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ABSTRACTS

♦ **Steady state visually-evoked responses in Drosophila models of epilepsy**

1 Sultan Alamri, Alex Wade, Jonathan Robertson, Christopher Elliott (University of York)

In humans, epilepsy can be associated with visual deficits that can be measured with electrophysiological methods. For example, using SSVEPs we have recently demonstrated that patients with idiopathic generalized epilepsy (IGE) have abnormally weak contrast gain control. Until recently, however, it has been difficult to examine the physiological and genetic origin of these deficits directly. *Drosophila melanogaster* (the fruit fly) is a common animal model of neurological disease with a relatively simple visual system and excellent genetic tractability but relatively little is know about the effects of epilepsy on the visual responses in this organism. Here, we show that electrophysiological recordings of steady-state visually-evoked responses in Drosophila are qualitatively similar to those in humans and that spectral analysis of the evoked waveform can distinguish between different stages of the visual pathway. We also demonstrate that contrast masking and non-linear interactions between frequency-tagged signals are similar in both species and that they can be described by similar equations. These SSVEP measurements are sensitive to the presence of mutations in a K+/Cl-cotransporter gene kazachoc (KCC) that provides an excellent model of some forms of human juvenile epilepsy. We show that flies carrying the KCC mutations exhibit reduced gain control, weaker contrast adaptation and increased response noise immediately after eclosion. We also demonstrate that responses normalize in adulthood. The SSVEP therefore represents a bridge between human and invertebrate studies of epilepsy and provides an in vivo method for monitoring the effects of drug treatment at a very early screening stage.

♦ **Extrastriate projections in human visual system: Evidence from fMRI-informed tractography**

2 Ivan Alvarez, D Samuel Schwarzkopf, Chris A Clark (University College London)

The optic radiation (OR) is the main pathway for conveying retinal information to the occipital lobe. While commonly described as a projection to striate cortex, the OR has been demonstrated to project to areas V2 and V3 in the macaque (Yukie & Iwai, 1981, J Comp Neurol, **201**, 81–97; Bullier & Kennedy, 1983, Exp Brain Res, **53**, 168–172). This study investigates whether similar extrastriate connections are found in humans with in vivo diffusion MRI methods. Functional and structural MRI was acquired on 30 healthy adult volunteers with normal vision at 1.5T. A model-based population receptive field mapping approach (Dumoulin & Wandell, 2008, NeuroImage, **39**, 647–660) was implemented in fMRI (TR = 2376 ms, resolution = 3.3 mm^3) to delineate regions V1, V2 and V3. The lateral geniculate nucleus (LGN) was delineated anatomically. Diffusion-weighted images were acquired (TR = 7300 ms, resolution = 2.5 mm^3, 60 b = 1000 $s.mm^2$ volumes, 3 b = 0 $s.mm^2$ volumes) and processed with a constrained spherical deconvolution model. Probabilistic tractography was initiated at the LGN and terminated at the occipital region. We then segregated streamlines based on their termination site in areas V1, V2 or V3. Extrastriate projections of the OR were found in all (60) hemispheres. The anatomical distribution of OR components was consistent across subjects, with the dorsal projections (V2d, V3d) aligning laterally and superiorly, while ventral projections (V2v, V3v) aligned dorsally and inferiorly. This work is the first description of human extrastriate OR projections in vivo.

♦ **TARDIS, using time and relative dimensions in space to recognise objects**

3 James Austin, Mike Sole (University of York & Cybula Ltd)

Object recognition that is robust under translation, rotation and scale is a challenging area for both computer vision and the understanding of the visual system. A novel object recognition method is proposed, TARDIS, which is invariant to scale, rotation and translation. TARDIS is motivated from ideas based on the way neurons buffer information. Compared to computers, every neuron takes considerable time to transfer information from its dendritic inputs to the synapses on its axon. Furthermore, the longer the axons and dendrites are, the longer it takes for information to get from the input to the output. In electronic terms, every gate has a delay line on its inputs and outputs.

It is interesting to consider how this can enhance the capability of neural computation compared to computer systems. This property can be used to measure the distance between features in the visual field. If we consider a neuron taking feature information—it is possible for another neuron to triangulate its position based on data it receives from other neurons, in a similar way as location systems use the signals from sterilities. By capturing this information in a relativistic way, and using state machines at each point in the image we show how the invariance problem can be solved. We will describe the motivation for the work, the method and results on simple objects, distorted letters.

♦ **A database of whole-body action videos for the study of action, emotion, untrustworthiness, 4 identity and gender**

Nick Barraclough, Bruce Keefe, Chris Racey, Matthias Villing, Samantha Strong, Joanna Wincenciak (University of York, University of Sussex, Tübingen, Bradford, & University of Glasgow)

We have generated a database of high-definition (HD) videos for the study of the perception of traits inferred from whole-body actions. Twenty nine actors (nineteen female) were filmed performing different actions: walking, picking up a box, putting down a box, jumping, sitting down, and standing and acting, whilst conveying different traits including four emotions (anger, fear, happiness, sadness), untrustworthiness, and neutral, where no specific trait was conveyed. For the actions conveying the 4 emotions and untrustworthiness, actions were filmed multiple times with the actor conveying the traits with different levels of intensity. In total we made 2783 action videos (in both 2-dimensional and 3-dimensional format), each lasting 7 seconds with a frame rate of 50 fps. All videos were filmed in a green-screen studio in order to isolate the action information from all contextual detail, and to provide a flexible stimulus set for future use. In order to validate the traits conveyed by each action, we asked participants to rate each of the actions corresponding to the trait that the actor portrayed in the 2-dimensional videos. To provide a useful database of stimuli of multiple actions conveying multiple traits, each video name contains information on the gender of the actor, the action executed, trait conveyed and the rating of its perceived intensity. All videos can be downloaded free at the following address http://www-users.york.ac.uk/~neb506/databases.html.

♦ **Self-portraits taken with a smartphone do not support known principles of composition 5 but they support a bias to select the right side of the face**

Marco Bertamini, Nicola Bruno (University of Liverpool &Università di Parma)

Artists tend to create portraits showing the left side of a face, especially for female faces (Powell & Schirillo, 2009, Laterality, **14**, 545–572). There is also some evidence that the opposite is true for self-portrait possibly in relation to the use of mirrors. One hypothesis is that this is due to the asymmetry in facial expressiveness. We collected self-portraits by naïve photographers who used a smartphone front camera to take selfies. We found a bias for a right pose, leading to a left side bias of the face (because the camera works like a mirror). This was true even when biomechanical constraints would have favoured the opposite. This result undermines explanations based on posing conventions due to artistic training, and is consistent with the hypothesis that side biases in portraiture and self-portraiture are linked to asymmetries in facial expressiveness (Bruno & Bertamini, 2013, PloS ONE, **8**:2). We also used the same procedure to test three known principles of photographic composition: The rule of thirds, the golden ratio rule, and the eye centering principle. Smartphone self-portraits provide an ideal database due to the control on the composition of the photograph. We did not find support for any of the three principles in a large sample of non-professional photographers ($N = 388$), suggesting that, unlike the left bias, they are not strongly rooted in spontaneous perceptual preferences.

♦ **Perceived depth of 3D disparity-defined objects: continuous edges confer less apparent 6 depth**

Philip P K Cammack, Julie M Harris (St Andrews University)

Binocular disparity is a visual cue to depth and shape, to which the human visual system is highly sensitive. Models of disparity extraction explain how disparity at any specific location is obtained, but they do not usually consider how those disparities are combined to form a depth representation for a whole object. To begin to fill this gap in the literature, we explored the perceived depth of disparity defined objects, via random dot stereograms depicting roughly square objects 5.7 degrees (10.5 cm) across presented in front of a flat frontoparallel background. The disparity gradient of the edges of objects was varied, but peak depth held constant. Five participants were asked, via a 2AFC task, to compare the peak depth of discontinuous- (vertical depth edge) and continuous-edged (varied disparity gradient, from approximately 1.7 arcmin/mm to 14 arcmin/mm) objects. We found a flattening effect

dependent on the gradient of the continuous depth edge: the shallower the gradient, the smaller the apparent peak depth. Our results suggest that the visual system does not have independent access to the peak depth, and that some kind of depth integration across the scene must occur.

♦ **Peripheral visual responses in the retina and visual cortex are larger and faster in deaf adults**

7 Gabriela De Sousa[1], Charlotte Codina[2], David Buckley[2], Mark Hymers[1], Heidi Baseler[1] ([1] University of York, [2] University of Sheffield)

Superior peripheral visual sensitivity has been demonstrated in adults with early, profound hearing loss. Previous studies have attributed this difference largely to enhanced attentional mechanisms mediated by plastic changes in the brain. However, visual sensitivity differences in the deaf and hearing have recently been correlated with anatomical differences in the retina (Codina et al., 2011, PLoS ONE **6**(6): e20417). The current study investigated whether physiological differences are also observable in the retina and early visual cortex of the deaf. Individuals with congenital, profound hearing loss ($N = 11$, mean age = 37) and age-matched hearing controls ($N = 8$, mean age = 34) participated, all had good uncorrected visual acuity (0.150 LogMAR or better in either eye). Multifocal electroretinograms (mfERGs) and visual evoked potentials (mf VEPs) simultaneously assessed retinal and cortical function across the visual field using 60 independently reversing checkerboards, extending out to ±60 deg to maximise visual field coverage. Multifocal ERG peak amplitudes were larger and mfERG peak latencies were shorter in the deaf than hearing participants in the far periphery. Multifocal VEP peak amplitudes were also larger in the periphery, while mf VEP peak latencies were shorter at all locations. Congenitally, profoundly deaf participants exhibit larger and faster electrophysiological responses in both the retina and early visual cortex to peripheral visual stimulation compared to hearing controls. Our results lend functional significance to retinal structural differences reported in the deaf, suggesting that enhanced peripheral visual sensitivity in congenitally deaf adults may reflect much earlier visual pathway plasticity than previously believed.

♦ **Small connective fields in the extrastriate regions of a hemispherectomized patient**

8 Mirjan van Dijk[1], Nicolas Gravel[2], Koen V Haak[3], Nomdo M Jansonius[1], Pim van Dijk[1], Frans W Cornelissen[1] ([1]University Medical Center Groningen, [2] University of Groningen, [3] Radboud University Nijmegen)

The human visual cortex contains maps of the visual field. Much research has been dedicated to answering whether and when these visual field maps and their connections change if critical components of the visual circuitry are damaged. In a previous study (Haak et al., 2013, Cortex, 1–12), our group used population receptive field (pRF) mapping (Dumoulin & Wandell, 2008, NeuroImage, **39**, 647–660) to study the retinotopic organization of a 16-year-old hemispherectomized girl. Her left hemisphere was removed at the age of 3 as a treatment for chronic focal encephalitis and intractable epilepsy. In line with the hemispherectomy, Goldmann perimetry showed a homonymous right hemianopia. Whereas the pRF mapping indicated normal visual field maps in the early visual cortex, the maps in the extrastriate cortical areas contained an enlarged foveal representation and much smaller population receptive fields compared to normal. Here, we applied connective field modeling (Haak et al., 2013, NeuroImage, **66**, 1–9) to the functional data of this patient. This method models the responses of voxels in one part of the brain (eg V2) as a function of activity in another part of the brain (eg V1). Our results indicate that while there are substantial regional differences, the connective fields in the early visual cortex of the hemispherectomized patient appear normal. In contrast, those in extrastriate regions on V1 are—on average—relatively small compared to those in three control participants. This finding suggests that the origin of the smaller extrastriate pRFs may lie in a deviant cortico-cortical connectivity.

♦ **The influence of luminance transients on joint-action effects**

9 Silviya Doneva, Geoff Cole (University of Essex)

The past ten years has seen a large growth in the number of ‘joint-action’ studies in which cognitive processes are examined when two people mutually perform a task. The most common explanation for the effects observed is an account based on co-representation of perception and action in which the observation of a movement is represented within one’s own action planning. However, many such studies fail to take into account the influence of luminance transients, and subsequent attentional orienting, that occur when a co-actor responds. We used a commonly employed ‘movement-congruency’ paradigm in which two participants sitting opposite each other take turns to reach out and touch one of two targets, appearing either to the left or right hand side of the workspace.

In Experiment 1, participants responded using either the same body part as their co-actor or a different body part. In Experiment 2 participants performed the same paradigm alone and their attention was shifted by on-screen luminance transients that mimicked the same transients that occur during action observation. Our results revealed a movement-congruency like-effect in both experiments, despite participants not 'mirroring' their partner (Experiment 1), and performing alone (Experiment 2). These findings suggest that lower-level perceptual mechanisms might explain some joint-action effects.

♦ **Evidence for saccade preparation in human superior colliculus**

10 Michele Furlan, Andrew T Smith, Robin Walker (Royal Holloway University of London)

The superior colliculus (SC) is a small midbrain structure that plays a crucial role in the control of eye-movements (saccades), directed attention and fixations. A great deal is known about the functional role of SC from studies of non-human primates and other species but little is known about the functions of the human SC. A small number of studies have started to apply functional imaging techniques to study the visual representation in human SC but very few have investigated the oculomotor functions. Here we applied a combination of univariate (General Linear Model, GLM) and multivariate analysis (Multi Voxel Pattern Analysis, MVPA) to demonstrate oculomotor activity associated with saccade-target selection. We used 3T fMRI to record the BOLD response in the SC while participants were either preparing or executing saccadic eye movements. Our results showed that executing a saccade produced a significant change in SC hemodynamic activity and most importantly, that even preparing a saccade produced an increase in activity. The saccade-related activity was observed in the contralateral (and to a lesser extent ipsilateral) SC, and lower activity was also shown for return (re-centering) saccades. A second experiment also revealed saccade-related activity for pro and anti-saccades. MVPA analysis was able to recognise two different patterns for leftward and rightward responses. This study provides clear evidence of pre-saccadic preparatory activity recorded in human SC using fMRI and different patterns underlying the representation of the two visual hemifields.

♦ **The role of cortical and subcortical suppression in spatial attention**

11 Andre Gouws, Antony Morland (University of York)

There is clear evidence that spatial attention increases neural responses to attended stimuli in extrastriate visual areas, and to a lesser degree in earlier visual areas. Other evidence shows that neurons representing unattended locations can also be suppressed. The extent to which enhancement and suppression is observed, their stimulus dependence and the stages of the visual system at which they are expressed remains poorly understood however. Using fMRI we set out to characterize both the task and stimulus dependence of neural responses in the lateral geniculate nucleus (LGN), primary visual cortex (V1) and visual motion area (V5) in humans to determine where suppressive and facilitatory effects of spatial attention are expressed. Subjects viewed a lateralized drifting grating stimulus, presented at multiple stimulus contrasts, and performed one of three tasks designed to alter the spatial location of their attention. In retinotopic representations of the stimulus location we observed increasing attention-dependent facilitation and decreasing dependence on stimulus contrast moving up the visual hierarchy from the LGN to V5. However, in the representations of unattended locations of the LGN and V1 we observed suppression, which was not dependent on the attended stimulus contrast. These suppressive effects were also found in the pulvinar, which has been frequently associated with attention. We provide evidence therefore for a spatially selective suppressive mechanism that acts at a subcortical level.

♦ **Perceptual learning in patients with macular distrophy**

12 Mark Greenlee, Katharina Rosengarth, Caroline Schmalhofer, Markus Goldhacker, Sabine Brandl-Rühle, Tina Plank (University of Regensburg)

Hereditary and age-related forms of macular dystrophy (MD) lead to loss of cone function in the fovea, resulting in central scotoma and eccentric fixation at the so-called preferred retinal locus (PRL). We investigated whether perceptual learning enhances visual abilities at the PRL. We also determined the neural correlates (3-Tesla fMRI) of learning success. Twelve MD patients (eight with age-related macular dystrophy, four with hereditary macular dystrophies) were trained on a texture discrimination task (TDT) over six days. Patients underwent three fMRI sessions (before, during and after training) while performing the TDT (target at PRL or opposite PRL) with monocular viewing. Reading speed, visual acuity (Vernier task) and contrast sensitivity were also assessed before and after training. All but one patients showed improved performance (ie significant change in stimulus onset asynchronies, hit rates and reaction times) on the TDT. Eight patients also showed moderate increases in reading speed,

six patients showed improved thresholds in contrast sensitivity and nine patients showed improved thresholds in a Vernier visual acuity task after perceptual learning. We found an increase in BOLD response in the projection zone of the PRL in the primary visual cortex in nine of twelve patients after training. The change in fMRI signal correlated ($r = 0.8$; $p = 0.02$) with the patients' performance enhancements when the target was in the PRL. The results suggest that perceptual learning can enhance eccentric vision and cortical processing in MD patients.

♦ **Plasticity, and its limits, in the adult visual system: four days of contrast adaptation**

13 Koen V Haak[1], Elizabeth Fast[2], Min Bao[3], Stephen A Engel[2] ([1]Radboud University Nijmegen, [2]University of Minnesota, [3]Chinese Academy of Sciences)

In the visual system, neural function alters dramatically as people adapt to changes in the visual world. Most past work on visual adaptation, however, has altered visual input only over the short-term, typically a few minutes. Here, we present an experiment that investigates adaptation over a much longer term. For four days, subjects viewed the world through virtual reality goggles that display video acquired from a head mounted camera, processed in real time on a laptop computer. In order to characterize long-term visual plasticity, we used image manipulations that targeted early visual cortex, and measured adaptation with perceptual tests. Adaptation showed an early local maximum in strength during the first day, and declined markedly in the next session. In following days, adaptation as measured by an appearance task strengthened continuously, while an orientation task showed an increase and then decrease in strength. These results indicate distinct neural controllers for shorter-term and longer-term adaptation. The shorter-term controller resembles that identified in most prior studies of cortical adaptation, and has a temporal limit of about a day before it declines. The longer-term controller has not been seen before in the laboratory, and its limit extends beyond four days. Adaptation has costs that occur when adaptive changes in neural coding at earlier stages of the visual hierarchy are not detected by later stages. The decline in strength of both shorter- and longer-term adaptation likely reflects the visual system's ability to identify, and possibly correct for, these costs.

♦ **Grey matter biased imaging using dual inversion- recovery improves grey matter**

14 **segmentation over standard T1-weighted imaging for voxel-based morphometry**

Sandra Hanekamp, Doety Prins, Jan-Bernard Marsman, Branislava Curcic-Blake, Remko Renken, Frans Cornelissen (University Medical Center Groningen)

Voxel-based morphometry (VBM) can be used to compare grey matter volumes across different groups of participants. Current methods rely on T1 scans to estimate grey matter volume. Here, we investigated if grey matter biased imaging by using a dual-inversion recovery (DIR) sequence could facilitate VBM. A higher tissue contrast for grey matter may improve the performance of the algorithms used in VBM, potentially resulting in a more precise and sensitive segmentation of grey matter. The brains of 12 healthy participants (mean age of 63 years, 5 females) were scanned with a 3 Tesla MR system and using T1 and DIR sequences. For segmentation of grey matter we used VBM in the framework of Statistical Parametric Mapping 8 (SPM8) by using the DARTEL toolbox (Ashburner, 2007, NeuroImage, **38**, 95–113). We found significant differences in grey matter probability between T1-weighted and grey matter biased images. In segmented DIR images, higher grey matter probability was assigned throughout the entire cortex. Furthermore, in the basal nuclei – areas known to be difficult to segment in T1-weighted images –a sharper distinction between grey and white matter was revealed by visual inspection. Our results imply that DIR imaging provides a more accurate representation of cortical grey matter than T1-weighted imaging. We propose that grey mater biased imaging may therefore serve to improve grey matter segmentation. This may be important specifically in studies into morphological changes following ocular disease (Hernowo et al., 2013, Cortex, 1–12) or studies which depend on defining visual areas to perform an accurate retinotopy.

♦ **Small foveal stimuli are not ideal pursuit targets**

15 Stephen J Heinen, Elena Potapchuk, Scott N J Watamaniuk (Smith-Kettlewell Eye Research Institute)

A small spot stimulus that fits in the fovea is used almost exclusively to study smooth pursuit. Given that the pursuit system is modeled as motion-driven, this is curious, since the spot is a poor motion stimulus. Furthermore, most pursuit objects in the natural scene are larger. We showed previously that large, random dot stimuli (10 deg) invoked fewer saccades than the spot, and increased pursuit gain (Heinen & Watamaniuk, 1998). This might be because motion summation created a stronger pursuit signal; alternatively, peripheral stimulation reduced dependence on the fovea for pursuit.

Here observers pursued a single dot, or configurations of 4 and 5 dots, designed to differentially probe foveal and peripheral pursuit contributions. The 5-dots were arranged in a 6 deg '+' configuration. The 4 dots were arranged identically, but with no central spot. Consistent with our previous results, 4 dots yielded fewer saccades and higher gain than the spot. However, while the 5-dot stimulus further increased gain, it produced similar saccade frequency as the spot, suggesting that the foveal target triggered saccades. In a second experiment using 4-dot configurations with different diameters (1–12 deg), more saccades occurred when the configuration was small and stimulated the fovea, but gain remained constant with configuration size. The results suggest that two independent mechanisms subserve pursuit, one that corrects position error between the fovea and a salient feature, and another that is motion driven. We visualize the weighing of position and motion mechanisms during pursuit using motion/position 'Punnett squares', adapted from genetics.
[Supported by NIH Grant R01 EY021286]

♦ **The influence of optic flow on regular, over-ground locomotion speed**

16 Alicja Jedrzejewska, Kate Howard, David Redmill, Casimir Ludwig (University of Bristol)

Optic flow is a cue to the velocity of self-movement. Previous studies of treadmill locomotion (Prokop et al., 1997, Experimental Brain Research, **114**, 63–70; Mohler et al., 2007, Experimental Brain Research, **181**, 221–228) have shown that a mis-match between walking speed and optic flow influences locomotion. If the rate of flow is fast, participants slow down; if the rate of flow is slow, participants speed up. However, it remains to be seen whether optic flow exerts such influence during regular, over-ground locomotion through a static, textured environment. Subjects walked across a ~12 m walkway that consisted of light stripes on a dark background, orthogonal to the walking direction. The rate of optic flow was varied through the spatial frequency of the stripes. In the critical conditions, the frequency changed from low (1 cycle/m) to high (2 cycles/m) or vice versa. This change occurred either linearly ($N = 15$) or step-wise halfway through the walkway ($N = 15$). In the linear change condition, subjects showed a relative slowing in their walking speed when the frequency of the stripes increased. There was no consistent effect of spatial frequency in the step change condition. The effect in the linear condition was extremely small (~1% of the baseline walking speed). At present, we cannot draw firm conclusions why the effects in our over-ground protocol are much smaller than during treadmill locomotion. We will discuss the saliency of optic flow, concurrent attentional demands, and the attribution of changes in optic flow.

♦ **Visual attention: Development of behaviour and brain responses**

17 Louisa Kulke[1], John Wattam-Bell[1], Janette Atkinson[1], Oliver Braddick[2] ([1]University College London, [2]Oxford University)

The ability of infants to switch attention from a central fixation stimulus to a peripheral visual target, measured in the Fixation Shift Paradigm (FSP), is a reliable measure of normal and abnormal attention development in infancy (cf. Atkinson & Braddick, 2012. Dev Med Child Neurol, **54**, 589–595). The switching of attention occurs later if the central fixation stimulus stays visible when the target appears (competition condition), than if the central stimulus disappears (non-competition condition), as a shift under competition requires additional disengagement from the central stimulus. This difference decreases with age, most likely as a result of emerging cortical control of attention. We have developed an automated approach using remote eye-tracking (Tobii X120) which offers improved accuracy and shorter testing times in comparison to former methods. High-density electroencephalography (EEG, 128 channel system from Electrical Geodesics, Inc.) was used in combination with eye-tracking to investigate gaze behaviour and its underlying neural mechanisms simultaneously. Our results from infant and adult subjects confirm a developing ability to disengage attention as measured in the FSP. EEG results indicate differences in patterns of activation between adults and infants, indicating that the development of attention behaviour is accompanied by changes in cortical activation. The new method is suitable for fine-grained assessment of typical and atypical development of attention and its underlying brain mechanisms.

♦ **The role of visual motion areas in global motion integration in deaf and hearing adults**

18 Alexandra Levine[1], Shradha Billawa[1], Laura Bridge[1], Sally Clausen[2], Mark Hymers[1], Heidi Baseler[3] ([1]University of York, [2]Durham University, [3]Hull-York Medical School)

Congenitally, profoundly deaf individuals exhibit greater sensitivity to peripheral visual motion stimuli. Previous research attributes this advantage in part to greater recruitment of area V5 in deaf than hearing individuals (Bavelier et al., 2001, The Journal of Neuroscience, **21**(22), 8931–8942).

However, a direct link between neural activation and behavioural motion sensitivity has not been established in these populations. The current study used functional MRI to investigate the relationship between cortical activation and visual performance differences in deaf and hearing adults. Participants included fourteen hearing and four congenitally, profoundly deaf adults without visual deficits. Motion coherence thresholds were measured in each individual using a random dot optic flow stimulus restricted to the central (0–5 deg) or peripheral (40–72 deg) visual field. fMRI responses were measured while participants viewed a wide field (±72 deg) of either incoherently or coherently moving dots (optic flow) and retinotopic mapping stimuli. Activity within V1 and visual motion areas V5 and V6 was measured and correlated with psychophysical thresholds for each individual. V1 and V5 were equally activated by both incoherent and coherent motion, while V6 preferred coherent motion. Although behavioural motion sensitivity in the optic flow task did not differ between groups, it was significantly correlated with coherent motion activation in V5 in all participants for both the central and peripheral tasks. The results suggest that direction judgments based on global motion integration involve processing in V5, but not V6, despite V6's large peripheral representation and proposed role in egocentric motion processing.

♦ **Questions about symmetry perception answered with ERP techniques**

19 Alexis Makin, Marco Bertamini, Giulia Rampone (University of Liverpool)

Many animals are sensitive to visual symmetry, possibly because it indicates health in potential mates, or because it helps with scene segmentation. We have answered several questions about symmetry perception with a series of ERP experiments. Compared to random patterns, symmetry produces a negative component at posterior electrode sites from 250 ms onwards. We have shown this Sustained Posterior Negativity (SPN) is largest for reflectional symmetry, but that it is nevertheless evident for rotation and translation (Makin et al., Psychophysiology, 2013). The SPN is found even when symmetry is unattended or part of a background region (Makin et al., Journal of Vision, 2014). This implies that regularity networks are activated automatically, independently of other visual features and task demands. Source localization techniques imply that extrastriate visual regions generate the SPN (Makin et al., Neuropsycholgia, 2012). In our recent work, we have used the SPN to investigate view-invariance. We tested whether the SPN generators are sensitive to (1) symmetry in the retinal projection only, or (2) or symmetry in the world, irrespective of view angle. We found that the SPN was view-invariant when people explicitly classified patterns as symmetry or random. However, when participants attended to colour instead of regularity, the SPN was significantly reduced for slanted displays. We conclude that the brain's symmetry-sensitive networks are not always view-invariant, but view-invariance can still be achieved efficiently when this facilitates current goals.

♦ **The control of saccade sequences**

20 Eugene McSorley (University of Reading)

We move our eyes more than 150 000 times per day in a continuous sequence: eye movements are central to our visual interaction with the world and experience. However much research in this area has examined single eye movements in isolation. As a result, we have a far less clear understanding of the extent to which information about our environment is encoded continuously to enable the construction of the sequences of eye movements we need. It is clear from existing work that the visual information that elicits a series of eye movements is partially encoded prior to their execution. What is not clear is how far this encoding extends along a set of visual targets. In order to examine the limits of visual encoding of information for eye movement sequences we manipulated the amount of prior information given about the visual sequence by varying the number of saccade targets presented at any one time. Increasing this number should allow additional information to be partially programmed prior to the execution of that saccade. In line with this, we found that as more information about the location of upcoming saccade targets was given, the number of saccades executed in the sequence decreased as did the latencies of the saccade response. This benefit did not appear to saturate up to sequences of 7 visual targets. Furthermore we found evidence for longer amplitude 'target' driven saccades being distinct from a population of short amplitude 'corrective' saccades. We suggest that saccades are programmed much further in advance than previously thought.

♦ **Going with the flow when driving with road edges?**

21 Callum Mole, Georgios Kountouriotis, Jaclyn Billington, Richard Wilkie (University of Leeds)

Two useful sources of information when steering along a road are retinal flow (flow; the motion of surface texture elements across the retina caused by self-motion) and road edges. Influential models

of driving have focussed on 'near' and 'far' RE components (Land & Horwood, 1995; Salvucci & Gray, 2004), but the human brain uses flow even when RE should be sufficient (Kountouriotis et al., 2013). The aim of this study was to assess the use of flow when near or far RE components were present when steering down a virtual road. We systematically biased flow independent of veridical RE, so that use of flow would lead to predictable understeer or oversteer. We also varied RE information across conditions by displaying: full road, near road (up to 6 m ahead), far road information (12 m to horizon) or no road information (just a fixation target). When only near road information was present there was little effect of flow bias. Importantly, the presence of far road information increased the influence of flow, even when near road information was available. This confirms observations that the visual–motor system uses flow despite veridical RE information (Kountouriotis et al 2013). Critically, it indicates that flow may be used predominantly for prospective steering control rather than immediate error correction when driving.

♦ **Evidence for visual feature representations in both retinocentric and headcentric, but not**
22 body or world-centric reference frames

Sandeep Parwaga, Phil Duke (University of Leicester)

Despite movements of the eyes, head and body, our perception of the world is stable and allows us to interact successfully with the environment. How are such perceptions formed? One possibility is that retinocentric image features are transformed into representations at higher levels, such as head-, body-, or maybe even world-centred representations. The present study investigated this hypothesis using a contingent tilt aftereffect (TAE) paradigm designed to reveal adaptive representations beyond the retinocentric level. We found TAEs contingent on eye gaze direction, but not head or body direction. This demonstrates that visual features are represented in a headcentric frame and suggests no higher levels of perceptual representation. Having found evidence for an adaptive headcentric representation, we examined its contribution to the classical TAE using a method designed to isolate retinocentric and headcentric components and examine their temporal characteristics. We found evidence that tilt representation involves (1) a retinotopic tilt encoding mechanism, which is sensitive to test stimulus duration, and (2) a gaze direction encoding mechanism, which is not. Our results suggest that retinocentric visual feature orientation is jointly encoded with gaze direction to produce head-centric—but not body or world centric—representations.

♦ **Neural dynamics of visual word recognition**

23 Andrew Quinn[1], Mark Hymers[1], Sam Johnson[1], Gary Green[1], Piers Cornelissen[2] ([1]University of York, [2]University of Northumbria)

Visual word recognition is a complex task which is critically dependent on efficient interactions between visual and non-visual processes. Previous coherence analyses between source magentoencephalography (MEG) estimates have identified a widely distributed and densely interconnected network of brain regions that are associated with reading (Kujala et al., Cerebral Cortex, 2007; **17**, 1476–1485). The present study develops these findings by investigating the direction of information flow within the reading network and how this changes over time. Seven participants completed 1500 trials of a single word (either of high, medium or low word frequency) one-back task during a high resolution MEG recording. Delay and dimensionality parameters for a time delay embedding were objectively assessed across source current flow estimates within the reading network within short, densely overlapping time-windows spanning the stimulus presentation time. This embedding was subsequently used as a predictor for future activity in a MultiVariate AutoRegressive (MVAR) model. Separate models were fitted for the low and high frequency words before Partial Directed Coherence (PDC) was used to characterise interactions within the network in the frequency domain. Non-parametric permutations were used to establish connections which were significantly different when reading high or low frequency word. Overall, results suggest that visual word recognition is subserved by a complex pattern of interactions which vary over both time and frequency. Moreover this network demonstrates extremely rapid parallelization throughout the network from its entry point at the occipito-temporal cortex.

♦ **The robust and embodied nature of the SNARC effect is revealed through fast action selection**

24 Rebecca Sheridan[1], Oscar Giles[1], Maaike van Rooijen[2], Bert Steenbergen[2], Mark Mon-Williams[1], Amanda Waterman[1] ([1]University of Leeds, [2]Radboud University Nijmegen)

Embodied cognition suggests that cognitive processes are shaped through dynamic sensorimotor interactions. This is exemplified by the notion that numerical representations are spatially orientated in adults—the 'Spatial-Numerical Association of Response Codes' effect. It has been argued that the

SNARC effect is 'hard-wired' but recent evidence suggests "the effect is fleeting" with adults being able to rapidly adapt to new spatial-numerical mappings (Fischer et al., 2010, Brain and Cognition, **72**(3), 333–336). We developed a simple task to distinguish between these accounts. Participants were required to make aiming movements to an unmarked line, crossing it at the appropriate location indicated by a number (1–9). The colour of the number signalled whether the line ran from left to right or vice versa. The line direction was initially consistent (always left to right or reversed) but a mixed block was subsequently presented in which line direction was randomised. One group undertook the 'normal' (left–right) block first followed by the 'reversed' block whereas the other group were tested with the 'reversed' block first. The SNARC effect was small or absent in the consistent blocks indicating flexibility of number representation in conditions of stability. The two groups showed the same (large) SNARC effect in the mixed blocks indicating a stable hard wired spatial-number representation when actions needs to be selected rapidly—as predicted by embodied cognition.

♦ **25 The impact of visual–motor distortion on learning and performing skilled actions: How should we train minimally invasive surgeons?**

Megan Skelton, Faisal Mushtaq, Oscar Giles, Alan White, Peter Lodge, Mark Mon-Williams, Richard Wilkie (University of Leeds)

Minimally invasive surgery (MIS) has transformed medicine with improved outcomes due to decreased patient recovery times. But MIS has a steep learning curve due to the complex visuomotor demands entailed in successful performance (eg Secin et al., 2010, The Journal of Urology, **184**(6), 2291–2296). In MIS, a remote monitor (placed at a variety of positions relative to the surgeon) relays images of the surgical site and the end-point of the tools. There are several entrance ports that may be used, each of which will alter the mapping between movement on the display and the actual hand movement. Thus, visuomotor complexities include reduced visual information, degraded haptic feedback and a restricted range of movement. We ran a series of experiments using state of the art technology (Geomagic Touch and Kinematic Assessment Tool, Culmer et al., 2009, Journal of Neuroscience Methods, **184**(1), 184–192) to investigate the effect of altering visual–motor mappings on performance and novel skill acquisition. Our results show that changing the display or port position impacts negatively on performance. Nevertheless, structural learning theory suggests that exposure to a variety of visual-motor mappings during training may aid skill acquisition and our findings supported this prediction. We also investigated the degree to which training transfers between hands (as MIS is usually conducted bimanually). In a palpation task, we found asymmetrical inter-limb transfer with improved transfer from the preferred hand. Our findings are a first step in a long but important journey to better understand how to improve MIS performance and optimise MIS training programmes.

♦ **26 Children and adults use prior knowledge and stereo cues differently when making shape judgements**

Danielle Smith, Danielle Ropar, Harriet Allen (University of Nottingham)

There is little consensus in previous research regarding the extent to which either low-level visual cues or prior knowledge affects judgements of apparent shape. We conducted an experiment to compare the influences of each of these on shape constancy. We used a stimulus where each source of information could be independently modulated: a (real) slanted circle, in a darkened box, viewed through an aperture. The circle was viewed monocularly or binocularly, and was presented with, and without a surface pattern and with and without knowledge of the true shape. Observers were asked to reproduce the retinal projection of the shape inside the box using the method of adjustment to alter the height of a circle presented on a laptop screen. Both adults and children exaggerated circularity (ie indicated shapes closer to reality than the retinal projection) when the stereo and texture cues were present, with the stereo cue dominating shape judgements for all participants. However, knowledge of real shape had a differential effect on adults and children. When adults were informed about the circle's true shape they tended to adjust their judgement of apparent shape downwards, towards the retinal projection (ie shape constancy was reduced). In the case of children, knowledge of reality increased the degree of shape constancy, but only for monocular viewing conditions. Our findings suggest that although both low-level and high-level information are responsible for shape constancy, the relative contribution (ie prior probability distribution) of each type of information changes throughout development.

♦ **Asymmetry detection thresholds in novices assessing dynamic stimuli**

27 Sandra Starke, Thilo Pfau, Stephen May (Royal Veterinary College)

Symmetry perception in static images such as faces, objects or geometrical designs has been intensely studied. Perception of symmetry within dynamic patterns (such as human gait) has received less attention. We aimed to determine the asymmetry detection threshold of novices assessing pelvis movement of a horse, important for veterinarians when identifying a mild limp. 3D computer animations of a trotting horse equipped with markers on both hips were created and multiplied into nine scene conditions: three background colours and three complexity settings 'horse+marker', 'marker only' and 'horse only'. Vertical translation of the horse was perturbed to range from 0 to 70% asymmetry between the two successive amplitudes of each stride. Eighteen novice participants indicated the perceived absence or presence of movement asymmetry. Detection thresholds at the 50% level were calculated using binomial logistic regression for each participant and each condition as well as across pooled conditions. The mean (SD) asymmetry detection threshold ranged from 16 (6) % to 22 (12) % for individual conditions, with no significant difference between conditions ($P = 0.708$, Friedman Test). The average detection threshold across all conditions pooled was 16 (8) % asymmetry. The lowest thresholds of individuals triggered high false positive rates. We conclude that novices are very good at detecting movement asymmetry in a horse model, which contrasts with poor agreement on mild lameness cases even in expert clinicians. In real horses, unsystematic movement, uncertainty what to look for and other factors likely elevate the detection threshold above values reported here.

♦ **Transient versus sustained: Modelling temporal impulse functions in visual discrimination**
28 of dynamic natural images

Michelle To, Iain Gilchrist, David Tolhurst (Lancaster University, University of Bristol, & University of Cambridge)

Can a computational model predict how observers rate perceptual differences between paired movie clips? Previously, we examined three models with V1 simple cell receptive fields. The Spatial Model compared corresponding frames between each movie pairwise, combining those differences using Minkowski summation. The Temporal Model compared successive frames within each movie, summed those differences for each movie, and then compared the overall differences between the paired movies. The Spatiotemporal Model combined estimates from both models, and yielded the strongest predictions (To et al., 2012, Perception, **41**,1270). However, these models compared movies frame-by-frame without modelling naturalistic temporal impulse functions. Here we investigate whether including sustained and transient filters improves model performance. Seven students viewed 198 pairs of movies clips, rating how different the two clips appeared to them on a magnitude scale. Sixty-six pairs were naturalistic as reported in To et al. (2012); the remainder were low-pass and high-pass spatially filtered versions of those originals. Overall, modelling temporal filtering, in particular transient, improved the models' performance: the correlations between model predictions and observers' magnitude ratings rose from 0.507 to 0.731 ($p = 0.02\%$). When the ratings for normal and spatially filtered movies were analysed separately, we found that sustained impulse functions carried more weight in ratings for normal and high-pass movies, whereas transient impulse functions were more important for spatially low-pass movies. This could suggest that high spatial frequency channels with sustained responses primarily code for spatial details in movies, while low spatial frequency channels with transient responses code for dynamic events.

♦ **The functional organization of scene-selective cortices in the human brain is tightly linked**
29 to the statistical properties of the image

David Watson, Tom Hartley, Timothy Andrews (University of York)

Scene-selective regions play a key role in the perception and recognition of the visual world. However, the underlying organisational principles of these regions have not been fully resolved. In this study, we directly compare and contrast the contribution of low-level image properties and high-level scene category to the response properties of scene-selective regions. Using a fMRI block design, neural responses were measured while 24 participants viewed images of two categories of scene: indoor and natural. Images were also filtered in spatial frequency to generate four stimulus conditions: (1) indoor, high-pass; (2) indoor, low-pass; (3) natural, high-pass; (4) natural, low-pass. The patterns of response within scene-selective regions to each condition were compared using MVPA. We found patterns of response to be more similar between conditions with the same spatial frequency content than between conditions with the same scene category. A representational similarity analysis was used to compare

image-based and category-based models to the fMRI data. We found that while both image properties and category information explained a significant proportion of the variance in the neural response patterns, a significantly greater proportion of this variance was accounted for by the image properties. These results suggest that the functional organisation of high-level visual regions is tightly coupled to the low-level properties of the image.

♦ **Neural correlates of tuned suppression in human V1: Implications for pop-out and saliency**
30 Lauren Welbourne, Antony Morland, Alex Wade (University of York)
An influential model of visual pop-out suggests that the saliency of low level features such as colour or orientation is determined by the amplitude of the responses that they evoke in V1. An underlying assumption of this theory is that these responses are modulated by tuned, long-range iso-feature suppression. Specifically, the theory supposes that elements that are homogeneous for a particular feature (for example colour or luminance sign) suppress each other in V1 while a unique element of a different colour would be released from suppression and become highly salient. In comparison, heterogeneous element arrays would tend to self-suppress less, resulting in higher overall neuronal activity. We first aimed to determine whether the different levels of neuronal activity predicted by the V1 saliency hypothesis could be identified using fMRI. An event-related design was used to measure V1 responses to various luminance based target-detection tasks. Target elements were either defined by a unique orientation or unique contrast, and were presented in homogeneous and heterogeneous noise conditions. We identified V1 ROIs in eight subjects using retinotopic mapping, and compared the level of response between each condition. We found higher fMRI BOLD signals in V1 in response to the heterogeneous noise conditions compared to the homogeneous noise conditions for both types of saliency task. These findings support the suggestion that iso-feature suppression in V1 is present in both the orientation and luminance domains, thereby lending support to the hypothesis that saliency can be predicted by the fMRI response amplitudes at this early level of visual processing.

♦ **Alpha lateralization during the discrimination of symmetry**
31 Damien Wright, Alexis Makin, Marco Bertamini (University of Liverpool)
Research has shown that there is an asymmetry in cognitive functions between the two hemispheres. Although the precise roles are still very much debated it has been highlighted that the right hemisphere is particularly involved in spatial attention tasks (Nobre et al., 1997, Brain, **120**, 515–533). Our research has shown that a reduction in right lateralized alpha power along with a sustained posterior negativity is produced when discriminating regularity (Makin et al., 2012, Neuropsychologia, **50**, 14, 3250–3261). This experiment examined if these neural responses were a result of a shift in visuospatial attention to the left hand side of the pattern. Participants had to discriminate between patterns of circles that were created by reflection or by translation. The axis of the reflection or the direction of translation was either vertical or horizontal. Regardless of orientation, a reduction in right lateralized alpha power was observed for reflection and translation (stronger for horizontal orientation). A sustained posterior negativity was also produced in all conditions. A significant N1 component between reflection and translation was observed for the vertically orientated displays, which is consistent with psychophysical studies showing that vertically oriented transformations are easier to detect (Friedenberg & Bertamini, Acta Psychologia, **105**, 107–118). We conclude that the observed lateralization is not a result of a shift in visuospatial attention but it is due to a greater involvement of the right hemisphere in spatial tasks.

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