

## TALKS:

1. Stefan Treue, *Attention to visual motion: physiology, psychophysics and some modelling*

2. Andrew Parker, *Use and implementation of mark-correlation function for determining spatial structure in high resolution BOLD fMRI images of early visual cortical areas.*

The presence of spatial structure within high resolution BOLD (Blood Oxygen Level Dependent) MR imaging has been advanced as a signature of columnar structure within visual areas of the cerebral cortex. Here we present a new approach to evaluation of the presence of spatial structure, based on the statistics of spatial point processes. These statistical tools have been developed to address the question of whether biological or geophysical field maps contain random or ordered distributions of observations. Here we apply the mark correlation function to the distribution of response preferences for binocular disparity across early visual areas, V1, V2, V3 and V3a, imaged at 0.75mm resolution with high-field strength, 7 tesla, MR imaging. The mark correlation function compares the actual distribution of disparity preference within the observed data against shuffled distributions of the data set, as well as against simulated data sets containing spatial correlations across the imaging field that match the underlying spatial correlations of the experimental data. The mark correlation statistics show there is structure in the spatial distribution of disparity preferences of nearby pixels within the imaging field, most likely compatible with a local clustering of responsiveness to binocular disparity. We compare these statistics across visual areas and against the predictions of different possible forms of columnar structure that have been proposed.

3. Efthymia Diamanti, *Modulation of visual responses by navigational signals during active behaviour*

Vision provides signals to guide navigation, and navigation in turn influences visual input. Do neurons in visual cortex combine signals related to vision and navigation? How do such responses relate to responses during passive viewing?

We used 2photon calcium imaging to record neural activity across visual cortex (V1, LM, AL, PM, RL, A, AM), while headrestrained mice ran along a virtual reality corridor. The corridor contained two landmarks (vertical grating or plaid) repeated twice, creating two visually identical sections. Imaging sessions involved three conditions: (1) closedloop, where the speed of the virtual corridor matched the animal's running speed; (2) openloop, where previous closedloop visual scenes were played back to the animal; (3) vertical drifting gratings at varying temporal and spatial frequencies. In closedloop, many neurons as early as in V1 did not respond similarly to identical visual landmarks. Instead, they fired at a single virtual position. A similar trend was observed in all other areas. Responsiveness at a specific position could not be explained by simulations of complex cells or by running speed. In open-loop, there were fewer cells being responsive and the reliability of responses was markedly reduced. Finally, cells tuned to vertical drifting gratings did not necessarily respond to the vertical grating landmarks in virtual reality.

We conclude that during active navigation responses across visual cortex are modulated by spatial context. These responses are more reliable than during passive viewing and not elicited solely by cells preferring classic stimuli similar to the landmarks in virtual reality.

4. Catherine Manning, *Electrophysiological correlates of motion processing and decision-making in children and adults*

Children make better decisions about visual motion as they get older, reaching adult-like performance only by mid- to late-childhood. Perceptual decision-making involves

multiple processes, but it is not yet clear how these processes and their neural correlates develop through childhood. In this study, 102 children between the ages of 6 and 12 years and 20 adults judged the direction of coherent motion stimuli and responded as quickly and accurately as possible, while high-density EEG was recorded. As expected, younger children made slower and less accurate responses than older children and adults. We used a data-driven approach to identify EEG components that were reliable from trial-to-trial. We found two stimulus-locked components with distinct topographies: a) an early sensory component with a posterior topography and timecourse similar to previously reported coherence-onset visual evoked potentials, and b) a later, sustained centro-parietal component thought to reflect the evolution of a decision variable, scaling with motion coherence and predicting reaction times. Similar topographies were reflected in two corresponding response-locked components, which reflected a mixture of both sensory and decision-specific activity increasing up to the response. These components showed a marked reversal after the response, which may reflect processes related to response execution, confidence or error monitoring. The stimulus- and response-locked components all showed clear developmental changes. We suggest that children's development of coherent motion sensitivity is driven both by the maturation of sensory and decision-related processes.

## 5. Wendy Adams

### 6. Christopher Fassnidge, *The sound of silent motion: converging support for a disinhibition account of visual-to-auditory synaesthesia*

We have been investigating a little-known phenomenon whereby visual motion and flashes can evoke illusory sounds. Converging evidence supports a disinhibition explanation of this visually-evoked auditory response (vEAR).

In a lab study, 20% of normal participants reported 'hearing' our flash stimuli. In a large-scale internet survey of >4000 participants, 20% responded 'Yes' when asked whether they ever experienced auditory sensations from visual movement.

vEAR reports were associated with the opposite phenomenon of auditory-evoked phosphenes, musical imagery and tinnitus-like experiences. Reduced cortical inhibition (or elevated excitability) might explain these diverse phenomena better than specific anatomical abnormalities, often proposed for other forms of synaesthesia. Auditory vividness ratings of silent videos also correlated with schizotypal personality, which has independently been associated with reduced inhibition in sensorimotor areas.

We also found that visual sequence discrimination could be disrupted by 40Hz transcranial Alternating Current Stimulation to either occipital or temporal sites, which presumably interrupts latent cross-modal crosstalk between visual and auditory cortices. In contrast, 10Hz stimulation revealed a push-pull pattern of mutual inhibition between vision and audition in non-vEAR participants, but no stimulation effect in vEAR. This is again consistent with reduced cortical inhibition in vEAR. Canonical forms of synaesthesia (e.g. grapheme-colour) are rare and have thus often been attributed to aberrant cross-activations between specific sensory brain areas. However the relatively high prevalence of vEAR and its association with other diverse phenomena, along with effects of disrupting inhibition mediated by alpha oscillations, provides converging evidence that vEAR reflects generally reduced inhibition of normally-occurring cross-modal cross-activations.

### 7. Peter Bex, *Generalization of the flash distortion effect*

A sequence of faces presented in the peripheral visual field may appear grotesquely distorted (Tangen et al, 2011, *Perception*, 40, 5, 628), an effect that has been attributed to adaptation of opponent mechanisms in face-space. We examine this phenomenon and explanation with 5 aligned image categories: upright celebrity

faces, inverted faces, animal faces, face-like car-front images and different images of the same celebrity; and 4 metrics: distortion occurrence, distortion onset time, detection of physical distortion and distortion matching. Distortion occurrence depended on image category ( $F(4,20)=20.2$ ,  $p<0.01$ ) and were less likely to occur in animal or car images (all  $p<0.01$ ). Onset times were significantly different across image category ( $F(4,20)=18.2$ ,  $p<0.01$ ), but were not significantly different for upright, inverted or same celebrity images (all  $p>0.05$ ). There was no significant difference in the detection of physical distortions ( $F(4,20)=2.5$ ,  $p=0.07$ ), however the magnitude of matching distortions differed across image category ( $F(4,20)=9.5$ ,  $p<0.01$ ) and were significantly greater in upright faces, inverted faces, and same identity faces than animal or car faces (all  $p<0.05$ ). The spatial scale of perceived distortion corresponded to approximately 1 cycle at the inter-pupillary distance of the faces. These results show that flashed image distortions occur in human, but not non-human face-like images, consistent with the representation of faces in a unique space. However, the presence of distortions in inverted faces and images of the same person is not consistent with opponent dimensions in this space.

#### 8. Sophie Weurger, *Skin appearance: Colorimetric and behavioural measurements*

Understanding human skin appearance is a subject of great interest in science, medicine and technology. In medicine, skin appearance is a vital factor in surgical/prosthetic reconstruction and disease diagnosis. In vision science, it has been argued that the trichromatic visual system has evolved to optimally discern subtle skin colour changes.

We have looked at several aspects of skin appearance: colorimetric and spectroradiometric measurements of skin; behavioural data for skin discrimination performance and how discrimination performance depends on skin texture and ambient illumination.

Our main results are: the discrimination of subtle skin tone changes primarily depends on the ambient illumination; discrimination is superior under a daylight metamer in comparison to artificial light (TL84) of the same luminance. In comparison to uniform skin patches or scrambled skin texture, intact skin texture does not confer any advantage for discrimination performance.

#### 9. Ben Tatler, *Everyday vision*.

The human behavioural repertoire is intricately linked to the gaze control system: many behaviours require visual information at some point in their planning or execution. The information that we require for successful completion of behavioural goals is likely to be drawn from two sources: visual information available on the retina for the current fixation, and information stored from previous fixations. Thus, in order to understand how information is gathered and used from the environment, we must understand both how gaze is allocated in order to sample information, and the fate of information once sampled but no longer fixated. When considering these questions, it is appropriate to consider vision not as an isolated system—as is often the case in laboratory-based paradigms—but as part of a broader network of vision, action, and planning during interactions with the environment. A clear emerging theme in studies of gaze control within the context of this broader network is that if our goal is to understand how vision supports our day-to-day activities, then it is important to study vision in the context of natural, everyday behaviours. If we simplify the context in which we conduct our experiments then we alter the manner in which the world is sampled and encoded to memory.

#### 10. Nicole Ruta, *Why did Medieval painters manipulate figure size? A perceptual psychology approach to art history*

Prior to the discovery of linear perspective in Western painting artists would arbitrarily vary the size of figures in compositions, often dramatically. According to the standard

'hierarchical scaling' explanation, the size of figures was increased in proportion to their status (White, 1973). In 1907 the art historian Oskar Wulff offered an alternative, and as yet untested, hypothesis: that figure size was determined by 'inverse perspective' that artists used to elicit empathy and direct visual attention. We tested this hypothesis using a variety of psychological measures, including eye tracking.

We selected 10 Medieval paintings demonstrating features of inverse perspective and manually converted each using Adobe Photoshop into a new version to approximate rules of linear perspective. When compared in a free viewing task, participants spent more time fixating on figures overall when looking at the original paintings compared to the converted ones. When asked to select which version better represented the intentions of an artist who wanted to draw attention to a given figure, participants were significantly more likely to select the original version. We also investigated differences in reported levels of empathy for the manipulated character between the two versions. Finally, a drawing task that measured imagined visual space revealed a pattern that closely matched the compositional structure of the original paintings. We conclude that Medieval artists' composition of pictorial space was far more sophisticated than standard art histories allow, and more closely representative of visual space than previously recognised (Ruta et al. 2016; Pepperell & Haertel, 2014).

#### 11. Laura Young, *A self-organising photoreceptor mosaic simulation for studying spatial sampling in the retina*

It is evident both from histology and from adaptive optics imaging that the photoreceptor mosaic is approximately hexagonal in arrangement but is not entirely regular. Although sampling in the retina is discrete we do not observe sampling artifacts, such as Moiré patterns, associated with aliasing effects. The randomness of the positions of the photoreceptors mitigates this effect at the expense of noise. We present a self-organising simulation of the layout of the retinal cone mosaic that, without enforcing a hexagonal geometry, produces a random hexagonal-like packing arrangement. This model is also able to produce foveated retinal mosaics that have a spatially varying photoreceptor density. We make comparisons, via nearest neighbour metrics of regularity, to real photoreceptor mosaics that we have imaged using an adaptive optics scanning laser ophthalmoscope (AOSLO).

This technique can be used to generate photoreceptor maps for studying models of the spatial sampling of an image within the retina. These maps can also form the basis of more realistic simulations of AOSLO retinal images. These can be used to improve the benchmarking of image processing techniques, such as cone detection or fixational eye movement extraction, and for developing new algorithms.

#### 12. Christopher Tyler, *Is Traumatic Light Sensitivity Due to Rod Disinhibition at Photopic Light Levels?*

In terms of its best-accepted retinal sources, the electroretinogram (ERG) is a highly diagnostic signal that can assess the functional status of the photoreceptors (a-wave), bipolar cells (b-wave), pigment epithelium (c-wave), amacrine cells (oscillatory potential), and ganglion cells (photopic negative response, PhNR), separately for both the rod and the cone photoreceptor systems. At every light level, the rod-driven signals are typically ~2x slower than cone-driven components, equated for quantum catch. The specificity of these response components was used to identify retinal mechanism disruptions due to brain trauma with abnormal sensitivity to light, or photalgia, and determine its retinal-cell source in groups of non-photalgic, mildly photalgic and severely photalgic brain trauma. The non-photalgic ERG responses were similar to the cone-dominated responses of the controls, though lacking a PhNR. The mild photalgics showed a pronounced shift from a

photopic to a scotopic b-wave at comparable light levels, implying both that there is cone-to-rod suppression operating under normal conditions to suppress the rod response at moderate light levels, and that this suppression is diminished by the effects of the brain trauma in photalpic cases. These results suggest that the primary etiology of the painful light sensitivity is loss of the rod suppression, causing overactivation of the 100 million rods throughout the retina at moderate light levels. This previously unsuspected photopic rod suppression at photopic could be mediated by signals from the peripheral cone population, which constitute 99% of the overall cone population of the retina.

## POSTERS:

### 1. I. Betina Ip, *Dynamic changes in excitation and inhibition during the cortical response to visual contrast in the human brain*

Functional Magnetic Resonance Imaging is one of the most widely used non-invasive measures of visual responses in the living human brain. It uses the Blood-Oxygenation-Level-Dependent (BOLD)-signal as a metric of neural activity. A key challenge to the field is that the BOLD-signal is ambiguous regarding the relative contributions of neuronal excitation and inhibition. We aimed to address this challenge by using complementary MR imaging methods, fMRI and <sup>1</sup>H-Magnetic resonance spectroscopy (MRS), to identify simultaneous changes in hemodynamics and neurochemistry as a function of visual contrast levels. Participants viewed 64-sec stimulus blocks of flashing checkerboards at four stimulus contrasts (3, 12.5, 50, 100%), alternating with a blank mid-gray screen. Combined fMRI-MRS data were acquired from a 2x2x2 cm<sup>3</sup> voxel in the primary visual cortex. Increase in stimulus contrast evoked a linear increase in BOLD-signal. In addition, the response of major excitatory neurotransmitter glutamate increased with contrast whereas inhibitory neurotransmitter  $\gamma$ -aminobutyric acid responses decreased. Quantification of this change using an excitation:inhibition index demonstrated a switch from inhibitory-dominant to excitatory-dominant neurochemical response. In summary, we have identified a dynamic interplay between excitation and inhibition dependent on the response strength in the primary visual cortex. Our results are a step towards disambiguating contributions of cortical excitation and inhibition to stimulus evoked hemodynamic response.

### 2. Flora Ioannidou, *Is attention to social cues in natural scenes automatic?*

Previous studies have shown that eye movements are strongly influenced by the task participants are performing. It may therefore be expected that fixations on social (gaze and pointing) and symbolic (arrow) cues in a scene should also be task dependent. Previous studies suggest that gaze and arrow cues elicit faster response times and shift people's attention towards target stimuli even when cues are counter predictive of a target's location. However most previous studies have presented such cues in isolation and at fixation and it is unclear if the same effects would be observed when cues are presented away from fixation within naturalistic images. The aims of this study were to compare observers' gaze behaviour during free exploration of a scene compared to when a visual search task had to be carried out and when social (people looking or pointing) and symbolic (arrow) cues were present in the scenes. Cues were presented away from fixation and under different informative conditions (predictive and counter predictive to targets' location). Analysis of eye movements shows that the requirement to search for a specific object in the scene strongly suppresses the natural tendency to look at either people or arrows. Reaction times, however, show that objects that are pointed or looked at are more quickly localised than those in opposite locations. These results suggest that overt, but not covert attention is modulated by the task participants are performing.

### 3. Aminah, Al Hefzi, *Development of a new random words reading chart*

Purpose If reading speed is to be used as an outcome in rehabilitation studies or investigations of optical devices, it is necessary for it to be measured multiple times, and it is difficult to find a test which has multiple versions of equal difficulty. A test comprised of random words also avoids the prediction of words, and is a test of vision rather than reading ability. The aim of this study was to determine the repeatability of a new extended reading test in normally-sighted individuals.

Method. . The test consists of 150 words: 35 8-letter; 80 6-letter and 35 4-letter. Different versions were printed with lower case 8 point letters in Times Roman font, in black-on-white with 90% Michelson contrast..

Two groups of participants (22 aged under 35 years and 16 over 60 years) read aloud two randomly-chosen versions of the test in succession, at 30 cm viewing distance. The older group were allowed to use their appropriate reading add. Audio recordings were analyzed after the sessions to determine reading speed in words per minute (WPM).

Results. The mean (SD) reading speed was found to be 107.5, SD=19.8 for Group 1 and 93.2, SD=21.6 for Group 2. The coefficient of repeatability (CoR) was  $\pm 14$  wpm for the younger group and  $\pm 9$  wpm for the older group.

Conclusion CoR was comparable to that of other reading tests, and the test may therefore prove to be useful when measuring the effect of interventions to improve vision.

### 4. Man-Ling Ho, *Reconstructing subjective perception of object size with population receptive field modelling*

V1 has been found to encode the perceived, as opposed to the veridical, size of an object (e.g., Murray et al., 2006). Here we tested the extent to which population receptive field (pRF) modelling can be used to reconstruct subjective perception of an object's size based on V1 activity. We first used pRF modelling to estimate the location and size of receptive fields of individual V1 voxels for each participant. Next, we presented either a Ponzo illusion (Experiment 1,  $n = 10$ ) or a Muller-Lyer illusion (Experiment 2,  $n = 10$ ) stimulus that caused two equal length stimuli to be perceived as different lengths (or at different locations). Based on the pRF maps, we then sampled V1 responses across the stimulus location to reconstruct and quantify a signature of the subjective percepts of the apparent stimulus size. For both experiments, V1 responses averaged across participants clearly represented the apparent differences between stimuli. There was also a modest correlation between behavioural measures of perceptual bias and the fMRI reconstruction – however, this relationship is too weak to make accurate predictions of illusion strength from brain imaging data in single participants. Future work should strive to improve this correlation either through increasing the sensitivity of current reconstruction technique or the use of better behavioural measures.

### 5. Enrico Giora, *Impaired visual search in insomnia patients due to compelling recursive stimulus analysis*

This study investigates the effects of Insomnia Disorder (ID) on basic perceptual processing, through a visual search task. The performances of 23 insomniacs and 20 age- and sex-matched controls were compared. Stimuli consisted in matrices of contextual letters (Os, Xs, or Ls) containing a target (T) in the 50% of cases. As independent variables, target's salience and distractors' number were manipulated. In each trial stimuli were showed on a computer screen after the presentation of a fixation point. The observers had to detect as soon as possible the presence/absence of the target. After the answer, a masking was presented for 2000 ms. Accuracy and reaction times (RT) were recorded as dependent variables. Results confirmed the typical effects of a visual search task: RT increased with

distractors' numerosity and decreased with target's salience. Furthermore, an overall delay was found for stimuli in which the target was absent. By comparing the two groups, no difference in accuracy was found, whereas patients generally showed longer RT. However, distinguishing between conditions of target's presence/absence, the clinical group exhibited delayed RT only when the target was absent. The delayed RT observed in both groups for stimuli without target agrees with the idea of an exhaustive stimulus analysis, according to the Sternberg's model. Moreover, the longer RT exhibited by insomniacs in this condition can be interpreted on the basis of an automatic recursive stimulus processing, explainable by the hyperarousal concept of insomnia. This dissociation demonstrates the presence of a selective perceptual impairment occurring in ID patients.

#### 6. Aysha Motola, *Visual Rate Perception – More than the sum of its parts?*

Previous experiments have presented evidence towards a temporal 'rhythm aftereffect' analogous to aftereffects evidenced in other features of visual perception such as motion and orientation. Specifically, adapting to a fast rate makes a moderate test rate feel slow, and adapting to a slow rate makes the same moderate test rate feel fast (a repulsive after-effect) (Becker & Rasmussen, 2007; Levitan et al., 2015). We ask whether there is something special about visual 'rhythm', or whether it is simply represented by a series of 'intervals'. Using a combination of two-alternative forced choice (2AFC) and interval reproduction methods, observers were tested by adapting to given auditory and visual temporal rates (a 'slow' rate of 1.5Hz and a 'fast' rate of 6Hz via flashes on a screen), and were then presented with a response period where the effects of adapting to temporal rate were tested with single empty intervals of varying durations. Results suggest that adapting to a given rate does indeed influence the temporal perception of a single empty interval. This effect is present bi-directionally, across 1.5Hz and 6Hz of adapting frequencies and is also evidenced through both interval reproduction and two-alternative forced choice methods. Observers are rapidly able to adapt to different visual temporal rates and are also able to communicate this effect through judgements of subsequently presented single empty intervals. This suggests that what was previously understood as after-effects of adapting to rate (or rhythm), may actually be duration aftereffects of adapting to repeatedly presented single intervals of time.

#### 7. Zane Jansone, *Colour vision sensitivity changes before and after cataract surgery*

In optometrist practice we are dealing with patients who have cataract or had cataract removal surgery. We check their vision functions as visual acuity, contrast vision but usually optometrists don't check colour vision. Colour vision tests can give us information about pathological changes in eye structures. Our aim was to evaluate if the colour vision chromatic resolution changes before and after cataract surgery. We used saturated and unsaturated Farnsworth D15 Colour vision arrangement test because it is easy perceptible (essential to elder patients) and you can check colour sensitivity changes in tritan, protan, deutan confusion line directions. Results were analysed in three ways: by summing the colour differences between adjacent caps according to Bowman, by averaging colour difference vectors according to Vingry and King-Smith, and using linear regression line which is created from incorrect error cap arrangements. In our research participated 26 eyes with cataract. 66 from 92 eyes with glaucoma, macular diseases, diabetes, eyes with lower visual acuity than <0.10 decimal units were excluded from research.

All three tests showed that the cataract caused lens opacities, significantly decreases the vision chromatic resolution along visible spectrum. Before the cataract surgery, the D15 test stimulus arrangement sequence showed similarities with tritan colour deficiency. Results of two patients showed that the colour vision sensitivity has improved but they still have deviations from the standards, what allowed to conclude

that the colour vision sensitivity changes not only due to the lense light absorption, but due to other pathological factors. Studies done within IMIS2.

8. Rebecca Lowndes, *Population receptive fields in V1 enlarge as luminance falls from photopic to scotopic levels*

Under photopic conditions visual information is processed at the retinal level by cone photoreceptors while under scotopic light conditions visual signals are solely conveyed by rod photoreceptors. There is a markedly different distribution of rods and cones across the retina, most notably in the central fovea, where only cones are found. Spatial resolution under is lower under scotopic compared to photopic conditions even at eccentricities at which there are greater rods than cones. This largely reflects the greater spatial summation in the rod compared to cone system. We sought to examine whether the increased spatial integration that is a feature of the rod pathway is reflected in changes in population receptive field characteristics in primary visual cortex. To this end we employed established population receptive field mapping techniques under four different luminance levels – photopic, mesopic, light and deep scotopic. We then evaluated how the population receptive field size varied in a representation of the peripheral visual field in V1. This representation can be driven by either rods or cones. We found a strong effect of light level on population receptive field size, with the lower, scotopic light levels yielding larger estimates of size than those obtained at mesopic and photopic light levels. Our finding is in line with our hypothesis that neurons that integrate information over larger areas of the visual field are used under dim light conditions than those used under brighter light conditions, and that these effects are observable at the level of primary visual cortex.

9. Julie Skevik, *Combining vision and touch to detect hidden objects.*

Previous research has shown that people are able to discriminate properties such as size and shape with a higher level of precision when information is available from vision and haptics simultaneously, compared to either cue in isolation (Ernst and Banks 2002; Helbig and Ernst 2007). Here we investigated whether the same benefit would hold true in detection tasks, which have more relevance to applied situations such as the detection and delineation of cancerous tumours in medical imaging data (Abbey and Eckstein 2009). Observers had to detect which of two image patches on a computer monitor contained a hidden 2D Gaussian profile. Information was available from vision, touch or vision and touch. Haptic feedback was provided by a desktop Phantom force feedback device and maintained a constant level of reliability across conditions. Visual reliability was parametrically manipulated by adding Gaussian white noise to each image patch. Consistent with discrimination experiments, we find that observers are better at detecting the hidden Gaussian profile (across a range of visual noise levels) when both vision and touch were available compared to either modality in isolation. We discuss our results in relation to models of optimal sensory cue combination and examine the haptic predictors of good performance.

10. Luise Gootjes-Dreesbach, *Monitoring for 3D location changes in the presence of task irrelevant distractor features*

Observers are known to be oblivious to large changes in the 3D scale of their environment (Glennester et al., 2006) but less is known about people's sensitivity to non-rigid changes in 3D structure as they move. We have shown (VSS 2017) that participants' ability to detect a change in the position of objects is strongly disrupted by the presence of elements that are irrelevant to the task (viz. 'dipoles' connecting spheres that change to connect other pairs at the moment the target sphere moves). This raises the question of whether the decrease in performance is due to change in Gestalt grouping or image change. When we use colour rather than dipoles we find that both grouping (half the spheres switch colour) and image change (every sphere



switches colour) can be ignored, giving the same level of performance as no colour change. This fits with findings on the effect of colour changes on memory for 2D location (Jiang, Olson & Chun, 2000; Jiang, Chun & Olsen, 2004) and suggest that effect of connecting lines cannot be reduced to changing the grouping of the spheres into different objects. A framework considering sparse versus detailed content of memory may be more appropriate than one based on minimising errors in a 3D reconstruction.

11. Deema Awad, *Unconscious processing of facial dominance and trustworthiness: Low-level, not social factors determine access to awareness*

Rapid detection and evaluation of visual stimuli with social-emotional relevance is of fundamental importance for survival and for human communication, and it gains preferential access to awareness. While most studies focused on emotional facial expression access to awareness, Stewart and colleagues (2012) demonstrated that also trait-like social characteristic of faces influence access to visual awareness. Using the breaking continuous flash suppression paradigm (b-CFS), they demonstrated that faces that are perceived as most threatening (less dominant and more trustworthy) are prioritised in awareness. The present study tested whether these effects of social factors on access to awareness for faces indeed reflect differences in social-emotional meaning or whether it is influenced by physical, low-level stimulus differences. In Experiment 1 we replicated the effects of facial dominance and trustworthiness on suppression times in the b-CFS paradigm, more dominant and less trustworthy faces needed longer to overcome suppression and break into awareness. However, similar effects of dominance-related slowing and untrustworthiness-related slowing were obtained for inverted faces although it was more difficult to perceive these social characteristics from inverted faces. In Experiment 2, we tested whether local contrast differences in the eye regions may account for dominance-related slowing. Indeed, we found that the eye regions alone, even when presented inverted and with reversed contrast polarity, yielded the effect in b-CFS. Our findings support the notion that low-level physical factors account for these social-emotional influences on awareness of faces under CFS. Future studies need to exclude the influence of such low-level differences when studying social-emotional relevance on access to awareness.

12. Amalia Papanikolaou, *Interaction of adaptation states in the mouse primary visual cortex*

Sensory pathways in the brain adapt to the current environment by adjusting neuronal responses to the recent history of stimulation. How the adaptation state induced by one environment interacts with that induced by subsequent environments is unclear. We obtained extracellular recordings ( $n = 150$ ) from the primary visual cortex of four awake mice in response to a vertical bar that randomly varied in horizontal location. The ensemble of bar locations was either uniform, or biased to one location. After initial exposure to a uniform ensemble, we presented a biased ensemble for 5-minutes before returning to the uniform ensemble. Biasing the ensemble decreased the gain of neurons with receptive fields near the adaptor, and repulsed receptive fields away from the adaptor. Return to a uniform ensemble increased gain and attracted receptive field profiles toward the previously adapted location, relative to pre-adaptation measurements. In a second experiment, 5-minutes exposure to one location bias was followed by 1-minute exposure to a new location bias. The second bias decreased the gain and repulsed the receptive fields of neurons around the newly adapted location. Neurons near the location of the original bias showed increase in gain, but no change in receptive field profile, suggesting dissociation of changes in gain and receptive fields. A mixture of both adaptation states was maintained during subsequent exposure to uniform ensembles. Our observations show that changes in environmental statistics lead to

both rapid recalibration of neuronal responses, and a long-lasting aftereffect that is superimposed on subsequent adaptation states.

13. Marek, Pedziwiatr, *The causal influence of prior knowledge on oculomotor behaviour*

The extent to which eye movements during viewing of natural scenes are guided by low-level features or by high-level object representations is a matter of intense debate. The finding that low-level feature models show good performance in predicting eye-movements might indicate low-level guidance but could also result from the fact that features and object locations are confounded in natural scenes. Experimental work relating to this question has manipulated low-level properties of stimuli. Here, we take a different approach: leaving low-level features of images intact, we manipulate the ability to perceptually bind them into high-level scene representations by controlling observers' amount of prior object-knowledge. We used ambiguous, two-tone images as stimuli. These are derived from photographs of natural scenes, the templates. On first viewing, two-tone images appear to consist of meaningless patches. Once an observer has acquired prior knowledge of image content by viewing the templates, however, the visual system binds a two-tone image into a coherent percept of a scene. In the current study, we collected eye-gaze data while observers free-viewed template photographs (Template condition) as well as two-tone images before (Unresolved) and after (Resolved) providing prior object knowledge. Despite the fact that low-level features of two-tone images are identical in the Unresolved and Resolved conditions, we show that observers' eye-gaze patterns are more similar between Template and Resolved conditions than between Template and Unresolved conditions. These findings indicate that processes of perceptual organisation that are guided by prior object knowledge override low-level features in the control of human eye-movements.

14. Miaomiao Yu, *Using EEG to measure slow modulations in the human koniocellular pathway*

Cheong et al (2011) demonstrated the existence of slow, intrinsic rhythms in the marmoset koniocellular pathway. These slow rhythms (in the sub-10Hz range) were measured in the LGN and relatively absent from magnocellular and parvocellular cells. The authors also found that the intrinsic signals present in the K pathway interacted with visual inputs and that correlates of these interactions could be measured using EEG over visual cortex.

We use steady-state EEG to look for evidence of a similar rhythmic koniocellular pathway signal in humans. We present flickering sine wave grating stimuli that are restricted in chromaticity, exciting either the koniocellular (isoluminant yellow-blue) or parvocellular (isoluminant red-green) pathways or a mixture of parvocellular and magnocellular pathways (achromatic). We are unable to record from individual LGN neurons, but we hypothesise that nonlinear interactions between intrinsic rhythms and the input frequency in the LGN will generate cortical power at intermodulation frequencies: sums and differences of the input frequency and the intrinsic frequency. Because the intrinsic frequency may vary slightly across time, we expect these intermodulation terms to form a 'hill' of spectral power centred around 10Hz either side of the input frequency. These intermodulation terms would be present for koniocellular but not parvocellular or magnocellular input stimuli.

Our preliminary data suggest that elevated EEG signal power can be detected at intermodulation frequencies for S cone isolating conditions, but not for magnocellular or parvocellular stimuli, suggesting that they are generated by the interaction of input stimuli and an endogenous rhythm in the sub-beta range.

15. Matteo Lisi, *Signatures of a probabilistic strategy in the control of saccadic eye movements*

Saccades are rapid eye movements that orient the visual axis toward objects of interest to allow their processing by the central, high-acuity part of the retina. Our ability to collect efficiently visual information from the environment relies on the accuracy of saccades, which is limited by a combination of uncertainty in the location of the target and motor noise (van Beers, 2007). Additionally, saccades have a systematic tendency to fall short of the target (hypometria), which is thought to result from a deliberate strategy that seeks to minimize a cost function favouring hypometric errors (e.g. Harris, 1995). In this study, we tested whether this strategy is probabilistic, i.e. whether it seeks to minimize the expected cost of saccadic errors by taking into account uncertainty in a statistically principled way. We asked observers to judge the location of peripheral targets, or make saccades to them, and manipulated their sensory uncertainty by varying the blurriness of the targets. Location judgments became more variable with increased blurriness, confirming the effectiveness of our manipulation. Most interestingly, increasing uncertainty resulted not only in larger spread of the saccade endpoints, but also in more hypometric errors. Moreover, under high uncertainty, saccade endpoints were biased toward the average of target locations in a given block, suggesting that prior knowledge was integrated into saccade planning. In sum, we report that saccades made under varying levels of uncertainty about target location do indeed carry the signatures of a probabilistic-Bayesian strategy.

16. Elisa Infanti, *Spatio-temporal regularity sharpens population receptive field estimates*

Expectations, whether derived from contextual cues or previous experience, convey useful information to inform our perception, allowing us to anticipate what is coming next and directing our attention accordingly. We used functional MRI to test whether the spatial predictability of visual stimuli can modulate how they are represented in human visual cortex. Visual mapping studies typically employ ordered stimulus sequences - such as rotating wedges, contracting and expanding rings, or sweeping bars - to span the visual field. Here we present 2 studies (N=5) in which we mapped retinotopy in occipital cortex. We created three mapping sequences that differed in the spatial contingencies of consecutive wedge stimuli and in their predictability: 1) an ordered (rotating) sequence, 2) a random sequence, and 3) a predictable sequence, randomly generated but predictable because it was either learned (Experiment 1) or cued (Experiment 2). We adopted a population receptive field modelling approach to estimate the polar angle preference of voxels and their tuning functions for each mapping sequence. Ordered sequences produced narrower tuning functions than the random ones while learned predictable sequences lead to intermediate results. This effect increased in higher visual areas. However, sequences rendered predictable by external cues showed similar tuning as random ones. These results suggest that spatio-temporal regularities can bias processing by increasing the precision of the response. While this could reflect the influence of expectations, the more parsimonious explanation is that this is a result of regularity in the hemodynamic response.

17. Maris Ozolinsh, *Time decay of illusory "The break of the curveball" perception.*

Illusion was firstly demonstrated in the "Illusion Contest" where it was awarded as the best illusion of the year (Shapiro, <http://illusionoftheyear.com/2009/05/the-break-of-the-curveball/>). Authors explained essence and some details of perception mismatch in another paper (Shapiro, 2011). They have shown that visual perception of the trajectory of a falling ball deviates from vertical if the ball is spinning and contains texture and direction of the sight of view is peripheral.

We studied the phenomenon comparing slants of two falling balls viewed in opposite peripheral areas: reference object – a) uniform and neutrally gray falling at distinct angle; and b) textured object: falling vertically, with vertical stripe structure that moved

along horizontal direction within the object area. 2ATC paradigm: is the reference object slope steeper; was used to build psychometric curves. Observers in Part I were naïve participants that during one hour responded to series of events where reference objects had randomly selected slant of fall trajectory. Subjective equivalence point was determined at centres of sigmoidal fit of psychometric curves where ordinate was a reference real slant. Averaged (22 participants) illusionary slant of falling textured objects between was ALFA= $28 \pm 5$ deg (for viewing directionality  $\sim 8$ deg; falling vertical speed 0.18deg/sec, texture Michelson-contrast 0.82, "spinning" speed 2deg/sec). In Part II, two observers repeated experiments at similar viewing conditions each day for two weeks. Distinct decay of ALFA was determined with exponential time constant  $11 \pm 2$  days. Most surprisingly the decay curves converge to zero values for supposed infinite length of demonstrations. Preliminary discussion of the latter with illusion authors revealed coincidence of our results with author's suggestions. Support from IMIS2.

#### 18. Matthew Anderson, *Human-Centered Categorization Systems for Real-World Scenes*

Category representations are an essential part of high-level scene perception; describing an environment as a forest or a beach constrains the probable identity and location of objects, and identifies possible actions that an individual might take. Recent efforts to understand the computational processes underlying categorization have enjoyed considerable progress (review by Malcolm, Groen & Baker, 2016). However, most studies have used category sets derived from arbitrary labels created by small groups of researchers (e.g., Oliva & Torralba, 2001; Fei-Fei & Perona, 2005), or exhaustive vocabularies of place names (e.g., Deng et al., 2009; Xiao, Hays, Ehinger, Oliva, & Torralba, 2010); the psychological validity of such category sets is undetermined. In response, we developed a novel taxonomy of scene categorization by measuring the intuitive grouping judgements and labels used by naïve human participants to classify real-world stereoscopic images. We applied this method to the SYNS dataset (Adams et al., 2016) to generate categories according to three different attributes / dimensions: semantic, 3D spatial structure, and 2D appearance. Inter-category relationships between the three systems provided diagnostic information regarding category membership. Our findings support scene-centered theories of category representation, which assert that semantic categories can be derived from a limited set of global image properties (e.g., Oliva & Torralba, 2001).

#### 19. Gabriela Raleva, *No contribution of object category information in perceptual thresholds, evidence from Candy-Crush.*

An emerging view in visual learning is that the rewards associated with particular visual stimuli lead to enhanced early sensory representations. However, it is unclear whether object category information is required for reward-related facilitation of early sensory representations, or whether any facilitation occurs at a more fundamental level. Video games which rely on in-game icons of rewarding or neutral value offer an excellent arena in which to investigate the development of any changes in representation. To test these alternative explanations, we compared the ability of 33 Candy-Crush players against 32 non-players to detect icons which had rewarding or neutral roles within the game. Using diffeomorphic scrambling to preserve the basic visual properties, the threshold for detection of a rewarding icon, a neutral icon and a control pair of non-game icons within a 7x7 grid of distractor icons was measured. Each participant's thresholds were measured in a 2AFC staircase procedure. Both players and non-players were significantly better at detecting the rewarding in-game icon than the neutral icon and all participants showed similar reductions in threshold for the reward-associated control icon compared to the neutral control icon. Even

though our most practiced players had accumulated years of experience, there was no association between playing time and perceptual thresholds. Our results suggest that there is a strong contribution of the basic visual features to performance levels both with the Candy-Crush and control targets, and provide no evidence that even long experience with reward-association heightens perceptual sensitivity independent of object category information.

#### 20. Alexander Murvy, *Models of pointing in non-metric virtual environments*

We have shown (VSS 2017) that observers can learn to navigate in virtual maze environments that include 'wormholes' (Warren, et al. (2017). *Cognition*, 166, 152-163) which are invisible to the participant but which alter the structure of the maze as they pass through the entrance. This makes it impossible to reconstruct a consistent metric map of the maze. Here, we investigate the cause of systematic errors in pointing when wormholes are included in a maze.

In our experiment, participants in immersive virtual reality had to collect 4 coloured targets in a specified order. From the last target, participants had to point in the direction of the other targets. There were 5 repeats with the same target order ('learning' phase) and three repeats with a different target order. We tested participants in two different maze configurations and for each we tested them with 0, 1 and 3 wormholes. The wormholes increased the length and number of turns between pairs of locations in the maze but did not alter the topological structure. The pointing task demands that participants generate a metric representation even though there is no consistent metric solution for the wormhole environments. For each scene, we computed the most likely metric configuration of the targets that would be consistent with the participant's pointing directions. In the wormhole conditions, this provides a better explanation of pointing responses than ground truth (using Akaike information criterion) and provide clues about how participants represent the layout of a maze containing wormholes.

#### 21. Joshua Harvey, *Not all that glitters: probing material perception with a physical imitation-gold stimulus*

We have created a physical imitation-gold stimulus that presents unique visual properties. In the medieval period, decorative processes were developed for and applied to ornamental objects in order to lend stone and other materials a gold-like appearance. These processes were applied extensively in churches for decorating sacred objects, and involved enveloping the object in a base layer of metallic leaf, coated with a clear varnish of a particular chromaticity (in this case, yellow orange). By following medieval descriptions, we have manufactured preliminary samples of gold-like flat squares. While our stimulus has a phenomenological appearance close to gold, it exhibits several other notable features due to the microgeometry of both the metallic base layer and the varnish coating. First, variations in the varnish coating give rise to low spatial-frequency colour variations that are not present in gold. Second, the reflectance of the material contains two separate specular components: a chromatic specular component, akin to real gold, as well as a specular component retaining the chromaticity of the illuminant, from reflection off the air-varnish boundary. Third, due to the surface microgeometry these specular components give rise to a pronounced glittering when observed proximally; a product of discrepancies between two binocular images. Fourth, the material appears simultaneously metallic and glossy when viewed at particular orientations. The stimulus provides a novel opportunity for investigating the mechanisms of material classification, gloss perception, binocular disparity, and illuminant estimation for colour constancy using a physical real-world material.

22. Alexander Vasilyev, *A model of visual search in the presence of age-related macular degeneration.*

Age-related macular degeneration (AMD) is a disease that results in blurred or no vision in the center of the visual field. As a result, the visual behaviour of AMD patients significantly differs from that of healthy controls during the execution of visual tasks [1]. AMD patients display a lower accuracy in performance of visual search tasks [2], an asymmetric spatial distribution of saccades [3] and a larger number of saccades per trial [4]. Despite the considerable number of eye-tracking experiments conducted with AMD patients, computational models to explain the statistics of saccades for these patients are lacking. Our approach to modelling the execution of a visual (search) task consists of two stages. In the first stage we estimate the visibility maps that account for the corresponding sequences of eye-movements, using an iterative inference scheme that maximizes the sequence probability. In the second stage we simulate an information maximization model [5] using the inferred visibility maps. The simulations accounted for the characteristic behaviour of AMD patients, including the increased number of saccades per trial and the longer response times for AMD patients. We also find that the spatial distribution of simulated eye-movements is statistically consistent with the experimental data.

23. Sarah Regan, *Are hue and saturation carried in different neural channels?*

Chromatic discrimination data show that a smaller physical stimulus change is required to detect a hue change than a saturation change (Judd, *Palette* 30, 1968; Danilova & Mollon, *Proc. R. Soc. London. Ser. B* 283, 2016). On this basis, it has been suggested that hue and saturation are carried in different neural channels (Kuehni, *Color Space and Its Divisions*, 2003, p. 331). We used an adaptation paradigm to directly test for separate hue and saturation mechanisms. To target post-cardinal mechanisms, we presented stimuli to 6 colour-normal observers (number of trials per condition = 300) that were temporally modulated (two cycles at 1.5 Hz) in terms of either hue or saturation, but whose time-averaged trichromatic and colour-opponent cardinal-axis modulations were held constant across conditions (equal-energy grey background; luminance = 14 cd/m<sup>2</sup>). We measured detection thresholds without adaptation for hue modulation and saturation modulation, two within-condition adaptation thresholds (hue adapt/hue threshold, saturation adapt/saturation threshold), and two between-condition adaptation thresholds, (saturation adapt/hue threshold, hue adapt/saturation threshold). If hue and saturation are carried in different neural channels, we would expect within-condition adaptation to elevate detection thresholds more than between-condition adaptation. However, there was no significant difference between detection thresholds for within-condition adaptation versus between-condition adaptation (Wilcoxon signed-rank two-tailed test,  $Z = -1.782$ ,  $p = .075$ ). We therefore did not find psychophysical evidence for a neural channel that extracts hue thresholds more effectively than the neural channels that determine saturation thresholds.

24. Anna- Katharina Hauperich, *The importance of peripheral visual information for stable fixation: central stimuli provide more effective gaze stabilisation*

Visual fixation targets are usually comparatively small and presented directly to the fovea. However, individuals with central vision loss have poorer fixation stability, which can affect ophthalmic procedures that require a steady gaze. Our experiment examined the influence of peripheral visual information on the ability to maintain stable fixation. We presented two Gabor-like patches at 3° and 8° of retinal eccentricity, horizontally separated, and asked participants to estimate and fixate on the centre location that is equidistant between them. The orientation of the gratings was vertical in one half, and horizontal in the other half, of the sessions. Other visual information was limited by creating a dark environment. Stimuli were equated for discriminability by matching the discriminability of the Gabor-like pattern with a

Gaussian intensity pattern in an initial task. Eye movement data during fixation was collected using the scaled stimuli with an Eyelink1000 eye tracker (2kHz sampling rate) over a period of 5 seconds per trial. A bright random noise mask was used to maintain a light-adapted state during 3-second breaks between trials. We compared overall fixation stability and microsaccade frequencies and directions with regards to the eccentricity of the Gabor-like patches. Overall fixation stability for horizontal eye movement was significantly better in the 3° than the 8° conditions. Microsaccades were 1.29 times more frequent and spanned 1.13 times longer distances in the 8° condition, suggesting that, irrespective of discriminability, visual information closer to the fovea contributes more to fixational stability.

25. Claire Wu, *Orientation selectivity and adaptation are altered in a tauopathy model of Alzheimer's disease*

How Alzheimer's disease affects information processing mechanisms in neural populations is currently not well understood. This is in part because studies have focused on medio-temporal lobe areas where pathology first appears. However, information processing function in these areas is also less known. In contrast, we have a more comprehensive understanding of functional responses and their underlying mechanisms in the primary visual cortex (V1), where the pathology also appears. This makes V1 an ideal area to characterise changes in information processing functions and mechanisms on a single neuron and population level.

We recorded from V1 in awake head-fixed 5-6.5 month old Tg4510 mice, a tauopathy model of Alzheimer's disease, using silicon probes. Mice were presented with drifting grating stimuli at varying directions to assess orientation selectivity and responses to orientation adaptation. Tg4510 mice with tau pathology had enhanced orientation selectivity in V1 neurons, and increased suppression effects due to adaptation, compared to control Tg4510 mice in which tau expression was suppressed through feeding doxycycline. These findings suggest that at an intermediate stage of disease progression, tau pathology in visual cortex does not cause a straightforward loss of function, but instead selectively enhance some processing mechanisms.

26. Arnold, Wilkins, *On the reliability of colorimetry*

Purpose. To assess the reliability of clinical assessment with the Intuitive Colorimeter in the treatment of visual stress using precision ophthalmic tints.

We describe two independent studies in which patients underwent assessments with the Intuitive Colorimeter.

Methods. In both studies, assessments were undertaken on two occasions. The studies differed in respect of the models of colorimeter used, the assessment methods employed, the interval between examinations, and the masking of examiners.

Results. Both studies showed a similar reliability of the assessments. This reliability was entirely as expected from previous literature. The standard deviation of  $u'$

and  $v'$  coordinates was estimated to be 0.022. From this estimate it was possible to calculate the number of tints that any ophthalmic tinting system should be able to provide.

Conclusion. A minimum of about 400 trial tints is necessary, a figure compatible with previous estimates derived from different data using different methods.

27. Austyn Tempesta, *An association between extended headaches, altered event related potentials, and lack of habituation to visually aggressive stimuli*

Migraines cost the UK around £250M annually. Visual Stress / discomfort is a contributing factor in migraine, although the underlying neurophysiology is unknown.

We recorded ERPs from 35 participants while viewing gratings at three spatial frequencies (Thick=.5c/deg, Medium=3c/deg, Thin=12c/deg) for 3 second periods. Stimuli were presented in an interleaved, counterbalanced order. Separately, they completed questionnaires to assess their headache and visual discomfort status. Reasoning that medium gratings might illicit more positive ERPs than thick and thin for some portion of the P1-P2 complex, we partitioned the data into two groups (test, N=23; calibration, N=12) and used the calibration set to derive a temporal window on the rising edge of the P2 component, at Oz, where this held. Correlations with the questionnaire and data revealed that headache duration were related to the strength of response to medium gratings. Splitting the test set into two groups based on headache duration and further splitting recordings made early or late in each session, a 3-way (grating frequency x headache duration x time) ANOVA on the test set confirmed an accelerated P2 for the medium gratings. This effect was more prevalent in those suffering longer headaches, and attenuated over time for those with short but not long headaches. These results support the notion that those with severe headaches are more sensitive, and habituate less, to certain striped patterns than relatively headache free individuals.

28. Samuel Solomon, *Spatial and luminance specificity of repetition suppression in superior colliculus of awake mice*

Objects are more likely to be of potential interest when they are novel or unexpected. Repeated presentation of an object makes it more predictable and less interesting. The response of visual neurons in many brain areas is suppressed by repeated presentation of an object, but the degree to which this reflects stimulus adaptation or expectation is not clear. Activity in the superior colliculus is important in orienting animals towards or away from objects of potential interest. We therefore made extracellular measurements from single- and multiunit clusters in the superficial layers (n = 89) of the superior colliculus in two awake mice, while they passively viewed brief sequences of small white or black discs presented on a grey background. Each sequence comprised 4 repeats of a black or white disc in one spatial location (the adaptor), followed by a test stimulus that could be the same or opposite polarity, in the same location or adjacent to it. We monitored eye position and excluded trials in which eye movements substantially shifted the underlying receptive fields. The mean response to each test was compared with control measurements obtained in the absence of an adaptor. In the majority of units, adaptation suppressed responses to test stimuli of the same polarity and location as the adaptor. Responses to test stimuli in locations adjacent to the adapting stimulus were largely unaffected, even in those units whose receptive fields spanned both locations. Responses to test stimuli that were of different polarity to the adaptor was variable. In some units, responses were suppressed only for test stimuli of matched polarity, but in others, responses to both polarities were strongly suppressed. Polarity-specific suppression was more commonly found for black adaptors than for white adaptors. The spatial specificity of effects suggest that repetition suppression in superficial layers of mouse superior colliculus is primarily stimulus adaptation, as an expectation-related signal would be unlikely to show such high spatial specificity. The partial polarity-specificity suggests that this adaptation occurs in parallel input pathways, perhaps even in the retina.