian

area (VPS). Responses in the pursuit area of the frontal eye field (FEFsem) and in area FST were also significantly stronger for the 'EC' condition. We did not find consistent activity in area V6 nor in the cingulate sulcus, two regions that are particularly responsive in human using the same experimental protocol. Altogether, our results suggest that if monkeys also have extended cortical networks to guide their navigation, these networks are not exactly homologous to those observed in human.

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[4P096] The role of a vestibular input in self-motion perception by cutaneous sensation (1): Does the transfer of the perceiver's position facilitate or inhibit the self-motion?

**Kayoko Murata<sup>1</sup>, Hidemi Komatsu<sup>2</sup>, Yasushi Nakano<sup>2</sup>, Shigeru Ichihara<sup>3</sup>, Naoe Masuda<sup>2</sup>, Masami Ishihara<sup>1</sup>**

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Multiple sensory modalities, such as vision and audition, contribute to the perception of self-motion (Gibson, 1966). Murata et al. (2014) recently found a new type of self-motion (i.e., vection) elicited by cutaneous sensation which accompanies vestibular inputs, proving that the self-motion perception is a multiple sensory phenomenon. The present study investigated the functional role of vestibular inputs in self-motion perception. We compared the vection in the following three conditions. In the first condition, the source of cutaneous stimuli (i.e., the wind coming from an electric fan) was moved in such a way that the wind was approaching the participant. In the second condition, the source of the wind was fixed and the participant's position was moved in such a way that the participant was approaching the source. In the third condition, serving as a control condition, both the source and the participant's position were fixed. The latency and duration were measured as indices of the vection. The results showed that the vection in the second condition appeared to be stronger compared to the first and control conditions. The transfer of the perceiver's position accompanying the vestibular input (e.g., acceleration) may facilitate the self-motion.

[4P097] The link between slow phases of opto-kinetic nystagmus and vection perception in virtual reality

**Artem I Kovalev, Galina Menshikova**

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Illusory self-motion (vection) describes the sensation of ego-motion induced by viewing moving stimuli in the absence of physical movement. This experiment investigated whether visually induced circular vection is changed if rotational velocities of 20, 40 or 60 o/s of stimuli are used. The vection illusion was evoked by the rotating opto-kinetic drum with black and white stripes in CAVE virtual reality system. 16 participants with healthy vestibular systems took part in this study. Several dependent measures were obtained: vection onset latencies, vection intensity, Simulator Sickness Questionnaire (SSQ) scores to evaluate motion sickness. Subjects passively observed rotating stimulation and pressed the button to indicate the vection appearance. We also used the eye tracking to examine parameters of opto-kinetic nystagmus (OKN) during vection perception. Results showed that onset latencies were significantly shorter, intensity ratings and SSQ scores were significantly higher for velocity of 60 o/s. We analyzed durations of OKN slow phases in period of 10 seconds after pressing a button. It was found that for velocity of 60 o/s slow phases were shorter in these periods compared to other time periods. Herewith such significant differences were not revealed in dependent measures for other rotational velocities.

[4P098] Does self-movement silence change detection?

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When flickering objects are moved across the retina perceived flicker decreases: suggesting that retinal motion "silences" change detection. Does the full-field retinal motion generated by self-movement impair change detection too? Or might, a compensation process attenuate the silencing effect in this case? We simulated self-movement using the York University Tumbling Room, and measured detection thresholds for a flickering target seen amongst an array of 8 or 98 similar but non-flickering elements. The stimuli were displayed on a screen attached to the far side of the room. The room was static or rolled around the participants' line of sight at ~20 or ~80 degree per second. The display was viewed full field or through goggles arranged so that only the screen was visible. Ten participants adjusted the

magnitude of flicker until it was just detectable. Change detection was impaired by room rotation with the largest effect at the faster speed. Field size and dot density differences had little effect. We found no evidence of a strong compensation process that reduces change detection. We hypothesise that we do not normally experience “silencing” because oculomotor systems effectively stabilise the retinal image during normal self-movement.  
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[4P099] The sound of body movements: Synesthetic sound symbolism observed in human gesture

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BASE, Kokushikan University & Tokyo University of Agriculture & Technology

This study used a pseudo-words invention paradigm to determine whether observing body movements induces sound symbolic effects. Four types of gesture movies were used, in which an actor’s right hand moved in round or spiky shapes with smaller or larger amplitudes. A half of the subjects observed the gesture motions; the other half observed only movements of a point-light on the screen describing the same four types of motions. Each subject invented three different names that they felt most appropriate for each motion. The collected pseudo-words were phonetically analyzed. Gestures drawing spiky shapes obtained more obstruent consonants than gestures drawing round shapes. Front vowels, rather than back vowels, were associated with spiky movements. The size factor also affected phoneme selections: voiced obstruents and back vowels were more selected for larger motions, while voiceless obstruents and front vowels were preferred for smaller motions. There were no significant group (hand-gesture vs. point-light-gesture) effects on these biased distributions of phoneme selections. These results suggest that certain consonants and vowels tend to be chosen to systematically represent kinematic properties of body movements such as size and shape. In conclusion, the effect of synesthetic sound symbolism was reproduced using dynamic images, instead of static pictures.  
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[4P100] Interactions between articulation and hand movements - congruency effects in Czech

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We have previously shown links between audiovisual speech categorization and manual precision and power grips. We have also demonstrated links between speech production and grips, or forward and backward hand movements in Finnish participants. Here we studied whether similar links exist for speakers of Czech. Visual stimuli were presented specifying articulations to be uttered, e.g. A and I. In Experiment 1 the articulations were randomly paired with precision or power grip responses. The congruency effect was replicated so that precision grips were faster when pronouncing KA, KE or A, compared to TI, TE or I. The pattern was reversed for power grip. In Experiment 2 the articulations were paired with forward or backward hand movements. There was no effect for KE-TE, unlike Finnish. However, the congruency effect was replicated for other stimuli, so that forward movement was faster when pronouncing I rather than A or O, and vice versa for backward movement. These findings show that the links between articulation and hand movements we have previously discovered are not specific to Finnish, but extend also to another language. We predict that these effects would be reflected into speech perception, too, largely independently of language background.

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[4P101] The influence of implicit representations on haptic shape perception

**Elizabeth S Collier<sup>1</sup>, Tushar Chauhan<sup>2</sup>, Rebecca Lawson<sup>1</sup>**

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The implicit representation of the size and shape of our hands is systematically distorted (Longo & Haggard, 2010). Specifically, the hand is mapped as wider, and with shorter fingers, than in reality. If haptic perception of the spatial properties of objects is affected by our perception of our body, then haptically perceived shape could be similarly distorted. We tested this prediction across two experiments. Replicating Longo and Haggard (2010), we found that participants overestimated the width of their hand. In addition, participants judged blocks as wider than they were in reality. This suggests that systematic distortions in the implicit representation of the hand led to similar, systematic

distortions in haptic shape perception in the absence of vision. However, this bias only occurred for larger (~10cm) stimuli that generally had to be grasped with the fingers spread well apart, and not for smaller (~6cm) stimuli that could easily be grasped. We also tested for individual differences in the strength of this distortion. Overall, our results suggest that implicit hand representations influence subsequent haptic shape perception. Longo, M. R., & Haggard, P. (2010). An implicit body representation underlying human position sense. *Proceedings of the National Academy of Sciences*, 107(26), 11727-11732.

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[4P102] Cross-modal correspondence between visual symmetry and taste

**Nora Turoman, Charles Spence**

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There has long been recognition that people tend to associate seemingly unrelated information across the senses, such that rounded shapes are systematically matched with sweetness, while angular shapes, to sourness/bitterness. Here, I present a previously unexplored dimension of visual-gustatory correspondences by demonstrating that symmetry, presented visually, influences the matching of shapes to tastes. Moreover, I provide evidence to a potential driving mechanism of this matching, through affective factors like valence (pleasantness) and perceived threat. In two experiments, participants viewed a series of computer-generated outline shapes, and rated them on sweet, sour and bitter taste, as well as pleasantness and threat. Rounded shapes were not only more associated with sweetness, but also, perceived as more pleasant and less threatening, whereas the inverse was shown for angular shapes. Shapes with multiple axes of symmetry were perceived as the most sweet, least bitter, most pleasant and least threatening compared to shapes with one axis of symmetry (regardless of axis orientation; Experiment 1), or asymmetric shapes (Experiment 2). These findings underscore the impact of visual symmetry on multisensory perception, and suggest an affective mediation hypothesis of cross-modal correspondences, whereby a common affective response to stimuli in different modalities guides their association.

[4P103] Moving hands perception in virtual reality

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The aim of the study was to investigate the effects of virtual body characteristics on subject's perception. Subjects moved their right hand and observed the avatar in the first-person perspective in head-mounted display. Virtual arm (tracked by Kinect) was displayed 10 cm to the right of the actual position of subject's arm. There were three conditions: asynchronous (pre-recorded virtual arm movements didn't coincide with the actual ones), synchronous anthropomorphic and synchronous non-anthropomorphic. Subject was asked to perform purposeful actions (dropping things from the table) in synchronous conditions while virtual body was either similar to human or consisted of parallelepipeds. Subject performed pointing task that measured the proprioceptive hand perception accuracy before and after each condition. Self-identification with the seen body was assessed by a questionnaire. Statistical analysis (ANOVA, corrected for multiple comparisons) revealed that 1) significant changes of proprioception in pointing task were in both synchronous conditions, regardless of whether the arm was anthropomorphic or not; 2) changes were detected in the asynchronous condition which indicated that moving arm observation from the first-person perspective also changed body position perception accuracy. Questionnaire results showed that body ownership was induced by synchronous conditions (both anthropomorphic and non-anthropomorphic) but not by the asynchronous one.

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[4P104] Auditory space around the body

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It is not still clear how auditory stimuli, delivered in space around the body, are coded. Here, we evaluated 11 subjects while performing a pointing task around the upper and lower part of the body. Subjects were positioned in the middle of a circumference, on which six targets were placed. Task required to reproduce, with the arm or with the foot, the trajectory of a moving sound radially moved from the subject toward one of the 6 targets, and then, reach the end point of the sound. Results report a better accuracy and precision in localizing sounds delivered in the upper space.

Furthermore, subjects were more accurate and precise on the rear and lateral space. More intriguing, our data suggests that, when sound is delivered at ground level, frontal stimuli are perceived as coming from the rear space. The same pattern of data was found when subjects performed the same pointing tasks, but with a verbal answer, suggesting that the effect was mediated by the perceptual processing of the audio stimulus. We discuss these data in terms of audio space perception and body representation.

[4P105] Echolocation modifies your peripersonal space

**Alessia Tonelli<sup>1</sup>, Claudio Campus<sup>1</sup>, Andrea Serino<sup>2</sup>, Luca Brayda<sup>1</sup>, Monica Gori<sup>1</sup>**

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A small group of blind individuals use echolocation to navigate and detect objects in space. Somehow echolocation could be thought as a tool used to interact with far space, as for example the white cane. Several studies have shown that in the space surrounding the body, stimuli from different sensory modalities are integrated creating a multisensory representation of space, known as peripersonal space (PPS). PPS modifies by experience. It can be extended by the use of a tool. In this study we investigated whether echolocation could modify the PPS of the head in sighted participants. We measured the reaction time (RT) of participants to a tactile stimulation, at different position, while their listening task-irrelevant looming auditory stimuli. PPS task was performed before and after an echolocation detection task. During echolocation the object was located inside PPS at 35 cm ahead the participant. We took a control group that repeated the PPS task two times consecutively. We found a significant decrease of RT before and after the echolocation task, but not in the control group. Data suggest that echolocation modify PPS. This modification is not due to a learning processes of PPS task, but it might be related to echolocation.

[4P106] Audio helps to rescue visual events to awareness, but there is no shortcut through audiovisual integration

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Many studies claim that bottom-up cross-modal integration can lead to automatic visual enhancement by sounds. Remarkably, several studies show cross-modal integration even when visual stimuli are suppressed from awareness. However, the role of top-down regulation has not been fully discarded. Here, we measured perceptual switches in a binocular rivalry paradigm after uninformative sounds, or after abrupt visual events on the suppressed or the dominant percept. Flashes and sounds occurred unpredictably and in an uncorrelated fashion, sometimes occurring together. Interestingly, a flash on the suppressed eye induced a faster switch when coinciding with a sound, than the flash or the sound when presented alone. Yet, contrary to the cross-modal integration account, the faster switches induced by bimodal events were well predicted by a probability summation model, assuming independent contributions of vision and sound toward the dominance flip. Thus, we conclude that despite sounds can 'rescue' subliminal visual stimuli to awareness, this effect cannot be attributed to bottom-up cross-modal integration. Instead, our results favor an interpretation based on the sum of two transient events, both independently contributing toward a faster alternation of conscious percept.

[4P107] Face and voice contributions to gender discrimination

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Maximum Likelihood Conjoint Measurement (MLCM) [Ho et al., 2008, Psychol. Sci., 19, 196-204] was used to quantify multi-modal cue integration in gender discrimination. Observers were presented with brief video sequences of stimulus pairs in which the face and voice genders were independently morphed from male to female. Six groups of observers judged either which face, voice or stimulus was either most masculine or feminine (6 observers/group, each group balanced in sex, 36 observers total, 1500 trials/observer). The MCLM signal detection model allows direct comparison and testing of the contributions of the two dimensions and their interactions in terms of  $d'$ . Male and female judgment conditions were combined as the results did not differ significantly after the sign was taken into account. Top-down influences were evidenced by task-dependent modulation of the face and voice contributions, but both dimensions significantly contributed to the decisions. However, voice information dominated face information in gender perception. The results support a dense cortical network for representing gender in which voice and face signals

are integrated at multiple hierarchical levels suggesting that selection processes may not be able to completely disentangle them in decision processes.

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[4P108] Exploring mirror-sensory synesthesia: differential effects on altruism and emotional context in pictures

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Mirror-sensory synesthetes mirror the pain or touch that they observe in other people on their own body. We hypothesized that this synesthesia would influence the synesthetes' reaction to pictures with an arousing context. We expected larger differences on pleasantness and arousal ratings. Mirror-sensory synesthesia is related to empathy: we therefore also quantified altruistic behavior. We diagnosed mirror-sensory synesthetes with an established touch-interference paradigm: synesthetes made more errors than controls when discriminating real touch from synesthetic mirror-touch. Participants rated pictures with positive, negative, and neutral context for valence and arousal on a 9-point Likert-scale (we additionally recorded heart rate, skin conductance, and pupil dilation; data not discussed here). Altruism was assessed with a Dictator's Game in which participants divide money between themselves and a second player. Preliminary results from ten participants (five synesthetes, five controls) show that synesthetes are more affected by negative and positive pictures than controls. The absolute differences of positive minus negative valence/arousal ratings are larger in synesthetes (valence: 4.9 vs 3.2; arousal: -3.2 vs -0.96). The Dictator's Game confirmed heightened altruism in synesthetes ( $t(7)=2.93$ ,  $p<.05$ ). So far, the data suggest that mirror-sensory synesthetes are more altruistic and are more strongly impacted by positive/negative images.

Funding: This research was supported by a VENI-grant [grant number 451-14-025] from the Netherlands Organisation for Scientific Research (NWO) to TvL

[4P109] Multimodal effects of color and aroma on predicted palatability of red milk beverages

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We have revealed quantitatively the effect of various colors and aromas on the "predicted palatability" of drinks before consumption. However, it is necessary to conduct fundamental investigations of the relationships between color and aroma, in particular, in the case of one color with different strengths or aromas with different strengths. We used four types of milk beverages which were colored in red as visual stimuli. As olfactory stimuli, we used eight types of flavor samples: two concentration conditions of strawberry, peach, blueberry and mint. These stimuli were evaluated by twenty participants in their twenties. Each visual stimulus was in a plastic-wrapped glass, and each olfactory stimulus was in a brown bottle. In the visual evaluation experiment, participants observed one milk without any olfactory stimulus. In the olfactory evaluation experiment, they smelled a flavor sample without any visual stimulus. Finally, they observed one of the milk beverages while smelling a flavor sample in the visual-olfactory evaluation experiment. Evaluated items were "predicted sweetness, sourness, umami taste, hot flavor", and "predicted palatability". The results show that the weighting factor of color on evaluating "predicted palatability" of red colored milk beverages was extremely smaller than that of the aroma.

[4P110] The Effects of Multisensory Cues on the Sense of Presence and Task Performance in a Virtual Reality Environment.

**Natalia Cooper<sup>1</sup>, Ferdinando Millela<sup>2</sup>, Carlo Pinto<sup>2</sup>, Iain Cant<sup>2</sup>, Mark White<sup>1</sup>, Georg Meyer<sup>1</sup>**

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The aim of this study was to evaluate the effect of visual, haptic and audio sensory cues on participant's sense of presence and task performance in a highly immersive virtual environment. Participants were required to change a wheel of a (virtual) racing car in the 3D environment. Auditory, haptic and visual cues signalling critical events in the simulation were manipulated in a factorial design. Participants wore 3D glasses for visual cues, headphones for audio feedback and vibration gloves for tactile feedback. Participants held a physical pneumatic tool. Data was collected in two blocks containing all eight sensory cue combinations. All participants completed all 16 conditions in a

pseudorandom sequence to control for order and learning effects. Subjective ratings of presence and discomfort were recorded using questionnaires after each condition. The time taken to complete the task was used as an objective performance measure. Participants performed best when all cues were present. Significant main effects of audio and tactile cue presentation on task performance and also on participants' presence ratings were found. We also found a significant negative effect of environment motion on task performance and participants' discomfort ratings.

Funding: ESRC funding body

#### [4P111] Auditory and tactile frequency representations overlap in parietal operculum

**Alexis Pérez-Bellido, Kelly A. Barnes, Jeffrey M. Yau**

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Traditional models of sensory cortex organization segregate auditory and somatosensory information in modality-specific cortical systems. Recent studies have shown that spatially overlapping regions of sensory cortex respond to both auditory and tactile stimulation, but whether they support common functions for audition and touch is unknown. In the present functional magnetic resonance imaging (fMRI) study we employed univariate and multivariate analysis approaches to characterize human cortical responses to auditory and tactile frequency information. Participants received auditory and tactile stimulation (75, 130, 195, 270 and 355Hz) in separate scans as they performed an attention-demanding frequency discrimination task. This design enabled us to quantify BOLD signal changes and spatial activation patterns to identical stimulus frequencies presented separately by audition or touch. Our univariate and multivariate analyses showed that primary sensory areas display specific response patterns to auditory and tactile frequency, consistent with traditional sensory processing models. Interestingly, higher-order somatosensory areas in the parietal operculum exhibited frequency-specific responses to both auditory and tactile stimulation. Our results provide further evidence for the notion that overlapping cortical systems support audition and touch. Moreover, our findings highlight the potential role of higher-order somatosensory cortex, rather than auditory cortex, in representing auditory and tactile temporal frequency information.

#### [4P112] Colour associations in synaesthetes and nonsynaesthetes: A large-scale study in Dutch

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For synaesthetes, specific sensory stimuli lead to additional experiences, e.g. letters evoke colours. An interesting question is whether crossmodal associations in synaesthesia are similar to crossmodal associations in the wider population. We performed a large-scale online survey consisting of multiple cross-modal association tasks (> 19.000 participants; > 30.000 completed tests). Synaesthetic associations are consistent over time; using consistency scores we classified 1128 synaesthetes. We mostly observed coloured days or months (N=~450), and grapheme-colour synaesthesia (N=~650). We compared synaesthetes' and nonsynaesthetes' colour choices. In letter-colour and number-colour association tests, grapheme frequency influenced colour associations. For letters, nonsynaesthetes (N=6178) as well as synaesthetes (N=344) chose high-frequent colours for high-frequency letters ( $p < .001$  for both groups) and numbers ( $p < .01$ ), but in both cases the correlation coefficients were higher for synaesthetes. Certain colour associations were made significantly more often, e.g. A was red ( $p < .001$ ) and X was gray ( $p < .05$ ) for both nonsynaesthetes and synaesthetes. In the music-color task (N=1864, 101 synaesthetes), musical mood affected colour choices. Synaesthetes chose different colours for different instruments. Additional tests included vowel-colour, Cyrillic letters-colour, weekday-colour, and month-colour associations. We compared crossmodal associations in large samples of synaesthetes and nonsynaesthetes: the results, so far, suggest that synaesthetic associations are similar to nonsynaesthete associations.

Funding: This research was supported by the Netherlands Organisation for Scientific Research (NWO) and by Dutch broadcasting company NTR

#### [4P113] Effects of object-specific sounds on haptic scene recognition

**Simon Hazenberg, Rob van Lier**

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In three experiments, we investigated the influence of object-specific sounds on haptic scene recognition. Blindfolded participants had to recognize, through touch, spatial scenes comprising six objects that were placed on a platform. In

half of the trials, object-specific sounds were played when objects were touched (bimodal condition), while sounds were turned off in the other half of the trials (unimodal condition). After exploring the scene, two objects were swapped and the task was to report which of the objects swapped positions. In Experiment 1, geometrical objects and simple sounds were used, while in Experiment 2, the objects comprised toy-animals that were matched with semantically compatible animal sounds. In Experiment 3, we replicated Experiment 1, but now a task preceded the experiment in which the participants learned to identify the objects based on tactile and auditory input. In all experiments, the results revealed a performance increase only after the switch from bimodal to unimodal. Thus, the release of bimodal identification, from audio-tactile to tactile-only produces a benefit that is not achieved for the reversed order in which sound was added after having haptic-only trials. We discuss these findings and relate them to task-related factors other than mere bimodal identification.

[4P114] The interactions with own avatars may improve the presence effect in virtual environments

**Natalya Krasilshchikova, Galina Menshikova**

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Various studies have proved that the use of natural interfaces which able to exploit body movements can contribute to increase the feeling of presence in the virtual environments. We investigated the subject's interactions with her/his own avatar through the use of virtual embodiment technology. The experiment consisted of two parts. In the first part the participants were asked to carry out body movements that were exactly copied by their own avatar displayed in front of the participant and repeat their motor actions several times to verify the existence of their own avatar. In the second part the participant performing body movements at some moment could perceive the avatar's movements that did not correspond to participant's movements. To measure the level of interactions between the participant and her/his own avatar the physiological reactions (EMG activity) were recorded during the performance. Then participants filled out questionnaire (IPQ) assessing their presence effect. The results showed that the summary EMG activity was significantly higher when body movements consistency was broken. Also the results revealed the correlation between body physiological reactions and the presence scores. Our data support the interaction paradigm that is based on maximizing the match between visual data and proprioception.

Funding: The study was funded by Russian Scientific Fund project № 15-18-00109

[4P115] Crossmodal transfer of emotion by music is greater for social compared to non-social visual cues: an event-related potential (ERP) study

**Neil Harrison, Linda Jakubowiczová**

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Studies have shown that music can influence the processing of subsequently presented visual stimuli. However, in many of these affective priming paradigm experiments a very wide range of visual stimuli have been used as cues. Given that music is a highly social form of communication, we tested whether music would have a greater influence on the emotional perception of visual cues containing social cues, compared to those containing no social cues. In an emotional priming experiment, participants listened to excerpts of music (happy, sad, or neutral) before an emotionally neutral picture from the IAPS database was presented. The picture could be either social (containing humans) or non-social (without humans). Participants had to rate the valence of the picture. ERP results showed that sad music primes elicited a higher P300 amplitude for social versus non-social visual cues. For neutral music there was no difference in P300 amplitude for social versus non-social cues. Importantly, the difference in P300 amplitude between social versus non-social cues was larger for sad music compared to neutral music. These results offer novel insights into the influence of social content on the capacity of music to transfer emotion to the visual modality.

[4P116] Eye-Fixation Related Potentials evidence for incongruent object processing during scene exploration

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Object processing is affected by the gist of the scene within which it is embedded. Incongruent objects result in prolonged and more frequent eye-fixations than congruent objects. In parallel, previous event-related potential (ERP) research has suggested that the congruency effect is reflected by a late ERP resembling the N300/N400 effect. The

present study investigates the effect of semantic congruency on scene processing using eye-fixation related potentials (EFRPs). We simultaneously registered electroencephalographic (EEG) and eye-tracking signals of participants exploring natural scenes in preparation for a recognition memory test. We compared EFRPs evoked by congruent vs. incongruent eye-fixations (e.g., a fork in a kitchen vs. the same fork in a bathroom). First, we replicated previous eye movement results, showing that incongruent objects were fixated more and longer than congruent objects. Second, the EFRP analysis revealed that the P1 EFRP and a later EFRP emerging around 260 ms after the fixation onset were modulated by semantic congruency. The top-down encoding of the scene was built during the first eye fixations; a mismatch between the semantic knowledge of objects and the features of the scene affected scene exploration. These results suggest that top-down information influences early object processing during natural viewing.  
Funding: This research was supported by Grants N00014-14-1-0670 and N00014-16-1-2128 from the Office of Naval Research (ONR).

[4P117] Reducing the impact of a restricted field of view when watching movies

**Francisco M Costela, Russell Woods**

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Magnification is commonly used to reduce the impact of impaired central vision (e.g. macular degeneration). However, magnification limits the field of view (FoV; e.g. only 11% (1/9) of the original is visible with 3x magnification). This reduction is expected to make it difficult to follow the story. Most people with normal vision look in about the same place, the center of interest (COI), most of the time when watching “Hollywood” movies, presumably as it is most informative. We hypothesized that if the FoV was around the COI, it would provide more useful information than using the original image center or an unrelated view location (the COI of a different clip). To measure the ability to follow the story, subjects described twenty 30-second clips in natural language. A computational linguistics approach was used to measure information acquisition (IA). Significant reductions in IA were found as FoV decreased (11% and 6%; highest magnification) for the original-center and unrelated-COI view locations. FoV around the COI had higher IA than the other conditions for the 11% and 6% FoVs. Thus, magnifying around the COI may serve as a video enhancement approach, potentially applicable to people with central vision loss.

[4P118] The interactive role of nCRF on CRF at cat's primary visual cortex to natural stimuli

**Ling Wang, Lipeng Zhang, Zhengqiang Dai, Jiaojiao Yin**

Key Laboratory for Neuroinformation of Ministry of Education, Center for Information in Medicine, School of Life Science and Technology, University of Electronic Science and Technology of China

By means of simple grating stimulus, it is known that the neuron responses at primary visual cortex in CRF (classical receptive field) are affected by outer stimulus in nCRF (non-classical receptive field). But in natural environment, visual stimulus are far more complicated than simple grating stimulus. It is unclear about the interactive role of nCRF on CRF at primary visual cortex under natural stimulus. With several natural movies, we compared the neuron responses in CRF and in CRF+nCRF to explore the role of nCRF. Generally, the responses to natural stimulus were weaker than to simple grating stimulus. Further, we found that the neuron responses depended on the type of outer nCRF. In our results, the final neuron responses were presented as: 1) inhibited when adding inhibitory nCRF and the selectivity to special natural features became stronger at same latency with that in CRF; 2) facilitated when adding facilitative nCRF and the selectivity became stronger at a delay latency; 3) inhomogeneous when adding mixed nCRF, such as first facilitated then inhibited, and the selectivity became weaker and spread. The results illustrated that, at primary visual cortex, the nCRF played important interactive and dependable role on CRF in extracting natural features.

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[4P119] Awareness level modulates ERPs for evolutionarily threatening images: investigating the snake detection hypothesis

**Simone Grassini, Suvi Holm, Henry Railo, Mika Koivisto**

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The snake detection theory claims that snake stimuli have shaped human visual system. According to this theory, predatory pressure provoked by snakes have selected individuals who were better able to recognize snakes, transferring

such skill to their offspring. The snake detection hypothesis has been previously tested using Event Related Potentials (ERPs). These studies have found that snake images produce an enhanced amplitude around 225-230 ms (Early posterior negativity, EPN) from stimulus onset, compared to other animal stimuli. As the snake detection advantage might be from evolutionary origin, it has been suggested that it may not be dependent on subjective awareness. The present study aims to test the hypothesis that the electrophysiological advantage for snake images is independent from aware perception. In our experiment, images of snakes, spiders, butterflies and birds were presented in five different conditions, where awareness was modulated using backward masking. Our results showed that snake images provoked an enhanced ERPs amplitude compared to the other animal images in unmasked conditions. However, the difference become smaller in conditions of reduced awareness, and disappeared on the most challenging perceptual conditions. Thus, the results show that the stimulus must be consciously perceived before the enhanced EPN for snakes emerges. Funding: This study was supported by the Academy of Finland (project no. 269156).

[4P120] Interaction of perceptibility and emotional arousal in modulating pupil size. fMRI study.

**Kinga Woloszyn, Joanna Pilarczyk, Aleksandra Domagalik, Michał Kuniecki**

Jagiellonian University

Pupil size indicates emotional arousal. EEG study revealed that emotional arousal indexed by the early posterior negativity is modulated by perceptibility of stimuli, with larger amplitudes for more visible arousing stimuli. Our study investigates the relation between perceptibility and pupillary changes while viewing emotionally arousing vs. non-arousing pictures in different signal-to-noise conditions, as well as brain activity related to pupillary changes in different arousal conditions. Twenty healthy participants had fMRI scans while performing free viewing task. Stimuli were shown by goggles with eye-tracking camera. 50 arousing and non-arousing natural scenes were selected from emotional pictures databases. To each original image pink noise was added in the following proportions: 0, 60, 70, 80, 100%. Change in pupil diameter was modulated by both noise level  $F(4, 68)=5.43$ ,  $p=.001$  and arousal  $F(1,17)=42.74$ ,  $p < .001$ . Interaction between these factors was also significant  $F(4,68)=9.31$ ,  $p < .001$ . Over decreasing noise level high arousing stimuli increased pupil diameter while low arousing stimuli decreased it. Pupil changes were related to the activations in primary visual areas, bilateral amygdala and cingulate sulcus in high arousal condition and bilateral insula and superior frontal sulcus in low arousal condition, suggesting different mechanisms of pupil size regulation depending on arousal level.

Funding: This work was supported by the Polish National Science Centre (grant number 2012/07/E/HS6/01046).

[4P121] Automatic analysis of smooth pursuit episodes in dynamic natural scenes

**Michael Dorr, Ioannis Agtzidis, Mikhail Startsev**

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We investigated smooth pursuit behaviour in dynamic natural scenes. Smooth pursuits (SP) are difficult to detect in noisy eye-tracking signals because of their potentially slow speed and short duration, and thus labour-intensive hand-labelling is still considered the gold standard. In order to facilitate (automatic) analysis of potentially huge gaze corpora, we recently developed an algorithm for SP detection (Agtzidis et al., ETRA 2016) that combines information from the gaze traces of multiple observers and thus achieves much better precision and recall than state-of-the-art algorithms. We applied our algorithm to a publicly available data set recorded on Hollywood video clips (Mathe et al., ECCV 2012), which comprises more than 5 hours of gaze data each for 16 subjects. With these professionally produced stimuli, where often at least one object of interest is moving on the screen, subjects performed a considerable amount of SP: SP rates ranged from 0% to 45% per video (mean=9.5%) and from 6.7% to 12.5% per observer (mean=9.7%). SPs had a long-tailed speed distribution with a peak at about 3 deg/s (median=3.82 deg/s), and showed a marked anisotropy towards the horizontal axis.

Funding: Research funded by the Elite Network Bavaria.

[4P122] The Influence of Detailed illustrations on Comprehension Monitoring and Positive Emotions

**Yu Ying Lin, Kiyofumi Miyoshi, Hiroshi Ashida**

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Illustrations containing colors and realistic details were often used to accompany the text in scientific textbooks. The present study examined the effect of detailed illustrations on positive emotions and comprehension monitoring

accuracy. In the experiment, students studied six human anatomy lessons with either detailed or simplified illustrations, judged how well they understood each lesson, and completed tests for each lesson. Students rated their positive emotions before and after learning the lessons. Monitoring accuracy was computed as the intra-individual correlation between judgments and test performance. The results showed that students who learned with detailed illustrations were less accurate in judging their comprehension than students who learned with simplified illustrations. Moreover, positive emotions of the students who learned with detailed illustrations decreased significantly after studying the lessons. Students who learned with simplified illustrations did not change significantly in positive emotions. The results support the idea that adding irrelevant details in instructional illustrations may prompt students to rely on invalid cues for predicting their own level of comprehension, resulting in poor monitoring accuracy. Detailed illustrations may also have negative impact on positive emotions of students, possibly due to the realistic anatomical details contained in the illustrations.

[4P123] Constructing scenes from objects: holistic representation of object arrangements in the parahippocampal place area

**Daniel Kaiser, Marius V Peelen**

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The prevailing view is that scenes and objects are processed in separate neural pathways. However, scenes are built from objects; when do objects become scenes? Here we used fMRI to test whether scene-selective regions represent object groups holistically, as scenes. Participants viewed images of two objects that usually appear together in a scene (e.g., a car and a traffic light). These object pairs were presented either in their regular spatial arrangement or with the two objects interchanged. Additionally, every single object was presented centrally and in isolation. We modeled multi-voxel response patterns evoked by the object pairs by averaging the response patterns evoked by the two single objects forming the pair. We hypothesized that this approximation should work well when an object pair is represented as two separate objects, but should be significantly reduced when an object pair is represented holistically. The scene-selective parahippocampal place area (PPA) showed good approximation for irregularly arranged object pairs. Importantly, this approximation was significantly reduced for regularly arranged object pairs. No such difference was found in control regions, including object-selective cortex. These results indicate that object groups, when regularly arranged, are represented holistically in the PPA, revealing a transition from object to scene representations. Funding: The research was funded by the Autonomous Province of Trento, Call "Grandi Progetti 2012", project "Characterizing and improving brain mechanisms of attention - ATTEND".

[4P124] Visual processing of emotional information in natural surfaces

**Isamu Motoyoshi, Shiori Mori**

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Visual appearance of a surface tells us not only what it is made from, but also what it means for us. In the nature, some surfaces look beautiful and attract us whereas the others look ugly and avert us. To investigate visual process underlying such emotional judgments upon surfaces, we asked observers to rate comfortableness and unpleasantness for a variety of natural and artificial surfaces (193 images). Analyzing the relationship between the human rating data and image statistics of surfaces, we found that unpleasantness was correlated with the SD at mid-spatial frequency bands and the cross-orientation energy correlation at high-spatial frequency bands ( $p < 0.01$ ). Comfortableness was specifically related with the luminance vs. color correlation at high-spatial frequency bands ( $p < 0.01$ ). Similar patterns of the results were obtained for statistically synthesized texture images ( $r > 0.75$ ), and for stimuli with a short duration (50 ms) that makes it hard to recognize surface category ( $r > 0.8$ ). These results indicate the existence of a rapid and implicit neural process that utilizes low-level image statistics to directly summon emotional reactions to surfaces, independently from the recognition of material.

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[4P125] Encoding basic visual attributes of naturalistic complex stimuli

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Despite numerous studies with simple stimuli, little is known about how low-level feature information of complex

images is represented. We examined sensitivity to the orientation and position of Gabor patches constituting stimuli from three classes according to their image type: Familiar natural objects, Unfamiliar fractal patterns, and Simple circular patterns. All images were generated by re-synthesizing an equal number of Gabor patches, hence equating all low-level statistics across image types, but retaining the higher-order configuration of the original images. Just noticeable differences of perturbations in either the orientation or position of the Gabor patches were measured by 2-AFC on varying pedestal. We found that while sensitivity patterns resembled those reported earlier with simple, isolated Gabor patches, sensitivity exhibited a systematic stimulus-class dependency, which could not be accounted for by current feedforward computational accounts of vision. Furthermore, by directly comparing the effect of orientation and position perturbations, we demonstrated that these attributes are encoded very differently despite similar visual appearance. We explain our results in a Bayesian framework that relies on experience-based perceptual priors of the expected local feature information, and speculate that orientation processing is dominated by within- hyper-column computations, while position processing is based on aggregating information across hyper-columns.

#### [4P126] Perceptual Organization of Badminton Shots in Experts and Novices

**Ehsan Shahdoust, Thomas H Morris, Dennis Gleber, Tandra Ghose, Arne Güllich**

Perception Psychology, TU Kaiserslautern

Expertise leads to perceptual learning that is not present in novices. Here we investigate whether such differences in perceptual organization can be measured by event-segmentation task. To date, there is no published data on event-segmentation of racket sports. We used videos of three different badminton shots (clear, smash, drop). Participants (5 Experts, 5 Novices) performed a classic button-pressing task (Newtson, 1976) and segmented the video-clips (60 shots, 1.25 seconds/shot, presented in random order). Overall, novice and experts had high event-segmentation agreement ( $R^2=0.620$ ). Nevertheless, during the initial 0.5 sec period (“movement” phase) there was no agreement between experts and novices ( $R^2=0.045$ ): Experts did not mark foot movements as significant events. Repeated measures ANOVA (expertise\*time\*shot) revealed a significant shot\*time interaction affect ( $p=.037$ ) but no affect for expertise. Time point analysis revealed that this interaction affect was seen only 0.5–0.75 sec before shuttle contact ( $p=0.05$ ). We conclude that (a) each shot type has a differential temporal event segmentation sequence; and (b) experts only segment during the “shot” phase and not during the “movement” phase. These findings help in the understanding of the perceptual processing responsible for anticipation skills in badminton.

#### [4P127] Effects upon magnitude estimation of the choices of modulus’ values

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We used the magnitude estimation to investigate how the range of stimuli influences visual perception by changing the modulus value. Nineteen subjects with normal or corrected-to-normal visual acuity (mean age=25.7yrs; SD= 3.9) were tested. The procedure consisted of two gray circles luminance of 165cd/m<sup>2</sup>, 18.3 degrees apart from each other. On the left side was the reference circle (VA of 4.5 deg) in which was assigned four arbitrary values: (1) 20, (2) 50, (3) 100 and (4) 500. The subjects' task was to judge the size of the circles on the right side of the screen assigning the number proportional to the changed size, relative to the circle presented on the left side of the screen (modulus). In each trial, ten circle sizes (1.0, 1.9, 2.7, 3.6, 4.5, 5.4, 6.2, 7.2, 8.1, 9.0 degree of visual angle at 50cm) were presented randomly. Our results shows a high correlation between the circle size judgment and different modulus sizes ( $R=0.9718$ ,  $R=0.9858$ ,  $R=0.9965$  and  $R=0.9904$ ). The Power Law exponents were (1) 1.28, (2) 1.34, (3) 1.29 and (4) 1.40. Increasing the size of modulus, bigger the exponent gets due the wide range of numbers available to judge the size.

#### [4P128] How information from low and high spatial frequencies interact during scene categorization?

**Louise Kauffmann, Alexia Roux-Sibilon, Dorante Miler, Brice Beffara, Martial Mermillod, Carole Peyrin**

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Current models of visual perception suggest that during scene categorization, low spatial frequencies (LSF) are rapidly processed and activate plausible interpretations of visual input. This coarse analysis would be used to guide subsequent processing of high spatial frequencies (HSF). The present study aimed to further examine how information from LSF and HSF interact during scene categorization. We used hybrid scenes as stimuli by combining LSF and HSF from two different scenes which were semantically similar or dissimilar. Hybrids were presented 100 or 1000 ms and

participants had to attend and categorize either the LSF or HSF scene. Results showed impaired categorization when the two scenes were semantically dissimilar, indicating that the semantic content of the unattended scene interfered with the categorization of the attended one. At short exposure duration (100 ms), this semantic interference effect was greater when participants attended HSF than LSF scenes, suggesting that information from LSF interfered more with HSF categorization than HSF did with LSF categorization. This reversed at longer exposure duration (1000 ms) where HSF interfered more with LSF categorization. These results suggest that the relative weight of LSF and HSF content varies over time during scene categorization, in accordance with a coarse-to-fine processing sequence.

[4P129] Large-scale human intracranial LFPs related to scene cuts in the TV series “Friends”

**Evelina Thunell<sup>1</sup>, Sébastien M. Crouzet<sup>1</sup>, Luc Valton<sup>2</sup>, Jean-Christophe Sol<sup>1</sup>, Emmanuel J. Barbeau<sup>2</sup>, Simon J. Thorpe<sup>1</sup>**

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Movies and TV series offer an opportunity to study the brain in conditions that closely match natural audio-visual settings. We recorded intracranial neural activity (LFPs) from epileptic patients as they watched episodes of the TV series “Friends”. To characterize the responsiveness of each intracranial electrode, we analyzed the response induced by scene cuts, which constitute major audio-visual events. We found scene cut-related activity throughout the brain, in visual and auditory, but also in higher-order cortices, which was consistent across hemispheres and patients (N=3). In the occipito-temporal cortex, the responses resemble typical visual evoked activity with peaks from around 100 to 600 ms depending on electrode location. In the hippocampus, perirhinal cortex, and temporal pole, we found activity already 400 ms before and lasting at least 400 to 700 ms after the scene cut. The pre-scene cut activity might reflect auditory responses to pre-cut changes of the sound atmosphere or anticipation of the scene cuts based on implicit knowledge of typical scene lengths and scene evolution. Electrodes in the frontal lobe show distinct responses between 100 and 700 ms. In summary, the scene cuts elicited clear exogenous and feed-forward, but perhaps also endogenous and top-down, responses in many different brain areas.

Funding: This research was supported by the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement nr 323711

[4P130] Experimental cognitive toponymy: what’s in a (place) name?

**David R Simmons, Leslie Spence**

School of Psychology, University of Glasgow

How do we decide what to call a landmark or geographical feature? The new field of cognitive toponymy focuses on the role of cognitive psychology in place name choices. To investigate the role of visual perception in place naming, we asked 19 young observers to verbally describe photographs of 60 geographical features. These photographs were deliberately chosen to be of distinctive landscapes, located in Scotland, which have existing names (unknown to the participants) based on their distinctive appearance. Full-colour images were presented on a computer screen at a viewing distance of 40 cm for one minute. The responses were recorded, transcribed and analysed to identify categories and sub-categories. Colour terms featured approximately 60% more often in descriptions than the next most common category, geographical classification (e.g. “hill”, “mountain”), and more than twice as much as the other common categories: composition (“dusty”, “rocky”), shape (body parts, animals), slope (“flat”, “steep”), texture (“bumpy”, “jagged”) and vegetation (“grassy”, “mossy”). Surprisingly there was very little (< 10%) correlation between the descriptions recorded and the historical names of these features. This method allows us to begin to unravel the cognitive processes which underlie place-name decisions and gain insight into historical naming puzzles.

Funding: Royal Society of Edinburgh Cognitive Toponymy Research Network

[4P131] What is actually measured in the rapid number estimation task?

**Yulia M Stakina, Igor S. Utochkin**

Psychology, National Research University Higher School of Economics (HSE)

Our brain is able to estimate number of objects rapidly, even without counting them. It is still unclear whether it necessary in visual estimation an accurate representation of the object itself or sufficiently process the features of sample? To answer the question, we appealed to the feature integration theory and particularly to the phenomenon of

asymmetry in visual search [Treisman, A., Gelade, G., 1980. *Cognitive psychology*, 12. 97-136]. If rapid number estimation is based on features, we should expect an increase of accuracy on stimuli with additional features in comparison with stimuli without features. Conversely, If the evaluation is based on the object representations, all the stimuli, regardless of the number of features are treated equally effective. During our experiment subjects were presented images with objects consisting of different number or quality of elements (such as O, Q, I, X). They were asked to estimate number of certain items. In some trials, target objects were cued before the stimulation, in other trials cue occurred after target objects. We found, that ability to estimate was based on feature representation, but only in “target before” condition, while in “target after” condition estimations were based on object representation.

Funding: The study was implemented in the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) in 2016, TZ-64.

[4P132] The effects of spatial dividers on counting and numerosity estimation

**Qi Li, Ryoichi Nakashima, Kazuhiko Yokosawa**

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Nakashima and Yokosawa (2013) reported that frames subdividing search displays facilitate serial but not parallel search. They suggested that frame enclosures of multiple items induce a grouping effect that facilitates the allocation of focused attention (grouping hypothesis). The purpose of this study was to further examine the grouping hypothesis by comparing the effects of spatial dividers on counting and numerosity estimation. It is known that counting is related to focused attention while numerosity estimation depends on distributed attention (Chong & Evans, 2011). In the counting task, participants counted the number of circles in the display. The circles were presented until a response was made. In the numerosity estimation task, participants provided a quick estimate of the number of circles in the briefly presented display. The number of frames subdividing the stimulus displays was manipulated in both tasks. The grouping hypothesis predicts a facilitative effect of spatial dividers only on the counting task, which requires focused attention. The results revealed that spatial dividers facilitated counting, but had little impact on numerosity estimation. These findings confirm the grouping hypothesis, and extend previous work by showing that the facilitative effect of spatial dividers on serial search generalizes to other tasks involving focused attention.

[4P133] Serial dependence for perception of visual variance

**Marta Suarez-Pinilla, Warrick Roseboom, Anil Seth**

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Despite being a crucial descriptor of the environment, variance has been largely overlooked in ensemble perception research. Here we explored whether visual variance is directly perceived and applied to subsequent perceptual decisions. In Experiment 1, participants scored the 'randomness' of motion of a cloud of dots whose individual trajectories were extracted from a circular Gaussian distribution with random mean (0-359°) and 6 standard deviations (5° to 60°). In Experiment 2, 1/3 trials did not require a response. Experiment 3 demanded confidence reports alongside randomness. We analysed participants' responses for serial dependence and observed a significant influence of the previous trial, with larger standard deviations in trial n-1 eliciting larger 'randomness' responses in the current trial, irrespective of whether the previous trial demanded a response, or whether the average motion direction was similar. This effect was larger when participants reported higher confidence in trial n-1, was not observed for trials n-2 to n-4, and was reversed for trials n-5 to n-10, with smaller standard deviations driving larger trial n responses. These results suggest that visual variance is transferred across observations irrespective of response processes, with recent sensory history exerting an attractive Bayesian-like bias and negative aftereffects appearing at a longer timescale.

[4P134] Visual-auditory interaction in perception of the variance

**Sachiyo Ueda<sup>1</sup>, Ayane Mizuguchi<sup>1</sup>, Reiko Yakushijin<sup>2</sup>, Akira Ishiguchi<sup>1</sup>**

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Human observers perceive the statistical information of environment to interpret them effectively. In particular, the variances are very important because they can be basis for perception of variety of objects in environment. It has been shown that human observer could perceive the variances effectively within the limits of in a single stimulus property. In real life, however, it is common to identify variances across several properties or modalities consisting of a single object. In this study, we used visual-auditory stimuli and explored whether cross-modal correspondent variance will facilitate perceiving the variance of a selected modality. We use sequential visual-auditory stimuli which have

variances in terms of size of visual stimuli and pitch of auditory stimuli. The participants estimated magnitudes of the variance of the size or the pitch. As a result, cross-modal correspondent stimuli did not have effects on the precision of the variance estimation. Constant pitch stimuli, however, produced underestimation of the size variance in the size-selected condition. It suggests that the variance magnitude of ignored auditory stimuli effected on magnitude of the variance of visual stimuli. This result suggests visual-auditory interactive mechanism in perception of the variance.

[4P135] Automatic detection of orientation variance within scenes

**Szonya Durant<sup>1</sup>, Istvan Sulykos<sup>2,3</sup>, Istvan Czigler<sup>2,3</sup>**

<sup>1</sup>Department of Psychology, Royal Holloway, University of London; <sup>2</sup>Institute of Cognitive Neuroscience Research Centre for Natural Sciences Hungarian Academy of Science; <sup>3</sup>Eötvös Loránd University Budapest

Visual Mismatch Negativity (vMMN) is an early ERP component that has been suggested to reflect automatic pattern detection over a sequence of images. It has been suggested that scene statistics are automatically detected. We tested whether orientation variance within scenes can elicit vMMN. We presented a set of Gabor patches of a given (random) mean orientation on each presentation in a sequence, and varied the variance of the orientations of the patches, so that some sets all had a similar orientation (ordered) or the individual orientations were random (disordered). These two types of sets of Gabor patches formed the standards and deviants in an unattended oddball paradigm. We found that a more disordered set of stimuli elicited a vMMN amongst ordered stimuli, but not vice versa. This suggested that the visual system was able to build up an expectation about a certain level of order, but not able to pick up on a pattern from disordered stimuli. Furthermore, in a test of ability to discriminate between ordered and disordered stimuli, we found that better discrimination corresponded with a larger vMMN amplitude. Automatic detection of the variance of orientations within a scene was shown and vMMN magnitude correlated with discrimination ability.

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[4P136] Anchoring predictions in scenes: Electrophysiological and behavioral evidence for a hierarchical structure in scenes.

**Sage E Boettcher, Melissa L.-H. Võ**

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Real-world scenes follow certain rules, “scene-grammar”, which are not well understood. We propose that scene-grammar is hierarchically structured, with three levels: scenes, anchors, and objects. Anchors are distinguishable from other objects in that they are large, salient, diagnostic of a scene, and importantly hold spatial information. In a behavioral experiment, participants clicked on the most likely location of an object (e.g. soap) relative to an anchor (shower) or another object (shampoo). We found that anchors show a smaller spatial distribution of clicks — i.e. stronger spatial predictions — compared to their object counterparts. An additional EEG experiment focused on understanding the interplay between these levels. Participants viewed two images presented in succession and determined their relationship. The first image – the prime – was either a scene (kitchen) or an object (pot). The second image was always an anchor, either consistent (stove) or inconsistent (bed) with the prime. The N400 ERP-component reflects semantic integration costs. A stronger semantic prediction activated by the prime should result in a greater violation and N400. We found a larger N400 when observers were primed with objects compared to scenes. This indicates that objects generate stronger predictions for anchors compared to the scenes containing them.

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[4P137] Neural substrates of early data reduction in the visual system

**Laura Palmieri, Maria Michela Del Viva**

Department NEUROFARBA, University of Florence

The visual system needs to extract rapidly the most important elements of the external world from a large flux of information, for survival purposes. Capacity limitations of the brain for processing visual information require an early strong data reduction, obtained by creating a compact summary of relevant information (primal sketch) to be handled by further levels of processing. Recently we formulated a model of early vision allowing a much stronger data reduction than existing vision models based on redundancy reduction. Optimizing this model for best information preservation under tight constraints on computational resources yields surprisingly specific a-priori predictions for the shape of physiological receptive fields of primary visual areas, and for experimental observations on fast detection of

salient visual features by human observers. Here we investigate the anatomical substrates of these fast vision processes by adopting a flicker adaptation paradigm, that has been shown to impair selectively the contrast sensitivity of the Magnocellular pathway. Results show that thresholds for discrimination of briefly presented sketches, obtained according to the model, increase after adapting to a uniform flickering field, while contrast thresholds for orientation discrimination of gratings do not change, suggesting the involvement of the MC pathway in this compressive visual stage.

[4P138] Simple reaction times as an implicit measure of the development of size constancy

**Carmen Fisher, Irene Sperandio**

Psychology, University of East Anglia

It has been suggested that simple reaction times (SRTs) can be used as a measure of perceived size, whereby faster SRTs reflect perceptually bigger objects (Sperandio, Savazzi, Gregory, & Marzi, 2009). As many developmental studies are limited to the child's comprehension of task instructions, the implicit nature of the aforementioned paradigm was deemed to be particularly appropriate for the investigation of size perception in children. Whether size constancy is an innate ability or develops with age is still under debate. A simplified version of Sperandio et al's (2009) paradigm was used to examine the detection profile in four age groups: 5-6, 9-10, 12-13 year-olds and adults. Participants were presented with pictures of tennis balls on a screen placed at two viewing distances. The stimulus size was adjusted, so the visual angle subtended by the stimulus was constant across distances. Luminance was also matched. It was found that SRTs responded to retinal and not perceived size in the 5-6-year-old group only, whilst older children and adults produced SRTs that were modulated by perceived size, demonstrating that size constancy was operating in these age groups. Thus, size constancy develops with age and is not fully accomplished until after 5-6 years of age.

[4P139] Dynamics of the perceived space under the self induced motion perception

**Tatsuya Yoshizawa, Shun Yamazaki, Kasumi Sasaki**

Research Laboratory for Affective Design Engineering, Kanazawa Institute of Technology

[Purpose] It is known that the perceived space is of non uniform in the Cartesian coordinate and is not same as the physical space. However, the dynamics of the perceived space surrounding us during the movement has not been clearly characterized yet, we therefore measured uniformity of the perceived space under the perception of the self-induced motion. [Methods] To give a feasible condition equivalent to the physical movement in terms of the visual state to observers, we used the perception of the self-induced motion. It is because the visual stimulus for the perception of the self-induced motion is the same as that when we are moving. Our observers performed the following two tasks in separate. They were asked whether three pairs of vertical bars with an optical flow background were allocated in the manner of parallel, or not, and whether all the pairs had the same distance between the bars, or not. [Results] In the both tasks, all observers showed the same performance which the perceived dimensions produced by the three pairs of the bars did not correspond with the physical dimensions. These results indicate that the perceived space is not of uniform despite whether an observer is moving or not.

[4P140] The perceived size and shape of objects in the peripheral visual field

**Robert Pepperell, Nicole Ruta, Alistair Burleigh, Joseph Baldwin**

Cardiff School of Art, Cardiff Metropolitan University

Observations made during an artistic study of visual space led us to hypothesise that objects seen in the visual periphery can appear smaller and more compressed than those seen in central vision. To test this we conducted three experiments: In Experiment 1 participants drew a set of discs presented in the peripheral visual field without constraints on eye movement or exposure time. In Experiment 2 we used the Method of Constant Stimuli to test the perceived size of discs at four different eccentricities while eye movements were controlled. In Experiment 3 participants reported the perceived shape of objects presented briefly in the periphery, also with eye movements controlled. In Experiment 1 the peripheral discs were reported as appearing significantly smaller than the central disc, and as having an elliptical and polygonal shape. In Experiment 2 participants judged the size of peripheral discs as being significantly smaller when compared to a centrally viewed disc, and in Experiment 3 participants were quite accurate in reporting the peripheral object shape, except in the far periphery. These results suggest objects in the visual periphery appear diminished when presented for long and brief exposures but only undergo shape distortions when

presented for longer times.

[4P141] Spatial phase discrimination in visual textures

**Endel Poder**

Institute of Psychology, University of Tartu

We can easily discriminate certain phase relations in visual textures but not others. However, the mechanisms of spatial phase perception are not well understood. This study attempts to reveal the role of local luminance cues in phase discrimination using histogram equalization of texture elements. From 2 to 5 texture patches were presented briefly around the fixation point. Observers searched for an odd (different) patch (that was present with the probability 0.5). Textures were composed of either simple Gabor waveforms (0 vs 90 deg phases), or compound Gabors (first plus third harmonics, edge vs bar phases). Both original and histogram equalized versions of patterns were used. The results show that phase is more easily seen in compound as compared to simple Gabors, and histogram equalization heavily reduces discriminability of phase differences. There was no effect of set size (number of texture patches). We conclude that local luminance cues play an important role in spatial phase discrimination in textures; there are some low level mechanisms that discriminate edges from bars; and division of attention does not affect the performance of the task used in this study.

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[4P142] Colour discrimination, coloured backgrounds, non-verbal IQ and global and local shape perception

**Alex J Shepherd<sup>1</sup>, Ardian Dumani<sup>1</sup>, Geddes Wyatt<sup>2</sup>**

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Background: Associations between global- and local-shape perception and colour discrimination were investigated. The shape tasks were completed on different background colours, although background colour was irrelevant to either task. The colours selected were tailored to the cone-opponent pathways early in the visual system. This study extends one presented at the 2015 ECVF by including non-verbal components of the WAIS, and Ravens Progressive Matrices Plus, to assess general ability. Method: Participants were presented with either a global square made up of small square (congruent) or diamond (incongruent) local elements, or a global diamond made up of small diamond (congruent) or square (incongruent) local elements. Each display was presented on five coloured backgrounds (tritan/S-cone: purple, neutral, yellow; L(M)-cone: red, neutral, green). Results: Participants were more accurate at the global task than local and responded more quickly for congruent than incongruent trials, as expected. There were no significant differences between performance on any of the coloured backgrounds. There were, however, significant correlations between colour discrimination (Farnsworth-Munsell scores) and some of the shape tasks. Participants with poorer colour discrimination were less accurate despite colour being irrelevant. There were significant correlations between performance on the Farnsworth-Munsell, local-global shape, and the WAIS and progressive matrices tasks.

[4P143] Examining the spatial extent of orientation-tuned contextual modulation in human V1 with fMRI

**Susan G Wardle, Kiley Seymour**

Department of Cognitive Science, Macquarie University

Recent results in macaque V1 and human psychophysics suggest that the orientation-tuning of surround suppression is modulated by the spatial extent of the surround [Shushruth et al., 2013, J. Neuroscience]. Here we examine the spatial range of orientation-tuned surround suppression in human V1 with fMRI. Both target and surround were 1 c/deg 4Hz counterphasing sinewave gratings at one of four orientations [0, 90, 45, 135 deg] presented in a block design. In each 20s block, the inner target annulus [radius: 1.5-3.5 deg] and a near [radius: 3.5-6 deg] or far [radius: 6-9.5 deg] surround annulus was presented for the first 10s, followed by the target alone for 10s. The orientation of the target and surround gratings was either parallel or orthogonal. Voxels responding preferentially to the target were isolated using independent localiser runs. Consistent with previous results, greater suppression of the BOLD response to the target occurred for a parallel near surround than for an orthogonal near surround. The results differed for the far-surround, and facilitation of the BOLD response to the target occurred for the orthogonal far-surround. The results suggest that the orientation-tuning of contextual modulation in human V1 is modulated by the spatial extent of the surround.

[4P144] Wish I was here – anisotropy of egocentric distances and perceived self-location

## **Oliver Tošković**

Laboratory for experimental psychology, Faculty of philosophy University of Belgrade

Perceived egocentric distances are anisotropic since vertical distances are perceived as larger than horizontal. This is explained by action-perception relation: enlargement of perceived vertical distances helps us in performing actions because they require more effort on that direction. Surprisingly, in previous studies we did not gain perceived distance anisotropy in near space, which would be expected according to our explanation. We performed three experiments, with participants sitting on a floor, in a dark room, instructed to equalize egocentric distances of two stimuli on vertical and horizontal direction. In first experiment standard stimuli distances were 1m, 3m and 5m, in the second 0.4m, 0.6m, 0.8m and 1m, while in the third they were 0.8m and 1m. In first two experiments participants matched stimuli distances from themselves, while in the third we varied the instruction in three ways: match the distances from you-self, from your right eye, and from your right shoulder. Perceived distance anisotropy exists in near and far space, since in all experiments vertical distances were perceived as larger. Instruction variations in did not change our results, meaning that participants do not locate themselves on some exact point, such as eye or shoulder, in this type of experiment.

[4P145] Visual discrimination of surface attitude from texture

**Samy Blusseau<sup>1</sup>, Wendy Adams<sup>1</sup>, James Elder<sup>2</sup>, Erich Graf<sup>1</sup>, Arthur Lugtigheid<sup>1</sup>**

<sup>1</sup>Psychology, University of Southampton UK; <sup>2</sup>York University Canada

Judgement of surface attitude is important for a broad range of visual tasks. The visual system employs a number of cues to make such estimates, including projective distortion in surface texture. While egocentric surface attitude is comprised of two variables (slant, tilt), prior surface attitude discrimination studies have focused almost exclusively on slant. Here we employ novel methods to estimate the full 2D discrimination function, using a real textured surface mounted on a pan/tilt unit and viewed monocularly through a 3° aperture. Our experiment was a 3-interval match-to-sample task in which the observer indicated which of the 2nd or 3rd (test) attitudes matched the 1st (standard) attitude. The stimuli could vary in both slant and tilt. We found that thresholds for tilt decrease with slant, as geometry predicts, however thresholds for slant remain relatively invariant with slant. This latter finding is inconsistent with the results of Knill & Saunders (2003), who measured slant thresholds for varying slant but fixed tilt. In contrast, our task required observers to simultaneously estimate both slant and tilt. We discuss the implications of this result for models of surface attitude estimation.

Funding: Work supported by EPSRC (UK) grant EP/K005952/1

[4P146] Shape discrimination. Why is a square better than a triangle for a jumping spider?

**Massimo De Agrò<sup>1</sup>, Iacopo Cassai<sup>1</sup>, Ilaria Fraccaroli<sup>1</sup>, Enzo Moretto<sup>2</sup>, Lucia Regolin<sup>1</sup>**

<sup>1</sup>General Psychology Department, University of Padua; <sup>2</sup>Esapolis Living Insects Museum of Padova Province and of the MicroMegaMondo of Butterfly Arc (Padualtaly)

The ability to discriminate shapes is typically present in animals endowed with complex eyes, like Salticidae, a family of spiders who navigate through their environment actively hunting for various prey (mostly other arthropods). We trained 36 juveniles or sub-adults (before sexual identification) of the Salticidae species *Phidippus regius* on triangle vs. square discrimination. Spiders were individually placed in a T-shaped maze and could choose among the two shapes, matched for total area. A prey was placed behind S+ (either square or triangle), which left/right position varied semi-randomly. Spiders were tested in an unrewarded discrimination trial. Spiders didn't shown a significant preference for the trained shape, though subjects that had been trained on triangle showed a preference for the square (2vs11,  $p=0.022$ ), spiders trained on the square instead did not exhibit any preference (8vs8). The trend for the subjects trained on the triangle to choose the novel stimulus was confirmed also when restricting the analysis to spiders who passed a subsequent motivation test (0vs8,  $p=0.0078$ ). This effect could depend on some peculiar features of the square, which may act as super-stimulus with respect to the triangle. Future investigation will focus on discrimination of alternative shapes, such as circle and square.

[4P147] Measures of orientation-tuned inhibition in human primary visual cortex agree with psychophysics

**Kiley Seymour<sup>1</sup>, Timo Stein<sup>2</sup>, Colin Clifford<sup>3</sup>, Philipp Sterzer<sup>4</sup>**

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The perceived tilt of an oriented grating is influenced by its spatial and temporal context. The Tilt Illusion (TI) and the Tilt After Effect (TAE) are clear demonstrations of this. Both illusions are thought to depend on shared neural mechanisms involving orientation-tuned inhibitory circuits in primary visual cortex (V1). However, there is little functional evidence to support this. We measured local functional inhibitory circuitry in human V1 of 11 participants using functional magnetic resonance imaging (fMRI). Specifically, we examined surround suppression of V1 responses, indexed as an orientation-specific reduction in Blood-Oxygenation-Level Dependent (BOLD) signal in regions of the cortical map being inhibited. In a separate session, we also measured TI and TAE magnitudes for each participant. We found that the level of surround suppression measured in V1 correlated with the magnitude of participants' TI and TAE. This good quantitative agreement between perception and suppression of V1 responses suggests that shared inhibitory mechanisms in V1 might mediate both spatial and temporal contextual effects on orientation perception in human vision.

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### ***Thursday September 1st Symposia presentations***

[41S201] Healthy ageing and visual motion perception

**Karin S Pilz**

School of Psychology, University of Aberdeen

Motion perception is a fundamental property of our visual system and being able to perceive motion is essential for us to navigate through the environment and interact in social environments. It has been shown that low-level motion perception is strongly affected by healthy ageing. Older adults, for example, have difficulties detecting and discriminating motion from random-dot displays. We have shown that these low-level motion deficits can be attributed to a decline in the ability to integrate visual information across space and time. Interestingly, in recent studies, we found large differences for motion direction discrimination across different axes of motion, which indicates that an age-related decline in low-level visual motion perception is not absolute. Despite age-related changes in low-level motion perception, the processing of higher-level visual motion is less affected by age. We recently showed that older adults are able to discriminate biological motion as well as younger subjects. However, they seem to rely on the global form rather than local motion information, which suggests that high-level motion perception in healthy ageing is aided by mechanisms that are not necessarily involved in the processing of low-level motion. I will discuss the findings within the context of age-related changes in neural mechanisms.

Funding: BBSRC New Investigator Grant (BB/K007173/1)

[41S202] How does age limit learning on perceptual tasks?

**Ben Webb, Paul McGraw, Andrew Astle**

Visual Neuroscience Group, The University of Nottingham, UK

Ageing appears to place biological limits on sensory systems, since sensory thresholds typically increase (i.e. visual performance deteriorates) on many perceptual tasks with age. Here we ask whether ageing places concomitant limits on the amount an organism can learn on perceptual tasks. We will argue that ageing should be considered alongside a range of other factors (e.g. visual crowding) that limit sensory thresholds on perceptual tasks, and that this initial performance level is what determines the magnitude of learning. Consistent with this view, we will show that initial sensory thresholds are inversely related to how much participants learn on perceptual tasks: poorer initial perceptual performance predicts more learning on perceptual tasks. Since sensory performance deteriorates with age, it follows that the magnitude of learning on perceptual tasks should increase with age. And this is exactly what we find: learning is larger and faster in older adults than younger adults on a crowded, word identification task in the peripheral visual field. And the magnitude of learning was a constant proportion of the initial threshold level. This Weber-like law for perceptual learning suggests that we should be able to predict the degree of perceptual improvement achievable at different ages via sensory training.

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[41S203] Is there a common cause for perceptual decline in the aging brain?

**Michael H Herzog<sup>1</sup>, Karin Pilz<sup>2</sup>, Aaron Clarke<sup>3</sup>, Marina Kunchulia<sup>4</sup>, Albulena Shaqiri<sup>1</sup>**

<sup>1</sup>BMI, EPFL Switzerland; <sup>2</sup>University of Aberdeen, UK; <sup>3</sup>Bilkent University, Turkey; <sup>4</sup>Beritashvili Institute, Georgia

Even in the absence of neurodegenerative disease, aging strongly affects vision. Whereas optical deficits are well documented, much less is known perceptual deficits. In most perceptual studies, one paradigm is tested and it is usually found that older participants perform worse than younger participants. Implicitly, these results are taken as evidence that all visual functions of an individual decline determined by one factor, with some individuals aging more severely than others. However, this is not true. We tested 131 older participants (mean age 70 years old) and 108 younger participants (mean age 22 years old) in 14 perceptual tests (including motion perception, contrast and orientation sensitivity, biological motion perception) and in 3 cognitive tasks (WCST, verbal fluency and digit span). Younger participants performed better than older participants in almost all of the tests. However, within the group of older participants, age did not predict performance, i.e., a participant could have good results in biological motion perception but poor results in orientation discrimination. It seems that there is not a single “aging” factor but many.

Funding: Velux Foundation

[41S204] Keeping focused: Selective attention and its effect on visual processing in healthy old age

**Clíodhna Quigley<sup>1</sup>, Søren Andersen<sup>2</sup>, Matthias Müller<sup>3</sup>**

<sup>1</sup>Cognitive Neuroscience Laboratory, German Primate Center – Leibniz Institute for Primate Research; <sup>2</sup>School of Psychology University of Aberdeen; <sup>3</sup>Institute for Psychology, Leipzig University

Selective attention prioritises relevant from irrelevant input by means of top-down modulation of feed-forward signals, from the early stages of cortical sensory processing onwards. Although attentional ageing is an active area of research, it is not yet clear which aspects of selective attention decline with age or at which processing stage deficits occur. In a series of experiments examining spatial and feature-selective visual attention, we compared older (60-75 years) with younger adults (20-30 years). Frequency tagging of stimuli and the electroencephalogram were used to measure attentional modulation of early visual processing. I will present the results of experiments requiring either covert spatial selection of spatially separated stimuli, or feature-based selection of overlapping stimuli. The results point to a differential decline in the modulatory effect of selective attention on early visual processing. The relative enhancement of visual processing by spatial attention seems as good as unchanged in healthy old age, while the effects of feature-selective attention show a decline that goes beyond slowed processing. The commonalities and differences in the mechanisms underlying spatial and feature-selective attention are still under debate, and this differentiated pattern of age-related change in tasks relying on spatial vs. non-spatial selection may contribute to our understanding.

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[41S205] Eye movements as a window to decline and stability across adult lifespan

**Jutta Billino**

Experimental Psychology, Justus-Liebig-Universität

Current theories of age-related functional changes assume a general reduction in processing resources and global decline across lifespan. However, in particular recent studies on ageing of visual perception have highlighted that a detailed differentiation between general decline and specific vulnerabilities is definitely needed. Eye movements provide the opportunity to study closely interwoven perceptual, motor, and cognitive processes. Thus, we suggest that they allow unique insights into decline and stability of specific processes across lifespan. We studied a battery of different eye movement tasks in a large sample of 60 subjects ranging in age from 20 to 80 years. The battery included saccade as well as smooth pursuit paradigms which involved varying cognitive demands, e.g. learning, memory, anticipation. We analyzed age-related changes in standard parameters of the different tasks. Our results corroborate the well-documented deterioration of processing speed with age, but at the same time reveal surprisingly preserved capacities to integrate bottom-up and top-down processes for efficient oculomotor control. These robust resources point out the often ignored complexity of age-related functional changes and emphasize that compensational mechanisms during healthy ageing might have been underestimated so far.

Funding: German Research Foundation, SFB/TRR 135

### ***Thursday September 1st Oral presentations***

[41T101] Attention is allocated ahead of the target during smooth pursuit eye movements: evidence from EEG frequency tagging

## **Jing Chen, Matteo Valsecchi, Karl Gegenfurtner**

Department of Psychology, Justus-Liebig-University Giessen, Germany

It is under debate whether attention during smooth pursuit is centered on the pursuit target or allocated preferentially ahead of it. Attentional deployment was previously assessed through an additional task for probing attention. This might have altered attention allocation, leading to inconsistent findings. We used EEG frequency tagging to measure attention allocation in the absence of any secondary probing task. The observers pursued a moving dot while stimuli flickering at different frequencies were presented at various locations ahead or behind the pursuit target. In Exp1 (N=12), we observed a significant 11.7% increase in EEG power at the flicker frequency of the stimulus in front of the pursuit target, compared to that in the back. In Exp 2 (N=12), we tested many different locations and found that the enhancement was present up to about 1.5 deg ahead (16.1% increase in power), but was absent at 3.5 deg. In a control experiment using attentional cueing during fixation, we did observe an enhanced EEG response to stimuli at this eccentricity. Overall, we showed that attention is allocated ahead of the pursuit target. EEG frequency tagging seems to be a powerful technique allowing to implicitly investigate attention/perception when an overt task would be disruptive. Funding: Jing Chen was supported by the DFG International Research Training Group, IRTG 1901, "The Brain in Action". Matteo Valsecchi was supported by DFG SFB TRR 135 "Cardinal mechanisms of perception" and by the EU Marie Curie Initial Training Network

### [41T102] Super-fast endogenous allocation of temporal attention

#### **Yaffa Yeshurun, Shira Tkacz-Domb**

Psychology, University of Haifa

It is well known that we can voluntarily allocate attention to a specific point in time at which we expect a relevant event to occur. Here, we employed the constant foreperiod and temporal orienting paradigms to examine the time course of this endogenous temporal attention. With both paradigms, the task was to identify a letter presented for a brief duration (16 ms), preceded by a warning signal. Unlike previous studies, we included a wide range of foreperiods (i.e., the duration of the foreperiod – the interval between the warning signal and the target – varied between 75 to 2400 ms). Critically, to avoid effects of exogenous temporal attention the warning signal did not include an intensity change. In comparison to a non-informative warning signal, identification accuracy was significantly higher when the warning signal indicated the most likely foreperiod. Importantly, such effects of temporal attention were found even with the shortest foreperiod – 75 ms. Given that letter identification was not speeded we can conclude that the allocation of temporal attention to a specific point in time improved perceptual processing. Moreover, this allocation of endogenous temporal attention was extremely fast, considerably faster than the allocation of endogenous spatial attention.

Funding: Israel Science Foundation

### [41T103] Using the pupillary light response to track visual attention during pro- and antisaccades

#### **Sebastiaan Mathôt<sup>1</sup>, Nicki Anderson<sup>2</sup>, Mieke Donk<sup>2</sup>**

<sup>1</sup>Laboratoire de Psychologie Cognitive, CNRS / Aix-Marseille Université; <sup>2</sup>VU University Amsterdam

How is visual attention distributed when preparing an antisaccade: a saccade away from a salient visual stimulus (cue) toward a non-salient saccade goal? Do you first attend to the cue, and only later to the saccade goal? Or do you simultaneously attend to both? We addressed this question with a novel pupillometric technique. Participants fixated the center of a gray display with a bright stimulus on one side, and a dark stimulus on the other. One stimulus (the cue) rotated briefly. Participants made a saccade toward (prosaccade trials) or away from (antisaccade trials) the cue. In prosaccade trials, a pupillary light response to the brightness of the saccade goal emerged almost immediately after the saccade. Given the high latency of the pupillary light response ( $\pm 250$  ms), this early response must have been prepared along with the saccade itself. However, in antisaccade trials the pattern was very different: The pupil initially responded mostly to the cue's brightness; only long ( $\pm 350$  ms) after the saccade did the pupil respond mostly to the brightness of the saccade goal. This suggests that, during preparation of antisaccades, attention is focused more strongly (but likely not exclusively) on the cue than on the saccade goal.

Funding: Marie Curie ACTPUP 622738

### [41T104] Hierarchical binding and illusory part conjunctions

#### **Ed Vul**

Illusory conjunctions and binding errors are typically construed as misattribution of features to objects. Here we show that such binding errors are not limited to basic features, but occur along multiple levels of a hierarchical parse of a scene into objects and their constituent parts. In a series of experiments we show that for many multipart objects, features can be bound to object parts, while (correctly bound) object parts are subject to illusory conjunctions into larger objects. These results indicate that binding is not attributable to the difficulty of aligning feature maps, but rather due to the uncertainty inherent in constructing a hierarchical parse of a scene.

[41T105] Neural mechanisms of divided feature-selective attention to colour

**Jasna Martinovic<sup>1</sup>, Sophie Wuerger<sup>2</sup>, Hillyard Steven<sup>3</sup>, Matthias Mueller<sup>4</sup>, Soren Andersen<sup>1</sup>**

<sup>1</sup>School of Psychology, University of Aberdeen; <sup>2</sup>University of Liverpool; <sup>3</sup>University of California San Diego; <sup>4</sup>University of Leipzig

Recent studies have delineated the neural mechanisms of concurrent attention to spatial location and colour, as well as colour and orientation, but mechanisms that implement concurrent attention to two different feature values belonging to the same continuous feature dimension still remain relatively unknown. We tested if neural attentional resources can be divided between colours that spatially overlap and if such concurrent selection depends on linear separability of targets and distractors in colour space. In two experiments, human observers attended concurrently to dots of two different colours contained within fully overlapping random dot kinematograms of four different colours. Stimulus processing was measured using steady-state visual evoked potentials (SSVEPs). When attended colours could be separated from the distractors by a single line in hue space, neural markers of attentional selection were observed in the SSVEPs. We also modelled how between-colour differences related to SSVEP attentional effects. Colour selection was found to sample information from colour mechanisms in an adaptive, context-dependent fashion. Thus, at least in the case of colour, division of early neural resources between features within a single continuous dimension does not need to be mediated by spatial attention and depends on target-distractor dissimilarities within the respective feature space.

[41T106] Learning to attend and ignore: The influence of reward learning on attentional capture and suppression

**Daniel Pearson, Thomas Whitford, Mike Le Pelley**

School of Psychology, UNSW Australia

Recent studies have demonstrated that pairing a stimulus with reward increases the extent to which it will automatically capture attention. We have shown that this value-modulated attentional capture effect holds for stimuli that have never been task-relevant. In a visual search task, the colour of a salient distractor stimulus determined the magnitude of reward available for a rapid eye-movement to a shape-defined target. Thus, while the distractor signalled the reward available for the trial, responding to it was never required in order to receive that reward. Indeed, if any gaze was captured by the distractor, the reward that would have been obtained was instead omitted. Nevertheless, distractors signalling the availability of high reward produced more capture than those signalling low reward, even though this resulted in the loss of more high-value rewards. We have demonstrated that this value-modulated capture effect is immune to volitional cognitive control, in that the effect persists when participants are explicitly informed of the omission contingency. However, training on the task allows participants to partially suppress capture by the high-value distractor. This suggests that reward learning processes simultaneously augment the attentional priority of stimuli in our environment, as well as our ability to suppress said stimuli.

[41T107] Macaque monkey use of categorical target templates to search for real-world objects.

**Bonnie Cooper<sup>1</sup>, Hossein Adeli<sup>2</sup>, Greg Zelinsky<sup>2</sup>, Robert McPeck<sup>1</sup>**

<sup>1</sup>Department of Biological Sciences, SUNY College of Optometry; <sup>2</sup>SUNY Stony Brook

Humans use categorical target templates to guide their search, but is the same true for macaques? Here we consider two tasks that differ in how targets were designated, one by showing a picture preview of a category exemplar (exemplar) and the other by using a category-specific symbolic cue (categorical). Stimuli were images of real-world objects arranged into variable set size object arrays. The target is randomly present in half of trials. The objects first fixated during search were determined and compared to the first-fixated objects from an image-based model of attention in the superior colliculus (MASC). On target-present trials, proportions of immediate target fixations were well above chance

and changed only minimally with set size. Critically, these patterns were nearly identical for exemplar and categorical search. Moreover, when a novel, never before seen exemplar of the target category was presented, strong and immediate guidance was again observed. On target-absent trials we found that the distractors that were more/less preferentially fixated by the macaque were similarly more/less fixated by MASC. We conclude that monkeys, much like humans, can form and use categorical target templates to guide their search.

[41T108] Moving beyond the single target paradigm: Set-size effects in visual foraging

**Arni Kristjánsson<sup>1</sup>, Ian M Thornton<sup>2</sup>, Tómas Kristjánsson<sup>1</sup>**

<sup>1</sup>Psychology, University of Iceland; <sup>2</sup>University of Malta

Set-size effects in visual search play a key role in theories of visual attention. But such single-target visual search tasks may only capture limited aspects of the function of human visual attention. Foraging tasks with multiple targets of different target types arguably provide a closer analogy to everyday attentional processing. We used an iPad foraging task to measure the effects of absolute and relative set size on foraging patterns during “feature-based” foraging (targets differed from distractors on a single feature) and “conjunction” foraging, where targets are distinguished from distractors by two features. Participants tapped all stimuli from two stimulus categories while avoiding two other categories. Patterns of runs of same target-type selection were similar regardless of set size: long sequential runs during conjunction foraging but short runs during feature foraging, reflecting rapid switching between target types. There were however strong effects of absolute and relative set size on response-times within trials and on the cost of switching between target categories and an interaction between relative set size and switch cost with lower target proportions yielding larger switch costs. We discuss how foraging strategies are affected by set-size manipulations perhaps through changes in saliency and crowding.

Funding: Funded by the Icelandic Research Fund (IRF)

[42T101] Neural responses to partially occluded symmetry

**Marco Bertamini, Giulia Rampone, Adel Ferrari, Alexis Makin**

Department of Psychological Sciences, University of Liverpool, UK

The Sustained Posterior Negativity (SPN) is a visual symmetry-related EEG component starting 250ms after onset. The amplitude of the SPN is well predicted by to regularity in the image. We studied whether the SPN can also emerge when information about symmetry is only revealed over time by dynamic occlusion. We used abstract shapes with vertical reflection symmetry compared to random configurations. A light-grey vertical bar occluded half of the shape; 500ms after stimulus onset, the bar shifted to the other side. The previously visible half became occluded, whilst the previously occluded half was uncovered and was visible for 1000ms. Participants perceived the whole shape and classified it as reflection or random with greater than 90% accuracy. This shows that parts can be correctly combined into wholes across time. ERP analysis showed an early-SPN, from 250ms to 500ms after presentation of the second half of the pattern. Interestingly, this effect was right lateralized. These results suggest that (a) Symmetry can be computed by integration of transient and partial information, generating a response in a symmetry-sensitive network. (b) The right hemisphere plays a major role in such process. (c) Short SPN latency indicates an early symmetry-detection sub-component of the classic SPN.

Funding: ES/K000187/1

[42T102] Grid-texture mechanisms in human vision: contrast detection of regular sparse micro-patterns requires specialist templates

**Tim S Meese<sup>1</sup>, Daniel Baker<sup>2</sup>**

<sup>1</sup>School of Life and Health Sciences, Aston University; <sup>2</sup>University of York

Previous work has shown that human vision performs spatial integration of luminance contrast energy, where signals are squared and summed (with internal noise) over area at detection threshold. We tested that model here in an experiment using arrays of micro-pattern textures that varied in overall stimulus area and sparseness of their target elements, where the contrast of each element was normalised for sensitivity across the visual field. We found a power-law improvement in performance with stimulus area, and a decrease in sensitivity with sparseness, and rejected a model involving probability summation across all elements. While the contrast integrator model performed well when target elements constituted 50-100% of the target area (replicating previous results), observers outperformed the model

when texture elements were sparser than this. This result required the inclusion of further templates in our model, selective for various regular texture densities. By assuming probability summation across these mechanisms the model also accounted for the increase in the slope of the psychometric function that occurred as texture density decreased. Thus, we have revealed texture density mechanisms for the first time in human vision at contrast detection threshold (where the fitted level of intrinsic uncertainty was low and the only free parameter).

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[42T103] Contour integration with corners

**Malte Persike, Guenter Meinhardt**

Psychological Institute, University of Mainz, Germany

Contour integration refers to the ability of the visual system to bind disjoint local elements into coherent global shapes. In cluttered images containing randomly oriented elements a contour becomes salient when its elements are coaligned with a smooth global trajectory, in line with the Gestalt law of good continuation. One of the hallmarks of human contour integration is its susceptibility to curvature. Abrupt changes of contour curvature strongly diminish contour salience down to the point of invisibility. We show that this visibility decline can be easily remedied. By inserting local corner elements at points of angular discontinuity, a jagged contour becomes as salient as a straight one. We report results from a series of experiments for contours with and without corner elements which indicate their psychophysical equivalence. This presents a significant challenge to the notion that contour integration mostly relies on local interactions between neurons tuned to single orientations, and suggests that a site where single orientations and more complex local features are combined constitutes the early basis of contour and 2D shape processing.

[42T104] Binding feedforward and horizontal waves in V1 requires spatio-temporal synergy

**Xoana G Troncoso, Benoit Le Bec, Christophe Desbois, Florian Gerard-Mercier, Yves Fregnac**

UNIC, CNRS, France

Long distance horizontal connections within primary visual cortex (V1), are hypothesized to mediate a neural propagation process that binds cells with similar functional preferences across the visual field. Intracellular experiments in the anesthetized cat have been designed to dissect out the spatial synergy and temporal coherence requirements necessary for synaptic integration operating beyond the receptive field (RF) extent (Gerard-Mercier et al, 2016). We used here 6-stroke apparent motion (AM) concentric sequences of Gabor patches at saccadic speeds, centered on the subthreshold RF and extending up to 25° into the periphery. The response to stimulation of the RF center alone was compared to the response to the AM sequence, which was either centripetal or centrifugal, with the orientation of the individual elements either collinear or cross-oriented to the motion path. We demonstrate supra-linear surround-center input summation, and a non-linear boosting of the neuronal discharge when the RF stimulation was preceded by the activation of a horizontal wave propagation. Filling-in/predictive responses were also induced by the periphery alone. This is consistent with our hypothesis that cooperative “Gestalt-like” interactions are triggered when the visual input carries a sufficient level of spatio-temporal coherence matching in its geometry and temporal signature the underlying V1 connectivity.

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[42T105] Mandatory feature integration across retinotopic locations

**Leila Drissi Daoudi<sup>1</sup>, Haluk Ögmen<sup>2</sup>, Michael H. Herzog<sup>1</sup>**

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Although visual integration is often thought to be retinotopic, visual features can be integrated across retinotopic locations. For example, when a Vernier is followed by a sequence of flanking lines on either side, a percept of two diverging motion streams is elicited. Even though the central Vernier is invisible due to metacontrast masking, its offset is visible in the following elements. If an offset is introduced to one of the flanking lines, the two offsets combine (Otto et al., 2006). Here, by varying the number of flanking lines and the position of the flank offset, we show that this integration lasts up to 450ms. Furthermore, this process is mandatory, i.e. observers are not able to consciously access the individual lines and change their decision. These results suggest that the contents of consciousness can be modulated by an unconscious memory-process wherein information is integrated for up to 450ms.

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#### [42T106] Perception of global object motion without integration of local motion signals

**Rémy Allard, Angelo Arleo**

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The global motion direction of an object can be correctly perceived even if local motion directions diverge from the global direction (e.g., edges of a rotating diamond perceived through apertures). The perception of such global object motion is generally attributed to integration of local motion signals. The fact that the spatial configuration can strongly influence the global motion perception at fixation has been interpreted as interactions between form and motion integration. To challenge this interpretation, the ability to perceive the global object motion was evaluated for various spatial configurations, when neutralizing energy-based motion processing (stroboscopic motion) and when neutralizing tracking motion system (peripheral viewing). As expected from previous studies, the perception of global object motion depended on the spatial configuration at fixation, but not in the periphery. Moreover, neutralizing energy-based motion processing did not impair the perception of global object motion at fixation, whereas it severely impaired the perception of global object motion in the periphery. These results suggest no substantial interaction between form and motion integration: integration of local energy-based motion signals (without form integration) in the periphery and tracking of a global object after form integration at fixation (without integration of local energy-based motion signals). Funding: This research was supported by ANR – Essilor SilverSight Chair

#### [42T201] Predicting behavior from decoded searchlight representations shows where decodable information relates to behavior

**Tijl Grootswagers<sup>1</sup>, Radoslaw Cichy<sup>2</sup>, Thomas Carlson<sup>1</sup>**

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An implicit assumption often made in the interpretation of brain decoding studies is that if information is decodable from a brain region, then the brain is using this information for behavior (but see Williams et al., 2007). In the present study, we sought to study the dissociation between “decodability” and neural correlates of behavior. We used a support vector machine classifier and searchlight analysis to first identify regions of the brain that could decode whether visually presented objects were animate or inanimate from two fMRI datasets (that used different stimuli). A second searchlight analysis was then used on the same data to identify regions whose activity correlates with reaction times for the same animate/inanimate categorization task from humans. We found decodable information along the entire ventral-temporal pathway, but regions that correlated with RT behavior were restricted to inferior temporal cortex (ITC). These results support ITC’s important role in object categorization behavior, consistent with previous region-of-interest based findings (Carlson et al., 2014). Our results further show that our behavioral RT-searchlight method complements standard decoding analyses by differentiating between information that is merely decodable, and information that is more directly related to behavior.

#### [42T202] Why cognitive scientists should abandon the analysis of mean RT using ANOVA and switch to event history analysis

**Sven Panis**

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During the last decades it has become clear that cognitive processes do not unfold as assumed by the discrete stages model. Instead, they unfold concurrently, interactively, and decisions consume time. Nevertheless, most cognitive scientists still treat behavioral latency data using the techniques compatible with the discrete stages model: the analysis of (trimmed) mean correct RT using ANOVA (and the analysis of mean error rate using ANOVA). I present different experimental data sets that illustrate why cognitive scientists should abandon the analysis of means and switch to the statistical technique for analysing time-to-event data that is standard in many scientific disciplines: event history analysis; also known as survival analysis, hazard analysis, duration analysis, failure-time analysis, and transition analysis. Discrete time event history analysis is a distributional method that takes the passage of time explicitly into account, and allows one to study the within-trial (and across-trial) time course of the effect of an experimental

manipulation on the hazard (or conditional probability) distribution of response occurrence in detection paradigms, and also on the conditional accuracy distribution of emitted responses in choice paradigms. Event history analysis can reveal what the mean conceals, and can deal with time-varying predictors and right-censored observations.

[42T203] Practice lowers contrast thresholds for detection, not sensory thresholds

**Joshua A Solomon, Christopher Tyler**

Centre for Applied Vision Research, City University London

In an m-alternative, forced-choice detection task, observers respond incorrectly for one of two reasons. One possibility is that the observer hallucinated one alternative, and that hallucination was more intense than the actual stimulus. The other possibility is that the observer didn't see anything, was forced to guess, and guessed wrong. This second option (the "sensory threshold" hypothesis) is reported to be inconsistent with the contrast detection behaviour of experienced psychophysical observers. Inexperienced observers, however, require relatively higher contrast levels for detection. To determine whether these raised detection levels were caused by a higher sensory threshold or some other factor, we asked inexperienced observers detect a briefly flashed Gabor pattern, both in the presence and in the absence of full-field, dynamic noise. Noise elevated detection levels by ~6 dB. Nonetheless, over the course of 5 days' testing, detection levels dropped ~3 dB in both conditions, implying that this practice effect was not due to a change in any sensory threshold. Instead, our measurements of detection psychometric functions are consistent with an effect of practice on two components of hallucination-inducing noise: one whose variance increases with that of the external noise, and one whose variance is independent of it.

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[42T204] The impact of feedback in pupil-based biofeedback applications

**Jan Ehlers, Anke Huckauf**

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Pupil diameter is at any time determined by the antagonistic interplay of two muscle groups governed by sympathetic and parasympathetic parts of the autonomic nervous system. Consequently, pupil size changes provide a direct impression of the user's cognitive and affective state and may serve as a reference value in classical biofeedback settings. Tallying with this, we recently demonstrated that sympathetic activity indexed by pupil dynamics allows specific manipulation by means of simple cognitive strategies (Ehlers et al. 2015). Subjects received visual real-time feedback on pupil size changes and successfully expanded diameter beyond baseline variations; albeit with varying degrees of success and only over brief periods. The current investigation addresses feedback type as a key criterion in pupil-based biofeedback performance. Three experimental groups used various cognitive strategies to increase/decrease sympathetic arousal (indexed by pupil diameter), whereby each sample performed on the basis of a different feedback mechanism (continuous, discrete & no feedback). Results indicate only a slight increase in pupil size during the absence of feedback, whereas discrete and continuous feedback enable strong self-induced pupil enlargement. Furthermore, continuous visualization of dynamics seems to trigger sympathetic activity and leads to increased pupil sizes even when a reduction of diameter/arousal is envisaged.

[42T205] Effects of flight duration, expertise, and arousal on eye movements in aviators

**Stephen L Macknik<sup>1</sup>, Adriana Nozima<sup>1</sup>, Leandro Di Stasi<sup>1</sup>, Susana Martinez-Conde<sup>1</sup>, Michael McCamy<sup>1</sup>, Ellis Gayles<sup>1</sup>, Alexander Cole<sup>1</sup>, Michael Foster<sup>1</sup>, Brad Hoare<sup>1</sup>, Francesco Tenore<sup>1</sup>, M Sage Jessee<sup>1</sup>, Eric Pohlmeier<sup>1</sup>, Mark Chevillet<sup>1</sup>, Andrés Catena<sup>2</sup>, Wânia C de Souza<sup>1</sup>**

<sup>1</sup>Downstate Medical Center, State University of New York; University of Granada, Spain

Eye movements can reveal where, what, why, and how the brain processes the constant flow of visual information from the world. Here, we measured the eye movements of United States Marine Corps (USMC) combat aviators to understand the oculomotor effects of fatigue as a function of time-on-flight (TOF), expertise, and arousal during flight training. Saccadic velocities decreased after flights lasting 1h or more, suggesting that saccadic velocity could serve as a biomarker of aviator fatigue. A follow-on study set out to determine, via oculomotor measures, if TOF affected the aviators' cognitive processes. We examined oculomotor dynamics in response to emergency procedures in flight, and found that the effects of TOF on eye movements were alleviated temporarily by the addition of high-arousal stressful conditions. Finally, we tasked novice pilots with repeatedly resolving a serious emergency procedure (dual engine

failure cascade), followed by watching a video with an expert solving the same emergency procedures. Half of the novices saw the video with the expert eye position indicated, and the other half watched the video without eye movements superimposed. Pilots who were given the expert eye movement information performed better subsequently, and specifically incorporated eye movement strategies from the expert in their behavior.

[42T206] A new 3d virtual reality system to assess visual function and to perform visual therapy  
**Jaume Pujol, Juan C. Ondategui-Parra, Rosa Borràs, Mikel Aldaba, Fernando Díaz-Douton, Carlos E. García-Guerra, Meritxell Vilaseca, Carles Otero, Josselin Gautier, Clara Mestre, Marta Salvador**

DAVALOR Research Center - Universitat Politècnica de Catalunya

Assessment of visual function in a clinical optometric examination is carried out through a battery of subjective tests. A complete examination is time-consuming leading to patient fatigue and the results can be influenced by the optometrist. Vision therapy procedures take even longer sessions and are also dependent on subjective patient responses. A new 3D virtual reality system with matching accommodation and convergence planes has been developed (Eye and Vision Analyzer, EVA, DAVALOR, Spain). While the patient plays a short videogame (< 5min), objective and fast measurements of most optometric parameters are obtained. The system generates 3D images on two displays. Vergence is induced through image disparity and accommodation is stimulated using a varifocal optical system. EVA also incorporates a Hartmann-Shack autorefractometer and an eye-tracker. Measurements are repeated until obtaining a high confidence level and patient collaboration is also measured. A clinical validation of the system was performed in a group of 250 patients. Optometric parameters related with refraction (objective and subjective), accommodation (amplitude, accommodative facility) and vergence (cover test, near point of convergence, fusional vergence and vergence facility) were obtained with EVA and compared to conventional clinical procedures. Results showed good correlation and differences obtained were always within clinical tolerance.

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[43T101] Breaking shape-from-shading inference through body form and countershading camouflage  
**Julie M Harris<sup>1</sup>, Olivier Penacchio<sup>1</sup>, P. George Lovell<sup>2</sup>, Innes Cuthill<sup>3</sup>**

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Humans, and possibly many other animals, use shading as a cue towards object-shape. Countershading, one of the most widely observed colour patterns in animals, can disrupt these cues to identification. This is a shading pattern on the body that compensates for directional illumination: being darker on the side exposed to a higher light intensity (typically, a dark back and a light belly). To function effectively, countershading must be tuned to 3D form, but natural countershaded reflectance patterns have never been measured while taking into account shape. Here we tested whether the countershading pattern on prey animals could be predicted from their shape, a key test for the camouflage as adaptation theory. We measured both reflectance and shape for several species of caterpillar. Shape was measured using an optical 3D scanner, and reflectance extracted by measuring outgoing radiance and calculating reflectance based on local shape. We compared the measured reflectance pattern with that predicted based on the measured geometrical shape and known illumination. We found that reflectance was well predicted by shape for some countershaded species. The results suggest that body shape and colour can both evolve to counter shape-from-shading inference.

Funding: BBSRC

[43T102] The role of projective consistency in perceiving 3D shape from motion and contour  
**Manish Singh, Xiaoli He, Jacob Feldman**

Center for Cognitive Science, Rutgers University, NJ

Observers spontaneously perceive 3D structure in motion displays that are projectively consistent with rotation in depth. They can, however, also perceive 3D structure in displays that are projectively inconsistent with a 3D interpretation, such as the “rotating columns” display (Froyen et al., JOV2013; Tanrikulu et al., JOV2016) containing multiple alternating regions. We examined the role of projective consistency in standard SFM displays by manipulating

(i) the degree of symmetry of the occluding contours; (ii) the speed profile of the dots, varying from constant speed ( $\alpha=0$ ) to full cosine speed profile ( $\alpha=1$ ). For each level of symmetry, we used the method of constant stimuli to obtain psychometric curves for proportion of “volumetric” responses as a function of  $\alpha$ . Results: 1) Observers’  $\alpha$  thresholds were around 0.4-0.6, where the speed profile deviates substantially from projective consistency; 2) Degree of asymmetry had a surprisingly small effect. The  $\alpha$  thresholds for the asymmetric displays were only slightly higher. The results show that 3D percepts are surprisingly robust to deviations from projective consistency—both of the speed profile, and of occluding contours. They argue for a more nuanced view of 3D perception in which projective consistency plays a less prominent role than in conventional accounts.

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[43T103] Is the Müller-Lyer illusion a perspective-based illusion?

**Dejan Todorović**

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An influential general view of visual illusions is that they arise when the visual system applies to 2D images certain processing strategies that are appropriate to handle 3D scenes. A prominent example is the idea that the Müller-Lyer illusion is a consequence of the interpretation by the visual system of certain 2D configurations as projections of portions of objects in 3D. Such perspective-based theories readily acknowledge that the illusion-inducing 2D configurations do not evoke conscious 3D percepts, but claim that they nevertheless contain strong 3D cues which unconsciously trigger processing mechanisms which would be appropriate for real 3D scenes. One way to test this idea is to study alternative 2D configurations which contain the basic Müller-Lyer ‘motive’ but lack 3D cues, or contain cues that evoke conscious 3D interpretations different from those assumed by perspective-based theories. In five experiments using various alternative 2D configurations it was found that they all evoked Müller-Lyer type illusory effects whose structure was very similar to effects evoked by the classical configuration, though generally somewhat weaker. Such findings are difficult to explain by perspective-based theories and challenge the notion that perspective interpretations provide a major contribution to the Müller-Lyer illusion.

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[43T104] Depth enhancement with synoptic viewing

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Viewing pictures or photographs of 3-D objects and scenes through a synopter - which has the effect of locating the two eyes at coincident spatial positions - has been shown to produce an enhanced depth percept (Koenderink et al. 1994). The accepted explanation is that synoptic viewing creates a vanishing disparity field, which is consistent with viewing a scene at infinity. Synoptic viewing creates both a vergence demand of zero (parallel lines of sight) and a vertical disparity field indicating viewing at infinity. To investigate how these factors influence the enhanced depth effect, we manipulated the vergence demand and the vertical disparity field independently using a wide field (26° x 20°) ‘virtual synopter’ display. Test images ranged from perspective line drawings to complex pictorial paintings which were viewed under three different conditions: monocular, binocular and synoptic. Observers judged the amount and vividness of the perceived depth before matching the perceived slant of the depicted surfaces using a gauge figure. Synoptic viewing produced the greatest depth enhancement and vergence demand was more effective than vertical disparity manipulations. Depth enhancement was greater for images containing only shading information (such as sculptures) compared to images that contained strong linear perspective cues.

[43T105] The Bologna’s tower paradox: a dynamic architectural zoom lens illusion in framed visual perception

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In the former monastic complex of San Michele in Bosco in Bologna (Italy), a 162.26 m monumental corridor is perfectly aligned in elevation and azimuth to the top of the medieval main tower of the city (1407 m away). Walking backward and forward along the corridor it is possible to experience a remarkable size illusion of the tower. Near the

window facing the city at the north end of the corridor, the tower is perceived quite small, being included in the wide urban view. Going backward the window frame progressively zooms in on the tower top that is perceived to enlarge and to become closer. The phenomenon is generalizable to all situations in which an object, placed quite far from the observer, is perceived through a frame while moving backward and forward. To test the phenomenon 9 pictures were taken along the corridor at 20 m intervals. Thirty-six picture pairs were presented to 144 participants that had to evaluate in which of the two pictures the tower was perceived larger and closer, using a two-alternative forced choice paradigm for both evaluations. Results confirmed that the tower was perceived significantly and progressively larger and closer in the more distant shot.

[43T106] Stereo disparity modulates evoked potentials associated with the perceptual classification of 3D object shape: a high-density ERP study

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One unresolved theoretical issue is whether the perceptual analysis of 3D object shape is modulated by stereo visual input. Some current models of object recognition attribute no functional significance to stereo input, and strongly predict that stereo should not modulate shape classification. To test this hypothesis high-density (256-channel) EEG was used to record the temporal dynamics, and perceptual sensitivity of shape processing under conditions of mono and stereo viewing. On each trial, observers made image classification ('Same'/'Different') judgements to two briefly presented, multi-part, novel objects. Analyses using mass univariate contrasts showed that the earliest sensitivity to mono versus stereo viewing appeared as a negative deflection over posterior locations on the N1 component between 160ms-220ms post stimulus onset. Later ERP modulations during the N2 time window between 240ms-370ms were linked to image classification. N2 activity reflected two distinct components – an early N2 (240ms-290ms) and a late N2 (290ms-370ms) that showed different patterns of responses to mono and stereo input, and differential sensitivity to 3D object structure. The results show that stereo input modulates the perception of 3D object shape, and challenge current theories that attribute no functional role for stereo input during 3D shape perception.

Funding: Royal Society (UK), Swiss National Science Foundation

[43T201] EEG frequency tagging reveals distinct visual processing of moving humans and motion synchrony

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The brain has dedicated networks to process interacting human bodies and willingly attributes interpersonal interaction to synchronous motion even in spatially-scrambled displays. However, it is not clear to what extent the neural processes underlying perception of human bodies differ from those of other objects moving in synchrony. Here we show a clear delineation of these processes by manipulating the motion synchrony and biological nature of point-light displays (PLDs) by conducting a 2(synchronous vs asynchronous)×2(human vs non-human) experiment. We applied the frequency-tagging technique by giving continuous contrast modulations to the individual PLDs at different frequencies (i.e.,  $f_1$  &  $f_2$ ). Then, in the frequency spectrum of the steady-state EEG recording we looked for the emergent frequency components (i.e.,  $f_1+f_2$ ,  $2f_1+f_2$ ), which indicate the integrated brain responses due to nonlinear summation of neural activity. We found two emergent components which signify distinct levels of interactions between the moving objects: the first component indicates the perception of human-like point-light dancers; the second one indicates the degree of motion synchrony. These findings dissociate the visual processing of moving human bodies from the processing of motion synchrony, in general suggesting that social interactions have shaped a dedicated visual mechanism for the processing of moving human bodies.

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[43T202] Perception of grasping of biological movement in typical and autistic children

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We investigated the ability of children (both typical and with ASD) to discriminate shape (a cylinder from a cube) by

observing a point-light movie of an actor grasping the object, either from an allocentric or egocentric viewpoint (observing action of others or self). For adults, the sensitivity was slightly greater for the egocentric than allocentric viewpoint (Campanella et al., Proc Roy Soc, 2010). Typically developing children younger than 7 years could not do the task, then improve gradually up to 16 years. Sensitivity was initially equal for the two viewpoints, then egocentric becomes more sensitive at about 16 year. High functioning autistic children showed a strong selective impairment, only in the allocentric condition, where thresholds were twice as high: egocentric thresholds were similar to age- and ability-matched controls. Furthermore, the magnitude of the impairment correlated strongly with the degree of symptomology ( $R^2 = 0.5$ ). The results suggest that children with ASD are impaired in their ability to predict and infer the consequence of movements of others, which could be related to the social-communicative deficits often reported in autism.  
Funding: Early cortical sensory plasticity and adaptability in human adults (ESCPLAIN - 338866)

[43T203] Engaging facial muscular activity biases the emotion recognition of point-light biological walkers  
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Blaesi and Wilson (2010) showed that the recognition of other's facial expressions was biased by the observer's facial muscular activity. It has been hypothesized that holding chopsticks between the teeth engages the same muscles used for smiling and therefore biases the expression recognition toward happy or more positive mood. However, it is yet unknown whether such modulatory effects are also observed for the recognition of dynamic bodily expressions. Therefore, we investigated the emotion recognition of point-light biological walkers along with that of static face stimuli, while subjects were holding chopsticks in their teeth or without doing so. Under the holding-chopsticks condition, the subjects tended to see happy expressions in the facial stimuli as compared to the no-chopstick condition, in concordance with the aforementioned study. Interestingly, the similar effect was found for the biological motion stimuli as well. These results indicate that the facial muscular activity alters not only the recognition of facial expressions but also that of bodily expression.

Funding: CREST, Japan Science and Technology Agency

[43T204] Model for the integration of form and shading cues in multi-stable body motion perception  
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Body motion perception from impoverished stimuli, such as point-light motion, shows interesting multi-stability, which disappears in presence of shading cues that suggest depth. Existing models for body motion perception account neither for multi-stability nor for the specific influence of such shading cues. We propose a new model that captures these phenomena. **METHOD:** We extended a classical hierarchical recognition model for body motion by: (i) a two-dimensional dynamic neural field of snapshot, which reproduces decisions about walking direction and their multi-stability; (ii) a novel hierarchical pathway that processes specifically intrinsic luminance gradients, being invariant against the strong contrast edges on the boundary of the body. **RESULTS:** We show that the model reproduces the observed multi-stability of perception for unshaded walker silhouettes. The addition of intrinsic shading cues results in monostable unambiguous perception in the model, consistent with psychophysical results. In addition, we show that the novel shading pathway is necessary to accomplish a robust recognition of the relevant intrinsic luminance gradients. **CONCLUSIONS:** By straight-forward extensions of a classical physiologically-inspired model for body motion recognition we were able to account for the perceptual multistability and the dependence on shading cues of body motion perception.

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[43T205] A computational model of biological motion detection based on motor invariants  
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Despite the advances in providing artificial agents with human-like capabilities, robots still lack the ability to visually perceive the subtle communication cues embedded in human natural movements which make human interaction so efficient. The long-term goal of our research is to endow the humanoid robot iCub with human-like perception and action capabilities, triggering the mutual understanding proper of human collaborations. Here we investigate how the visual signatures of the regularities of biological motion can be exploited as implicit communication messages during social interaction. Specifically, we explore the use of low-level visual motion features for detecting potentially interacting agents on the basis of biologically plausible dynamics occurring in the scene. To do this we adopt a descriptor based on the so called “Two-Thirds Power Law”, a well-known invariant of end-point human movements, for which we provide a thorough experimental analysis that clarifies the constraints of law readability. We then validate the computational model by implementing it on the robot and proving that it enables the visual detection of human activity even in presence of severe occlusions. This achievement paves the way for the use of HRI based applications on various contexts, ranging from personal robots, to physical, social and cognitive rehabilitation. Funding: The research presented here has been supported by the European CODEFROR project (FP7-PIRSES-2013-612555)

[43T206] Evidence for norm-based coding of human movement speed

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Estimates if the visual speed of human movements such as hand gestures, facial expressions and locomotion are important during social interactions because they can be used to infer mood and intention. However it is not clear how observers use retinal signals to estimate real-world movement speed. We conducted a series of experiments to investigate adaptation-induced changes in apparent human locomotion speed, to test whether the changes show apparent repulsion of similar speeds or global re-normalisation of all apparent speeds. Participants adapted to videos of walking or running figures at various playback speeds, and then judged the apparent movement speed of subsequently presented test clips. Their task was to report whether each test clip appeared to be faster or slower than a ‘natural’ speed. After adaptation to a slow-motion or fast-forward video, psychometric functions showed that the apparent speed of all test clips changed, becoming faster or slower respectively, consistent with global re-normalisation rather than with repulsion of test speeds close to the adapting speed. The adaptation effect depended on the retinal speed of the adapting stimulus but did not require recognizably human movements.

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