

Visions of Vision

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ABSTRACTS

◆ **Stereomotion speed discrimination at multiple disparity pedestals**

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When motion-in-depth is simulated in a random-dot stereogram (RDS), the changing disparity (CD) is accompanied by a concomitant interocular velocity difference (IOVD), the combination of lateral monocular motion signals at different velocities in each eye. Dynamic random-dot stereograms (DRDSs), however, feature a new random array of dots in each frame and therefore isolate the CD cue. In a 2IFC experiment, the relative contribution of CD and IOVD cues was assessed by measuring speed discrimination thresholds for RDS and DRDS stimuli for a range of mean disparity pedestals. Using ferroelectric shutter glasses and a high-speed fast-phosphor monitor (120 Hz per eye), four observers (three naïve) compared the perceived speed of foveally presented pairs of RDS or DRDS stimuli at disparity pedestals of -0.3 , 0 , or $+0.3$ deg. Stimuli measured $7.3 \text{ deg} \times 1.3 \text{ deg}$, receded with a median speed of 0.62 deg s^{-1} , and were presented for 600 ms. An ever-present background pattern of static random dots allowed us to avoid visibility issues, while monocular half-occlusion artifacts were minimised by employing horizontally extended stimuli. For each of three observers, thresholds for DRDSs were significantly higher than those for RDSs across the range of disparity pedestals tested (ANOVA, $p < 0.004$). The mean thresholds for these observers were 27%, 23%, and 23% for the RDS, and 43%, 41%, and 45% for the DRDS stimuli, at the three pedestals respectively. The remaining observer also showed higher DRDS thresholds, except at the near pedestal. In a control experiment, two observers showed no significant effect of varying stimulus duration (500–700 ms), suggesting that they are able to respond specifically to the speed, while ignoring initial/final disparity or total disparity displacement. In concert with other recent studies, we conclude that both disparity change and monocular motion cues influence stereomotion speed discrimination.

◆ **Motion vs position in the perception of head-centred movement**

- 2 Tom C A Freeman, Jane H Sumnall (School of Psychology, Cardiff University, PO Box 901, Cardiff CF10 3YG, UK; e-mail: freemant@cardiff.ac.uk)

Observers compensate for the retinal motion created by an eye movement by adding sensed retinal motion to the felt movement of the eye. One technique used to investigate the relationship between retinal and extra-retinal motion signals consists of asking observers to pursue a target and adjust the velocity of the background pattern until it appears stationary. Typically, the background must move in the same direction as the eye to achieve the null. This Filehne illusion suggests that extra-retinal eye-velocity signals are smaller than their retinal counterpart, a conclusion that underwrites much thinking in the literature. Like the motion aftereffect, however, the Filehne illusion is not accompanied by any compelling change in perceived position, yet motion and position are confounded when the traditional technique is used. We devised a new technique, based on global motion stimuli, that degrades the influence of familiar position cues. Stimuli consisted of signal and noise dots that were displayed as observers pursued a moving target. All dots moved at the same base retinal speed. Observers adjusted the percentage of signal dots until the stimulus appeared stationary with respect to the head. We found that, as base retinal speed increased, less signal was needed to achieve the null. One consequence is that the different signal and noise mixtures at the null point should appear to move at the same retinal speed. A second experiment confirmed this idea and also showed that the matched retinal speed equalled that obtained with the traditional nulling technique. Positional information appears to have little influence on the Filehne illusion.

◆ **Seeing edge blur: receptive fields as multiscale neural templates**

3 Mark Georgeson (Neurosciences Research Institute, Aston University, Birmingham B4 7ET, UK; e-mail: m.a.georgeson@aston.ac.uk)

Edge blur is an important perceptual cue, but how does the visual system encode the degree of blur at edges? Blur could be measured by the width of the luminance gradient profile, peak–trough separation in the 2nd derivative profile, or the ratio of 1st-to-3rd derivative magnitudes. In template models, the system would store a set of templates of different sizes and find which one best fits the ‘signature’ of the edge. The signature could be the luminance profile itself, or one of its spatial derivatives. I tested these possibilities in blur-matching experiments. In a 2AFC staircase procedure, observers adjusted the blur of Gaussian edges (30% contrast) to match the perceived blur of various non-Gaussian test edges. In experiment 1, test stimuli were mixtures of 2 Gaussian edges (eg 10 and 30 min of arc blur) at the same location, while in experiment 2, test stimuli were formed from a blurred edge sharpened to different extents by a compressive transformation. Predictions of the various models were tested against the blur-matching data, but only one model was strongly supported. This was the template model, in which the input signature is the 2nd derivative of the luminance profile, and the templates are applied to this signature at the zero-crossings. The templates are Gaussian derivative receptive fields that covary in width and length to form a self-similar set (ie same shape, different sizes). This naturally predicts that shorter edges should look sharper. As edge length gets shorter, responses of longer templates drop more than shorter ones, and so the response distribution shifts towards shorter (smaller) templates, signalling a sharper edge. The data confirmed this, including the scale-invariance implied by self-similarity, and a good fit was obtained from templates with a length-to-width ratio of about 1. The simultaneous analysis of edge blur and edge location may offer a new solution to the multiscale problem in edge detection.

◆ **Variations in perceptual changes viewing an ambiguous stimulus: I. Methodological difficulties**

4 Graham Hamilton, Steve Wilson, Paul Goddard (Department of Psychology, University of Lincoln, Brayford Pool, Lincoln LN6 7TS, UK; e-mail: ghamilton@lincoln.ac.uk)

Observers find it easy, whilst viewing a Necker cube (NC), to indicate the perceptual changes (PCs) that appear to occur between the ‘cube-up’ and ‘cube-down’ perceptual alternatives. Moreover, the frequency distributions associated with either the ‘cube-up’ or ‘cube-down’ percepts, when plotted as a function of percept duration, are adequately modelled by the gamma distribution (Borsellino et al, 1972 *Kybernetik* **10** 139–144). However, we failed to replicate this finding when our four experienced observers simply recorded PCs.

In order to investigate this failure we made a minor modification. In an observation period, observers indicated both the onset and offset for just one of the identifiable perceptual alternatives (eg ‘cube-down’) instead of recording PCs per se. In separate observation periods, we repeated this procedure for the other perceptual alternatives, ‘cube-up’ and also ‘2-D’. Adopting this modification gave frequency distributions for each of the perceptual alternatives that were adequately modelled by the gamma distribution.

Whilst we agree with Borsellino et al that the gamma distribution represents a good model for the distribution of durations of a particular percept, their analysis is an oversimplification in that they treat the NC as bistable rather than multistable. Unfortunately this raises a problem because, whereas an observer can register the changes between two perceptual alternatives in a single observation period with ease, it remains beyond both the manual and cognitive dexterity of our observers to record the onset and offset of all of the perceptual alternatives within a single observation period.

◆ **Variations in perceptual changes when viewing an ambiguous stimulus: II. Differences between naïve and experienced observers**

5 Paul Goddard, Graham Hamilton, Steve Wilson (Department of Psychology, University of Lincoln, Brayford Pool, Lincoln LN6 7TS, UK; e-mail: pgoddard@lincoln.ac.uk)

The perceptual changes (PCs) associated with viewing the Necker cube (NC) occur in two phases. For 2–3 min the rate increases before entering a stationary phase wherein the rate remains steady and the data are amenable to time-series analysis (Brown, 1955 *American Journal of Psychology* **68** 358–371; Borsellino et al, 1972 *Kybernetik* **10** 139–144). However, our experienced observers seemed to exhibit only the stationary phase. We wanted to know why the initial phase was absent.

Six naïve observers indicated onset and offset for a particular perceptual alternative (eg ‘cube-down’) during an observation period. This was repeated for the other perceptual alternatives associated with the NC (‘cube-up’ and also ‘2-D’). PC rate again appeared to be stationary

for each of the perceptual alternatives but, interestingly, the summed durations for, say, the 'cube-down' percept accounted for about 50% of the total observation period as did the sum of 'cube-up' percepts. The naïve observers tended to be aware of the 2-D alternative only when its existence was pointed out to them explicitly. Our experienced observers, meanwhile, experienced the 'cube-up', 'cube-down', and '2-D' alternatives for about 30% of their respective observation intervals.

Although we cannot account for the absence of the increase in PC rate in our data, it seems initially that naïve observers predominantly experience two of the alternative percepts available. Presumably, with increasing exposure they develop new perceptual alternatives for the NC during their transition into experienced observers. We recommend caution in interpreting the performance of naïve observers during this transition.

◆ **Local image structure, metamerism, norms, and natural image statistics**

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Metamerism affects spatial vision, ie for any given pattern of responses of visual neurons there is a large metamery class of images that could have caused it. The term 'feature detection' acknowledges the belief that a visual system should somehow proceed from initial quantitative measurements (eg linear neuron responses) to categorical qualitative descriptors (eg dark blob on the light side of a convex edge). This step is complex even when applied to single images, so the prospect of developing a theory that applies to vast metamery classes of possible images is dismaying. Koenderink (1993 *Journal of Intelligent Systems* 3 49–82) has pioneered a strategy that solves both problems: identifying a unique simple iconic image within each metamery class. This dispenses with the need to deal with the full metamery class, and, since the iconic images are simple, the extraction of qualitative structure will be facilitated.

The correct rule for selecting from a metamery class remains unknown, though candidates have been explored [Koenderink and van Doorn, 1996, in *Advances in Image Understanding* 96 113–129; Tagliati and Griffin, 2001, in *Scale – Space and Morphology in Computer Vision* Lecture Notes in Computer Science, volume 2106, Ed. M Kerckhove (Berlin: Springer) pp 51–62]. I have examined six new candidate rules based upon minimising norms of the luminance or the gradient magnitude. I have also explored a further rule based on choosing the most likely explanation within a metamery class. This is approached by calculating (on the basis of a natural image collection) the most likely explanation of 1st order structure in 1-D and 2-D. Finally, I consider to what degree there is coincidence between the norm and most likely approaches. Such coincidence is thought to be plausible though the best candidate (the total variation norm) has clear shortcomings.

◆ **Detection of 3-D motion is predicted from probability summation of mechanisms sensitive to lateral motion and motion in depth**

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When an object moves in 3-D, its motion can be considered as a combination of two orthogonal components, one parallel to the plane of the eyes (lateral motion) and one perpendicular to it (motion in depth). For any 3-D motion, the lateral-motion component is the same in both eyes, but the motion-in-depth component is roughly equal and opposite. How are such 3-D motions detected by the visual system?

Detection thresholds for motion in depth are substantially poorer than those for lateral motion, suggesting that different mechanisms could be involved in their detection. Here we test whether the detection of intermediate 3-D motions can be predicted by a combination of responses from two independent mechanisms, one sensitive to lateral motion, the other to motion in depth.

Minimum displacement thresholds (d_{\min}) were measured for the detection and direction discrimination of binocularly presented 3-D motions. We compared human performance with predictions based on the probability summation of a pair of independent motion mechanisms, one sensitive to lateral motion, the other to motion in depth. Detection of 3-D motion was well predicted by probability summation across the range of 3-D directions. Direction discrimination of 3-D motion was similarly well fit by the probability summation model for multi-frame motion displays. However, for two-frame motion displays, direction discrimination for 3-D motion was best fit by a model that uses a motion mechanism only in the frontoparallel plane.

◆ **Pattern-contingent colour aftereffects are formed at a subconscious level**

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According to the hypothesis we proposed earlier (eg Intskirveli et al, 2000 *Bulletin of the Georgian Academy of Sciences* **162** 141–143), McCollough-type aftereffects arise from compensatory and correcting mechanisms, and in particular from the mechanisms of colour constancy. New empirical support for this hypothesis has been found in psychophysiological experiments on eighteen human subjects with normal colour vision.

The subjects were presented with tachistoscopic stimuli in the standard paradigm for acquisition of the McCollough effect: horizontal black–red and vertical black–green gratings. The one novelty was that exposure time was chosen individually for each subject, and equalled the maximum time for which it was possible to recognise the grating orientation while colour was not recognised. In our experiments, this critical time was 1.5–2 ms. After each presentation, the display was filled with a masking image of randomly overlapping multi-coloured curves. The whole adaptation procedure lasted about 15 min, after which the subject was shown the test image: a combined grating, consisting of horizontal and vertical black-and-white stripes.

Seventeen out of eighteen subjects acquired a clear-cut McCollough effect. Horizontal stripes were perceived as greenish, and vertical ones as pinkish. The major quantitative indices (power of effect and retention duration) did not differ from those observed in the standard paradigm. Seeing a coloured aftereffect in conditions where the subject does not see the colour of adapting gratings implies that the main compensatory shifts must be generated at a subconscious level.

◆ **Pre-attentive segmentation and correspondence in stereo**

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Traditional stereo grouping models (eg Marr and Poggio, 1976 *Science* **15** 283–287) have focused on the stereo correspondence problem—the matching of the corresponding monocular inputs to obtain 3-D depth. Correct stereo correspondence is responsible for, eg, disparity capture (the propagation of depth information from the boundaries to the centre of a depth plane to break, eg, the wallpaper illusion), and (depth) transparency. V2 cells were recently observed to exhibit disparity capture via contextual influences (Bakin et al, 2000 *Journal of Neuroscience* **20** 8188–8198). Recent physiological data, however, revealed additional unexpected stereo grouping behaviour. Some V2 cells increase their responses to stimuli of their preferred depth when the stimuli within their receptive fields are at or near the boundary of a depth surface (von der Heydt et al, 2000 *Vision Research* **40** 1955–1967). Such highlights to depth edges are seemingly not required computationally merely to solve the correspondence problem. Computationally, these highlights make the boundaries of a depth surface more salient, serving pre-attentive segmentation and attracting visual attention. In special cases, they enable the psychophysically observed perceptual pop-out of a target from a background of visually identical distractors at a different depth. To achieve the highlights, mutual inhibition between disparity-selective cells tuned to the same or similar depths is required. However, such mutual inhibition should impede the computation for the correspondence problem, which requires mutual excitation, instead, between the same cells. In this work, I introduce the first computational model to address both stereo correspondence and pre-attentive stereo segmentation. The computational mechanisms in the model are based on intracortical interactions in V2. I demonstrate that the model captures the following physiological and psychophysical phenomena: (i) depth edge highlighting, (ii) disparity capture, (iii) pop-out, and (iv) transparency.

◆ **Rod contribution to colour appearance**

- 10 Lindsay MacDonald, Young-Shin Kwak, M Ronnier Luo (Colour and Imaging Institute, University of Derby, Derby DE22 3HL, UK; e-mail: L.W.MacDonald@colour.derby.ac.uk)

A research programme at the Colour and Imaging Institute is investigating the appearance of colours projected onto a screen, both in cinema viewing environments and in conventional room presentation conditions. This colour-appearance data set will be used to derive or modify a colour-appearance model such as CIECAM97s. However, most of the present colour-appearance models assume that the viewing environment is photopic, even though in many cases viewing conditions for displays in darkened rooms are actually mesopic. Therefore, in this study, we aim to understand better the rod contribution to colour appearance.

In a recent experiment, nine to twenty-one observers used the magnitude-estimation technique to make judgments of the lightness, colourfulness, and hue of test-colour patches presented on a grey background with additional 'decoration colours' around the periphery in a Mondrian pattern simulating a complex field. Thirty different test colours were presented in each of three phases with 154.0 cd m^{-2} (photopic) and 18.8 cd m^{-2} (mesopic) reference white for the conventional presentation condition, and 15.7 cd m^{-2} (mesopic) for the cinema condition. Ten colours were repeated in each session to check the intra-observer consistency. Each display was presented as a static image for a period of approximately 1 min. The test patch at the centre of the screen subtended a visual angle of approximately 1 deg, and the overall screen 20 deg, from the observer seating position. The observers' visual task was not constrained, ie not fixated on the test patch. Comparison of observed lightness showed that colours under the high-luminance condition appeared to be lighter than under the low-luminance condition, which was not predicted by CIECAM97s. At this stage, it is not clear whether this effect is due solely to rod contribution, but we hypothesise that the apparent increase in contrast is caused by a simultaneous contrast effect because the grey background appears brighter than would be expected from cone response alone. Proper understanding of the behaviour of cone and rod photoreceptors under mesopic conditions is important for the development of a comprehensive model of colour appearance.

◆ **The eyes can search large displays more effectively than small ones: An oculomotor paradox?**

11 Eugene McSorley, John M Findlay (Centre for Vision and Visual Cognition, Department of Psychology, University of Durham, Durham DH1 3LE, UK; e-mail: eugene.mcsorley@durham.ac.uk)

Several experiments were carried out to examine the use of spatial-frequency information in the accurate programming of saccades. Subjects were asked to search for a Gabor patch which had a predefined spatial-frequency content. In the first experiment, a target (of a predefined spatial-frequency content) was presented on the horizontal meridian at either 3 or 6 deg from the centre while a distractor (which had a different spatial-frequency content) was shown at the other eccentricity. Both patches were shown on the left or right hand side of the screen. In a second experiment, 16 vertically oriented Gabor patches were presented in two annuli with 8 stimuli on each. One target was shown along with 15 distractors. Subjects' eye movements were recorded on a DPI eyetracker. Subjects could not discount the presence of the distractor from the saccade programming when a distractor was placed between the target and the central fixation point. However, they were able to accurately direct first saccades on the basis of a difference in spatial frequency when the target was presented in the circular layout, even when a distractor was placed between the fixation spot and the target as in the first experiment. The results suggest the paradoxical conclusion that the greater the number of distractor elements the easier it is to localise the target. That this search paradox was carried out on the basis of grouping the distracting elements (Bravo and Nakayama, 1992 *Perception & Psychophysics* **51** 465–472; Duncan and Humphreys, 1989 *Psychological Review* **96** 433–458) is discounted.

◆ **Colour sensitivity function and specific visual adaptation**

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Here we extend previous work (eg Intskirveli et al, 2000 *Bulletin of the Georgian Academy of Sciences* **162** 141–143) to investigate whether colour-recognition ability is changed following acquisition of the McCollough effect. A total of twenty-one observers with normal colour vision took part in the experiments. Their colour vision was evaluated with an anomaloscope, Ishihara's test for colour-blindness, and Farnsworths–Munsell D-15 Panel Test. Observers were presented with colour stimuli on a black background, which were illuminated with white and colour (either red or green or blue) light mixtures of various ratios. For each observer, a light mixture threshold index was calculated by determining the percentage of each colour light that was necessary for the sample to appear achromatic. Observers then adapted to a stimulus that was appropriate for inducing a McCollough effect (black–red vertical and black–green horizontal gratings) and in seventeen out of nineteen observers this resulted in significant changes in the light mixture threshold index. The data verify our earlier hypothesis [Kezeli et al, 1991 *Proceedings of the Georgian Academy of Sciences* **17**(4) 221–226 (Georg.)] on the participation of colour-constancy mechanisms in the origination of McCollough-type aftereffects.

◆ **A non-orthogonal basis-set for orthogonal components of complex motion**

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Within certain constraints, the complex motions in optic flow can be decomposed into orthogonal two-dimensional vector fields of expansion/contraction, rotation, and two directions of deformation. It might be useful for vision to perform a decomposition of this kind because very different information is provided by the different components (eg rate of expansion informs about time-to-contact and deformation informs about surface pose). Psychophysical experiments suggest that human vision does contain specialised mechanisms for complex motion, though the details of the basis-set remain to be elucidated. Here, random-dot coherence thresholds were measured with a sub-threshold summation technique to test whether vision contains mechanisms that form an orthogonal basis-set. In stimulus pairings in which motion components were orthogonal both locally and globally, the components were detected independently (Meese and Harris, 2001 *Perception* **30** 1189–1202). However, for a pairing of deformation and rotation, where motions were orthogonal only globally, substantial summation was found, indicating non-independent detection. This result is consistent with a model containing detecting mechanisms with direction templates matched to the stimulus components, but implies that some of those mechanisms (eg rotation) are not antagonised by motion in their anti-preferred directions (Meese and Harris, 2001 *Vision Research* **41** 1901–1914). In a second experiment, linear summation over space and direction was found when four cardinal directions of local motion were arranged to approximate rotation, but not when the arrangement approximated deformation. This suggests that vision does not contain mechanisms with two-dimensional motion templates matched to deformation. In general, the results imply a visual system containing multiple mechanisms for complex motion, but not those from an orthogonal basis-set.

◆ **Dynamic visual processes in normal reading: Implications for developmental dyslexia?**

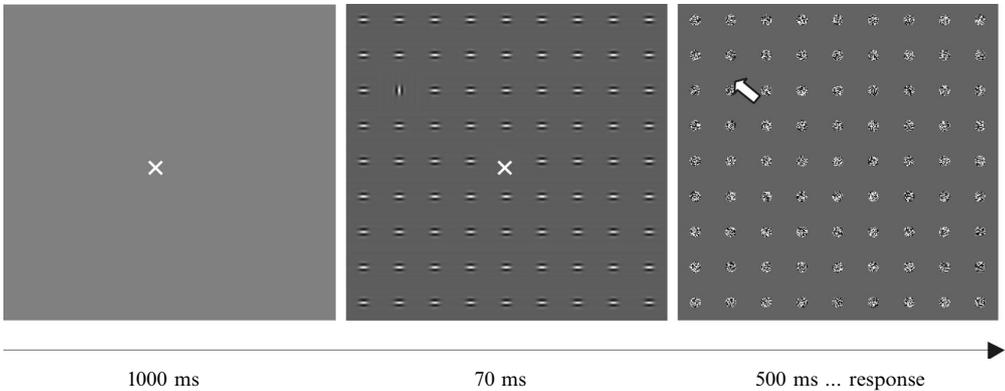
- 14 Kristen Pammer, Ruth Lavis, Piers Cornelissen (Department of Psychology, University of Newcastle upon Tyne, Newcastle upon Tyne NE1 7RU, UK; e-mail: kristen.pammer@ncl.ac.uk)

Data from two studies relating visual task performance to contextual reading are presented. In the first study, we investigated the relationship between contextual reading and (a) relative spatial encoding for symbol arrays, as well as (b) central versus peripheral sensitivity to the frequency-doubling illusion. In the first study, thirty unselected school children were measured on their ability to solve a foveally presented spatial-encoding task, as well as their sensitivity to the frequency-doubling illusion across the retina. Their performance in the frequency-doubling and spatial-encoding tasks was uncorrelated, suggesting that these tasks tap independent visual processes. Peripheral (but not central) sensitivity to frequency doubling, as well as spatial encoding, predicted statistically significant, independent proportions of variance in contextual reading (Neale Analysis of Reading Ability). These effects persisted even when variance due to age, IQ, phonological skill, and short-term memory was statistically accounted for. The data suggest that successful reading requires not only information about letter identity, but also at least two additional sources of information, probably related to spatial processing of words. The first is a central mechanism that may define the relative spatial location of letters within words, and the second is a peripheral mechanism that we speculate may be related to the attentional processes involved in coarse-scale localisation within a body of text. Consistent with this speculation, we found in the second study that reading accuracy for dyslexic readers was most impaired relative to chronologically and age-matched controls when contextual material was presented in whole paragraphs, rather than line-at-a-time or word-at-a-time reading conditions.

◆ **The shape of orientation pop-out**

- 15 Ariella Popple, Yury Petrov (Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: apopple@spectacle.berkeley.edu)

An orientation singularity is rapidly detected in a display of iso-oriented elements, but its location may be coded imprecisely (Solomon and Morgan, 2001 *Journal of Vision* **1** 9–17). We describe the exact shape of such pop-out at different positions in the visual field. The figure shows a trial sequence. Stimulus arrays were 9×9 (as shown) or 5×5 . There were 3840 target trials for each array, and up to 160 target-absent trials to estimate response bias. Nearly all errors were toward distractors near the target. Their distribution over the visual field was inhomogeneous, with most errors for targets at larger angles of visual eccentricity, above and below fixation. Results show that localisation was more accurate in the dense array, where there were more distractors, and more potential target locations. This finding is supportive of a role for contextual influences



in orientation pop-out, and precludes an explanation in terms of signal detection among independent orientation samples. Learning and attention had considerable effects on performance in this task, and their contribution is discussed.

◆ **Speed, accuracy and performance in visual search**

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In visual searches through random displays in which target contrast (c) and distractor number (set size, N) are varied, we model behaviour by

$$d' = \frac{\text{signal}}{\text{noise}} = \frac{cT}{(NTV_e + TV_i)^{1/2}}.$$

There are two free parameters: V_e , the external noise variance due to each distractor, and V_i , the internal noise. The total noise is the sum, on the assumption of independence of each noise source. The time T required for processing the display is the mean correct response time, T_m , less the simple response time, T_0 (the sensory + motor 'residual' latency, estimated from the time to respond to a target presented with no distractors). Signal strength is target contrast, c , multiplied by observation interval, T , on the assumption of a constant rate of information extraction. In our experiments, c was manipulated by varying the Euclidean distance in $[u', v']$ colour space between the grey field and an equiluminous coloured target; similarly for V_e and distractor contrast.

Bringing the response terms together, we can define search performance, Perf, in units of information per second, thus:

$$\text{Perf} = \frac{d'^2}{(T_m - T_0)}.$$

The remaining terms in the model equation predict that

$$\text{Perf} = \frac{c^2}{NV_e + V_i},$$

as a function of c and N .

This prediction captures much of our feature search and oddity search data (response times and d' , both of which vary with N). Perf presumes that any Yes/No response time differences reflect response biases, not processing differences such as those which would arise in self-terminating serial searches. Perf, like bits per second, solves the experimenter's dilemma of whether to report speed or accuracy, but, unlike bits per second, accepts two insights of signal detection theory: errors can arise from either poor criteria or low sensitivity, and the effects of small variations in error rates on sensitivity, d' , can be profound when errors are relatively infrequent. Moreover, when the stimulus terms N and c are fixed, Perf = constant generates a classic speed-accuracy tradeoff (Swensson and Thomas, 1974 *Journal of Mathematical Psychology* **11** 213–236).

◆ **Global motion mediated by a red–green mechanism**

- 17 Alexa I Ruppertsberg, Sophie M Wuerger, Marco Bertamini (MacKay Institute of Communication and Neuroscience, Keele University, Keele ST5 5BG, UK; e-mail: a.ruppertsberg@cns.keele.ac.uk)

The interaction of colour and motion cues for global motion integration across space has only recently been studied (Edwards and Badcock, 1996 *Vision Research* 36 2423–2431). By using random-dot kinematograms with 300 coloured Gaussian blobs (0.22 deg, 1 deg s⁻¹, 5.1 deg × 4 deg) we assessed the chromatic selectivity of the global motion mechanism. Observers had to distinguish between an interval with random motion and an interval with 40% of the blobs moving either left or right (2IFC).

In experiment 1 all blobs had the same colour in a given trial and were presented on a grey background (equiluminance = 50 cd m⁻²). We determined global motion detection thresholds (81%) as a function of the chromatic contrast in the equiluminant cone-opponent colour space [S–(M–L)-space]. Eight out of ten observers were not able to perform the task for S-cone isolating colours. In all other colour directions the thresholds were determined by the stimulation of the red–green mechanism. To test this hypothesis, we performed experiment 2 where we added chromatic noise (with a constant projection onto the red–green mechanism) to the red and green stimuli. We found that the width of the chromatic noise distribution did not affect the results and the thresholds were predicted by the projection onto the red–green mechanism.

We conclude that: (i) in our global motion task the S-cone input is negligible for the majority of the observers, and (ii) global motion extraction in the equiluminant plane appears to be mediated exclusively by a red–green mechanism and the observed sensitivity to global motion is predicted by the projection onto this mechanism.

◆ **Interactions between visual stimuli across the visual field**

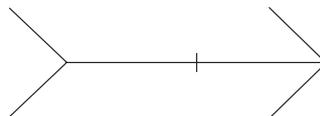
- 18 Robert J Snowden (School of Psychology, Cardiff University, PO Box 901, Cardiff CF10 3YG, UK; e-mail: Snowden@Cardiff.ac.uk)

The increase in the phenomenon of ‘crowding’—the loss of legibility of letters when surrounded by other letters—is well documented in the peripheral visual field, however its explanation is not yet clear. As letters contain energy at many spatial scales, it is possible that the increase in crowding in the periphery may simply reflect the increasing spatial scale of the peripheral retina. On the other hand, if crowding were still to increase in the peripheral field when the stimuli contained only a single spatial scale, this would suggest that the peripheral field is not merely a coarser version of the foveal field. To test this, detection thresholds were measured for a target stimulus that was flanked by two ‘masking’ stimuli. All stimuli were small patches of sine-wave grating so as to limit the spatial scale of the stimuli. Evidence was found for increasing interactions between the stimuli as one moves from the fovea to the periphery—though whether this reflects simply stronger interactions, or interactions over a greater distance is not yet clear. However, interactions as assessed by summation thresholds do not change across the visual field.

◆ **Revealing perception and action pathways in normal vision: clutching at straws?**

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Since Milner and Goodale’s ‘perception’ and ‘action’ streams supplanted ‘parvo’ and ‘magno’ as the thinking man’s visual system dichotomy of choice, the race has been on to reveal these streams in the normal visual system. The early front runner has been the proposal that visual illusions affect the ‘perceptual’, world-based ventral system but not the ‘action’, ego-based, dorsal system. We have probed this claim in a series of experiments utilising pointing accuracy towards the endpoints and midpoint (marked or unmarked) of the Judd illusion. Further we have investigated the effects of interposing a delay between stimulus presentation and the required response. Dorsal stream representations are short lived, and visually guided actions must switch to world based (perceptual) frames of reference after a short delay, allegedly. Thus pointing performance should become equivalent to perceptual performance after a delay.



The Judd illusion

We find that, perceptually, subjects do mislocate the endpoints of the horizontal line and its unmarked midpoint but similar errors are also made in the immediate 'action' task. Generally we find that both the perceptual task and the action task are susceptible to the illusion, but under some conditions, notably in the delayed presentation conditions, it appears that the 'perceptual' illusion and the 'action' illusion are not the same. Implausibly elaborate models explaining these results are presented.

◆ **Boundary extension in a virtual world**

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Boundary extension (BE; Intraub and Richardson, 1989 *Journal of Experimental Psychology: Learning, Memory, and Cognition* **15** 179–187) refers to a memory distortion in which observers appear to remember a greater expanse of a scene than was actually shown. For instance, if they are shown a close-up photograph of a child sitting on the stairs, they will later remember a wider-angle scene. Intraub and her colleagues suggest that BE is mediated by perceptual schemas that anticipate the probable contents of future views. The majority of BE studies have used photographs or line drawings. Here we used virtual reality (VR) to present 3-D objects either in isolation ('noscene' condition) or as the centre-piece of a virtual living room ('scene' condition). Observers were shown a 1 s view of each object from a particular viewing distance and orientation relative to the vertical axis of the objects. After a 5 s blank retention interval, the same object/scene appeared but the viewing distance and orientation were randomised. Observers actively recreated the original viewpoint by updating their virtual position using a joystick-like device. For the 'scene' condition a robust BE effect was observed, the magnitude of this error dropping sharply as initial viewing distance increased. In the 'noscene' condition observers underestimated their initial distance, a tendency that increased with viewing distance. Contrasting explanations based on either layout expansion or misjudged size/distance were explored in additional experiments. Discussion also focuses on the use of VR with its ability to quickly and easily manipulate the presence/absence of both scene and object within and across trials.

◆ **Complex scenes, simple neurons, and complex applications**

- 21 Tom Trościąńko, David Tolhurst, C Alejandro Párraga (Department of Psychology, University of Bristol, 8 Woodland Road, Bristol BS8 1TN, UK; e-mail: tomt@cogs.susx.ac.uk)

A great deal is known about the behaviour of the human visual system from both psychophysical and physiological studies with simple stimuli such as gratings. However, the visual environment consists of complex scenes and often elicits complex actions. Can we use information gained about the behaviour of simple units in the visual pathway to say something about how we perceive complex scenes? If so, what novel applications exist that can make use of this knowledge?

We have been considering the issue of power spectra of natural scenes. We have shown (Párraga et al, 2000 *Current Biology* **10** 35–38) that subtle shape discrimination tasks are optimised when image power spectra are 'natural'. Furthermore, a simple model of contrast discrimination by cortical neurons predicts discrimination performance quite well. This model has been tested more extensively at a variety of eccentricities, and found to apply there as well. Such a model could form the basis for predicting the visibility of differences between pairs of images. This has applications in computer graphics, where considerations of power spectra are relatively novel. There is evidence that images with power spectra corresponding to those of real images are judged more 'natural' than others—this has implications for generation of fractal terrains and texture mapping. Finally, we have recently shown that the spatial transfer characteristics of colour vision (which are probably mediated by single-opponent cells in the mammalian cortex) provide a close match to the properties of a subset of natural scenes—fruit on foliage—so the notion of optimisation to natural scene statistics may well apply in the chromatic domain as well. This may provide a metric for assessing the utility of colour information in various kinds of display.

◆ **How do task demands influence human gaze shifts in a 3-D scene?**

- 22 Andrew E Welchman, Julie M Harris (Department of Psychology, Ridley Building, University of Newcastle upon Tyne, Newcastle upon Tyne NE1 7RU, UK; e-mail: A.E.Welchman@ncl.ac.uk)

We move our eyes 3–5 times every second to obtain information about our visual surroundings. In everyday situations this information is embedded within a highly complex 3-D scene. How do different task demands influence the dynamics of these gaze shifts? We have begun to study this in a 3-D scene containing real-world objects.

Subjects viewed small wooden blocks presented within a purpose-built viewing box. Some of the blocks were perfect cubes (1 cm × 1 cm × 1 cm), whilst others had square faces and rectangular sides (eg 1 cm × 1 cm × 1.2 cm). The cubes were painted different shades of grey. On a single trial subjects made a 2AFC decision concerning which block was biggest or which had the lightest shade of grey. Subjects performed this task whilst their eyes were tracked binocularly with an ASL 501 tracker sampling eye position at 120 Hz. They were given no specific instructions regarding eye movement. Analysis was performed off-line with in-house software.

Subjects were found to make similar numbers of saccades and fixations under size and lightness conditions. Mean fixation durations were very similar under each condition. Changes in vergence were found to occur during both saccades and fixation periods; however, saccade-mediated vergence changes were much more common than fixation-mediated vergence changes (ratio 3 : 1). No differences in binocular saccade dynamics were observed under the two different conditions. Our current data suggest that a subject's task does not influence the dynamics of gaze shifts within a real 3-D scene; however, more complex stimulus arrangements may reveal differences between the two tasks.

◆ **Integration of spatial-frequency signals in visual search**

- 23 Michael J Wright, Louise Alston (Department of Human Sciences, Brunel University, Uxbridge UB8 3PH, UK; e-mail: michael.wright@brunel.ac.uk)

How do we locate and discriminate targets in multiple arrays? In localisation experiments, subjects indicated the position of an oddball spatial-frequency (SF) Gabor target stimulus amongst uniform SF Gabor distractor stimuli. In discrimination experiments, they indicated whether the target was higher or lower in SF than the distractors. SF difference thresholds were measured by a forced-choice method in which the constant stimuli were sets of SF differences (Δf). In both localisation and discrimination experiments, the stimuli were 150 ms single-frame presentations, usually of 4 Gabor targets. We used a procedure whereby a proportion ($k < 1$) of the SF difference signal, Δf , is added to the distractors (Baldassi and Burr, 2000 *Vision Research* **40** 1293–1300). We refer to this fraction as the bias. Thus, with zero bias, if the SF of the distractors was f cycles deg^{-1} , that of the target was $f + \Delta f$ cycles deg^{-1} . For a non-zero bias the SF of the target would still be $f + \Delta f$ but that of the distractors would be $f + k\Delta f$. Positive values of bias (k) weakened localisation but enhanced discrimination, whereas negative bias enhanced localisation and weakened discrimination. We found that the SF sensitivity (1/threshold) was a linear function of the bias. The slope of this function divided by the sensitivity at zero bias (S_0) is a variable (m) interpretable in terms of the way signals are combined across target and distractors. For localisation, m was close to -1 , despite stimulus changes (contrast, eccentricity, set size) and task changes (unidirectional versus bidirectional SF differences) that influenced threshold, S_0 . For discrimination, m was close to $+3$ for positive-bias stimuli, as predicted by pooling of signals across Gabor patches; but, for negative-bias stimuli, sensitivities followed those for localisation, implying that the signals were segregated rather than pooled. Thus the extent of integration of target and distractor stimuli in visual search depends on task demands as well as visual field eccentricity.

◆ **Fragmenting the barber-pole illusion**

- 24 Johannes M Zanker (Department of Psychology, Royal Holloway, University of London, Egham TW20 0EX, UK; e-mail: j.zanker@rhul.ac.uk)

In a barber-pole stimulus, different local motion signals (directions) arise from boundary regions and the central region of the aperture, which need to be combined in order to produce a coherent motion percept. Changing the stimulus geometry affects the tendency to perceive motion along the major axis of an elongated aperture (the barber-pole illusion). Subjects were asked to report perceived direction and the strength of their percept, while the orientation of gratings moving behind a rectangular aperture and the aspect ratio of the aperture were varied independently. Perceived motion direction is closest to perpendicular to grating orientation when aspect ratio approaches unity, ie square-shaped apertures, and when grating orientation is close to parallel to the shorter aperture boundary. The pattern of results indicates an interaction between the cycle ratio, which is the sine-wave grating equivalent of the terminator ratio for line stimuli,

and grating orientation that is effective in the central region. This suggests that a simple cycle (or terminator) ratio explanation cannot fully account for the properties of the barber-pole illusion, and generates the prediction that the illusion should be stronger if the overall length of the boundaries is increased while keeping overall stimulus area and aperture shape constant. The prediction was tested experimentally by fragmenting the aperture in a set of smaller apertures of identical shape and constant cumulative area, and measuring perceived direction. The results of this experiment indicate that the strength of the illusion increases with the number of aperture fragments, ie the ratio between circumference and overall area, or the relative contributions from the boundary regions.

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