

## Scottish Vision Group

Isle of Arran, Kinloch Hotel, 17-19 March, 2007

### **Image reconstruction guided by natural scene statistics predicts many aspects of lightness perception**

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The perceived lightness of objects remains consistent under huge variations in illumination. This requires that the visual system take one effect – the amount of light landing on the retina - and disentangle the contribution of two causes: the reflectance of surfaces and how intensely they are being illuminated. Solving such an under-constrained problem requires that the visual brain makes assumptions about the world that I propose are based largely on statistical properties of natural scenes. I present evidence that the visual system poses lightness perception as a reconstruction problem, inferring the image most likely to have elicited a particular set of responses from a bank of spatial filters. I further propose that reconstruction is based on the assumption that images exhibit scale-invariance (i.e. that they exhibit  $1/f^n$  statistics) and that illumination tends to vary slowly over scenes (allowing us to effect local luminance gain control by turning off a subset of low-frequency channels).

This model can both adequately reconstruct natural scenes and provide a quantitative account for a wide range of lightness effects including filling-in (whose explanation requires amplification of low spatial frequency structure) and simultaneous contrast (whose explanation requires attenuation of low spatial frequency structure). Reconciling conflicting requirements of these two classes of illusion is the key to providing a unified computational account of lightness perception.

The model requires isotropic filters and I wondered if this might indicate an early (possibly sub-cortical) locus for the lightness computation. Focusing on the Craik Cornsweet O'Brien effect (CCOB) - a "filling in" illusion consistent with amplification of low SF structure - high-resolution functional magnetic resonance imaging reveals that lateral geniculate nucleus (LGN) and primary retinotopic visual respond robustly to the CCOB. Scrambling low SFs - which destroys the illusion - significantly reduces LGN activity. Furthermore, the CCOB effect is strictly monocular (being absent under dichoptic viewing conditions). Thus there is now mutually consistent evidence from psychophysics, computational modelling and fMRI that brightness "filling-in" (at least) is a sub-cortical phenomenon, likely arising from a contrast gain control system that is optimised for natural scenes.

## **Attentional biases in hand movements: Asymmetries in the refractory period following bimanual reaching**

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While both left hand right hands no doubt share a degree of coupling (e.g. Kelso et al. 1979), there is clear empirical evidence for a right hand performance bias in 90% of the population (Goodale, 1990). It has been suggested that a preferential allocation of attention toward the dominant right hand may be at least partially responsible for this asymmetry (Honda, 1892; Peters, 1981), especially under bimanual conditions. In a series of studies, participants performed bimanual reaches to target pairs, followed by a unimanual reach to a latterly appearing target in the form of a discontinuous double step. It was predicted that an asymmetrical attentional bias would manifest in the form of a longer refractory period between the landing of the first (bimanual) movement and the onset of the second (unimanual) movement. Results are discussed in relation to input versus output biases and the generalisability of the attentional model to different tasks.

## **Transient pupil constrictions when viewing human and macaque faces**

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While it is well established that there are rapid transient constrictions of the pupil in response to various low-level aspects of visual stimuli that are processed along the ventral and dorsal pathways (e.g. light flux, colour, gratings and motion), we know of no previous studies that have demonstrated rapid transient pupil constrictions to more complex visual stimuli. Since the neural mechanisms that underpin face perception occur further along the ventral pathway than those that underpin colour processing, one would expect the presence of a transient pupil constriction when viewing faces. The response latencies may also be expected to be similar or larger than those elicited by coloured targets, reflecting activity further along the visual pathways. Here we present evidence from three experiments of a transient pupil constriction elicited by the onset of face stimuli, with a typical latency of approximately 360ms. The response amplitudes are significantly smaller for scrambled or inverted face stimuli. This suggests that the pupil response is associated with configural processing that occurs to a greater extent when processing upright faces than when processing other types of visual stimuli. Furthermore, the effect of inversion on the transient pupil constriction was smaller when stimuli were macaque faces than when stimuli were human faces,

suggesting that the pupil response is also influenced by familiarity with the category of face shown. These findings are consistent with the pupil response to faces being influenced by neural mechanisms along the ventral pathway that are important for face processing (e.g. the fusiform face area), and reveal a novel, objective and non-invasive method for studying face perception.

### **Rehabilitation of vision loss after brain injury**

Arash Sahraie

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Lesions of occipital cortex or optic radiation can lead to impairments in the corresponding visual field, termed cortical blindness. Apart from some spontaneous recovery taking place shortly after the initial injury, it is thought that the remaining deficits are permanent. There are approximately 7,500 surviving new cases of cortical blindness per year in the UK. The general advice to this group of patients is that nothing can be done to alleviate the blindness. Some residual visual capacities however, may persist within the field defect which is termed blindsight. We have determined the properties of mechanisms mediating blindsight. Subsequently, we have devised a programme based on repeated stimulation of the remaining channels of processing within the blind field. We have demonstrated that repeated daily stimulation of the blind areas over a three months period can lead to increased visual sensitivity in the cortically blind patients. The findings show evidence for plasticity within the adult brain, in chronic stages of brain damage.

### **Effects of instructions on driving performance during foggy conditions**

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Controlled laboratory studies have shown that the perceived speed of a moving object slows down at low background contrasts (e.g., Thompson, 1982; Anstis, 2003). During driving, foggy conditions lower the contrast of the surrounding environment, which could produce a misperception of the speed which a driver adopts, resulting in speeding.

This study aimed to investigate two methods of reducing speeding in foggy driving conditions; the first method was to give the drivers information about the perceptual distortion of speed; the second method was to give the drivers this information in addition to providing a sound signal, indicating to the drivers when they exceeded

the speed limit. It was predicted that the sound signal would free the driver's visual attention from the task of checking the speedometer. Eye movement data were recorded with an SMI iView Eye Tracker whilst participants used a desktop driving simulator. Average speed, average duration of speeding and speedometer fixation frequency were measured. Data were analysed using 1x3 within-subjects ANOVA. The sound signal was found effective in reducing speeding, but, at the same time, it increased speedometer fixation frequency. The findings are discussed with respect to strategic behaviour on part of the driver.

Anstis, S. (2003). Moving objects appear to slow down at low contrasts, *Neural Networks*, 16, 933–938.

Thompson, P. (1982). Perceived rate of movement depends on contrast. *Vision Research*, 22, 377–380.

## **The hedonics of colour**

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Which colours make us feel happy? And which sad? As in previous work, we have approached this issue systematically by running a series of experiments in which participants were presented with an array of three coloured patches, chosen from a limited set of ten, on a neutral gray background. Colours were specified using CIE coordinates. A series of four experiments were performed using 39 participants. In the first two, participants were asked to choose which of the three colours made them feel the happiest; in the second two, which of the three made them feel most sad. All possible three-colour combinations from each set were tested, allowing a happiness and sadness hierarchy to be established for each colour set. For the happy-sad dimension there was a clear effect of saturation, with the more saturated colours tending to evoke more “happy” responses and less “sad” responses. The saddest colours in a given set were always the least saturated. However, hue was found to be important for happiness in that the most happy responses were reported for a sunny yellow in both test sets. Taken together with the previous results, we suggest that there are four universal factors which strongly influence emotional responses to colour. The first is an arousal component related to the perceived depth of the colour (far-away things tend to be bluer and grayer). The second is a pleasure component related to the saturation of the colour. The third is an aversion to yellow-green and brown due to unpleasant associations, whilst the fourth is a strong affinity to sunny yellows due to associations with fine weather. These rules are largely consistent with extant data on colour and emotions and inform current theories of visual aesthetics.

## **A complete failure to see a perfectly regular stimulus**

Roger Watt and Sandra Quinn  
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A series of vertical lines that are regularly spaced along the horizontal as a grating look regular and can be easily discriminated from an irregular grating. However, when one further line is placed randomly in the space between each pair of adjacent vertical lines, the discrimination becomes impossible. This is surprising since all the information required to do the task remains in the stimulus. A simple explanation is that the visual system is only capable of making measurements between strictly adjacent lines, because these measurements do not make explicit the regularity.

## **Perception of ambiguous stereograms: can correlation explain matching bias?**

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The perception of depth from binocular disparity depends upon the resolution of the stereo correspondence problem: the visual system must identify points on the two retinal images that correspond to identical locations in physical space. Finding the solution to this problem requires the use of prior constraints on possible disparities in the scene and on the structure of matching points. Such constraints are often implicit in the cross-correlation-like processes commonly found in recent models of stereo matching. Here we examine the extent to which bias in the perception of a novel ambiguous stimulus may be explained by a simple cross-correlation matching model. The stimulus contains multiple strips of periodic dot patterns, where the length of the period defines the available disparities. Due to variation in period length between strips, our stimulus may be perceived as a convex or concave wedge, or as a top-near or top-far slanted plane. Observers reported their perception in a 4AFC task. Data were analysed as conditional probabilities associated with the perception of upper and lower halves of the stimulus. Our results show that observers prefer to match to the solution that minimises relative disparity. Furthermore, we show that this minimisation cannot be predicted by models reliant on either implicit constraints operating at an initial cross-correlation stage, or on explicit constraints biased towards a particular disparity sign or magnitude. Instead, our results suggest that the correspondence matching system makes use of more complex

constraints, which contemplate the probability of occurrence of different disparity structures.

Research supported by the BBSRC, UK. Grant No. C005260/1

### **Does stereo correspondence account for eye position?**

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In order to fuse the two eyes' images into one, the brain has to work out which point in the left retina is viewing the same point in space as a given point in the right retina -- the stereo correspondence problem. At first sight this seems like a two-dimensional problem -- the correct match could be anywhere in the left retina. But in fact, if eye position is known, geometry reduces this to one-dimension: the correct match lies somewhere on an "epipolar line" on the left retina. Artificial stereo systems use this constraint, updating the epipolar lines each time the cameras move, in order to make the search for correspondences efficient. But surprisingly, there is currently no evidence that the brain takes account of eye position in solving the stereo correspondence problem. I will describe a set of experiments designed to reveal if the brain takes account of the rotations of epipolar lines which occur when the eyes move from side to side, and present some preliminary results.

### **Binocular cues to motion-in-depth**

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Two potential binocular cues to motion-in-depth have been proposed namely, changing disparity over time (CDOT) and inter-ocular velocity differences (IOVD). Mathematically, the same end result can be obtained, whether the binocular disparity of a pattern is calculated first and the derivative with respect to time is then taken (i.e. CDOT), or whether the derivative with respect to time is taken first for the pattern in each eye and the difference of those values between the two eyes is taken (i.e. IOVD). However, the order of implementation in the visual system is a moot point. We have recently started an investigation into the efficiency with which the CDOT and IOVD cues can be used for perceiving

motion-in-depth. In this presentation we will first give a review of the current literature on this topic and proceed to describe the first set of experiments in our program. We designed random dot stereograms that have both CDOT and IOVD cues, CDOT cues alone, or IOVD cues alone. In the first experiment we measured in a 2I-2AFC task how efficient people are in detecting the stimulus. In the second experiment, we determined how efficient people are in discriminating the direction of motion (towards or away from the observer). We found that observers are approximately equally efficient at detecting the interval that contained the stimulus, regardless of the type of motion-in-depth cue. However, when asked to discriminate the direction of motion-in-depth, the task could not be performed when only the IOVD cue was available. We will discuss these results with regard to the different tasks involved in detecting and discriminating motion in depth.

### **Testing refined Bayesian model predictions of binocular 3-D motion perception**

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Previous research on 3-D motion perception investigated predictions of Bayesian models at a viewing distance of 114 cm, suggesting stereo-first rather than motion-first processing (Lages, 2006). Monocular velocity and binocular disparity input in a binocular viewing geometry gave symmetric predictions: an isotropic circle for the motion-first Bayesian model and an ellipse for the stereo-first Bayesian model. By reducing the viewing distance to 54 cm and changing the radial distance of the target stimulus, the present psychophysical experiment investigates possible distortions of these model predictions.

### **Motion aftereffects and the world**

Nicholas J. Wade and Kathrin Kaulard  
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The motion aftereffect (MAE) has been employed to link motion perception to cortical motion detectors. However, MAEs can also be produced in regions of the retina that have not been exposed to motion: inducing motion in a fixated and stationary grating by moving surrounding gratings yields an MAE in the central grating rather than the surround. MAEs from induced motion present an

embarrassment for interpretations in terms of motion detectors, and they have been considered as a special case. The MAE has two components: adaptation which is local and test which is global. In terms of the model proposed by Wade and Swanston, adaptation is retinocentric whereas the expression of this in a test pattern is patterncentric. Induced MAEs typically show smaller interocular transfer (IOT) than 'conventional' MAEs. We report experiments in which direct comparisons are made between IOTs for conventional and induced MAEs: their values are the same. The implications of these results for perception of the world are discussed.

### **Quantifying the contribution of structure information in direction discrimination of scrambled walkers**

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It has been shown that it is possible to reliably discriminate the direction of a fully scrambled point light walker, provided the trajectories are preserved. We investigated the strength of this motion signal by pitting it against a competing motion signal in the opposing direction that did or did not contain form information. To achieve this, we split motion-captured 15-point walkers into two subsets of points containing opposing direction information. In the structure present condition, one subset of points maintained their original joint locations and trajectories, whilst the others were scrambled to new joint locations and had their trajectories switched to move in the opposite direction. In the structure absent condition both subsets of points were scrambled and given opposing trajectories. For the structure present condition we defined the unscrambled points as having the "signal" direction and determined how many unscrambled points were required to reliably report this direction. For the structure absent condition we randomly assigned one set of points to have the "signal" direction and measured how many points were required to reliably report this direction. Using an adaptive procedure we determined the thresholds for discriminating walker direction. Results showed that in the structure absent condition thresholds were significantly higher than those for the structure present condition. Contrasting these thresholds gives a measure of the relative weight of the structural information in determining walker direction and, in addition to highlighting the importance of structural cues in direction discrimination, the techniques used to generate the displays may also prove useful in biological motion based neuro-imaging work.



## **Kinematic analysis of intentional motion in animacy displays**

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The impression of animacy from the motion of simple shapes typically relies on synthetically defined motion patterns resulting in pseudo-representations of human movement. Thus it is unclear how these synthetic motions relate to actual biological agents. Previous work by the authors has introduced a novel approach that uses video processing to reduce full-video displays of human interactions into animacy displays; thus creating animate shapes whose motions are directly derived from human actions. Furthermore, this technique facilitates the comparison of interactions in animacy displays from different viewpoints. Using the intentions of Chasing, Fighting, Flirting, Following, Guarding and Playing, this method has been successfully implemented to create displays where these intentions can be recognised, and results have shown an advantage for viewing intentional motion from an overhead viewpoint. The current work will look to explain this viewpoint advantage by performing a kinematic analysis of the positional co-ordinates of the actors, filmed to create the animacy displays. Motion properties examined will include the speed, acceleration and distance covered by each actor as well as relative properties between the two actors. Analysis will show differences in kinematic properties that may explain results from prior behavioural experiments, and will give the basis of a theoretical description of the motion properties that are the make-up of each intention.