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ABSTRACTS

ORAL PRESENTATIONS

◆ **Directionality, asymmetry, and infancy**

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Directional motion sensitivity is a pervasive feature of visual systems and a key element in many of the ways we use vision. However, in human development, behavioural directional discriminations and directionally specific VEPs emerge later in infancy than sensitivity to static orientation. Possible neurobiological reasons for this sequence are discussed.

The postnatal emergence of these directional functions needs to be reconciled with the presence from birth of optokinetic nystagmus (OKN), which also depends on directional selectivity. OKN in the newborn has a characteristic signature of monocular asymmetry: for each eye, temporal-to-nasal stimulus motion is much more effective than nasal-to-temporal. This asymmetry has been taken as evidence for an early, purely subcortical mechanism which cannot subserve cortical uses of motion information. Against this view is evidence from unilateral cerebral damage and from VEP responses, presumably cortical, which share this asymmetric signature. New findings from our laboratory show that the VEP and OKN asymmetries are not so simply related as has been supposed. Multiple directional motion systems interact in development, but understanding this interaction remains a challenge.

◆ **No 2nd-order input to optic-flow perception**

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Growing psychophysical and physiological evidence supports hierarchical models of motion processing in which local velocity signals are assembled to form receptive fields specialised for optic-flow components. For example, the equality of detection and identification thresholds for both radiation and rotation (Gurney and Wright, 1996 *Perception* **25** 5 – 26) requires the existence of labelled detectors for these patterns, and radiation looks faster than translation composed of identical local speeds (Bex and Makous, 1997 *Vision Research* in press) implicating two-stage analysis. We inspected four micropatterns that formed complex global configurations: whereas 1st-order micropatterns appeared as a single moving object viewed through four apertures, there was no such global coherence of 2nd-order micropatterns. This observation prompted a quantitative study of the contribution of 2nd-order motion to optic flow. Detection, identification, and direction discrimination thresholds were measured for 1st-order and 2nd-order patterns (sinusoidal contrast modulation of static and dynamic noise) of translatory, rotatory, and radial motion comprising four local micropatterns identical except for orientation. The perceived speed of rotation and radiation was also matched to that of translation. For 1st-order patterns the results confirmed the equality of thresholds and that radiation looked faster than translation or rotation. For 2nd-order stimuli, direction discrimination thresholds were much higher than identification or detection thresholds and all patterns appeared to move at the same speed. The results provide no evidence for labelled detectors for 2nd-order rotation and radiation and suggest that there is no 2nd-order input to the perception of optic flow.

◆ **Temporal effects of attention on motion sensitivity**

3 J E Raymond, H L O'Donnell, S P Tipper (School of Psychology, University of Wales, Bangor LL57 2DG, UK; e-mail: pss117@bangor.ac.uk)

Attention studies show that visual selection of a target can have a long-lasting effect on identification of a subsequently presented second target. Can temporal effects of selection affect sensitivity

to simple features and thereby provide an account for simple successive stimulus interactions? After viewing a brief (200 ms) episode of, say, rightward motion, observers are markedly less sensitive to rightward motion and more sensitive to leftward motion in a second episode presented a short time later. We investigated attentional modulation of this successive stimulus interaction using a dual-task priming/adaptation paradigm. We asked healthy adults to select one direction from a briefly presented dynamic random-dot display containing two orthogonal and transparent directions, and then to judge the direction of motion in a second dot display containing a single direction presented after a brief interval. The coherence of the second display was varied. The interval between the two episodes was also varied. We found large losses in sensitivity to previously selected directions combined with enhanced sensitivity to previously ignored directions. There was no change in sensitivity for directions opposite to either previously seen directions. These effects cannot be explained by notions of motion opponency or low-level data-driven sensory adaptation. They indicate that temporal effects of attention can dramatically alter sensitivity to simple stimulus features and provide a reasonable account for successive direction contrast effects.

◆ **Modelling biological motion analysis in terms of image flow**

4 A Johnston, P W McOwan¶ (Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; ¶ Department of Cybernetics, University of Reading, Reading, UK; e-mail: a.johnston@ucl.ac.uk)

Models of biological motion analysis are typically based on correspondence matches between separate frames of an image sequence, detection of spatiotemporal orientation by matched filters (motion energy analysis), or the orientation of spatiotemporal image gradients. Here we consider an alternative approach based on the computation of image flow over segments of boundaries in the image. As a two-dimensional spatial image moves over a boundary segment, it develops a spatiotemporal image which contains a history of the flow over the boundary. Integrating over this spatiotemporal region gives the total flow over the segment in a given temporal interval. We can also calculate the difference in the amount of light within the region at the beginning and end of the interval. Assuming conservation of the image brightness we can calculate the speed and direction of motion from the change in the image brightness over the interval and the various flows across segments of the boundary of the region in the image. Consideration is given to how this strategy might be implemented in the human and primate visual systems.

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◆ **Spatial segregation and the perception of motion**

5 J P Harris (Department of Psychology, University of Reading, Whiteknights, Reading RG6 6AL, UK; e-mail: J.P.Harris@reading.ac.uk)

How does the visual system allocate motion to different regions of the retinal image? The role of spatial information in this process was studied by measuring the strength of the motion aftereffect (by ratings of initial strength and timing of duration), produced by a standard adaptation regime, on a test window (with central fixation point) of previously moving stationary vertical test stripes, as a function of their relationship with stationary vertical surrounding stripes. In experiment 1, it was found that MAEs were stronger and more durable when the test stripes were offset by 90° than when they were perfectly aligned with the surrounding stripes. This effect of offset was stronger than the effect of surrounding the window with a border. In experiment 2, test stripe offset was varied systematically. MAE strength and duration rose with test stripe offset up to 72°, the largest offset between 0° and 180° used in this experiment. Although the MAE, on both measures, was reduced when offset was further increased to 180° (white stripes aligned with black), it was still higher at that offset than for 0° offset (white stripes aligned with white). In contrast, in a separate condition with no prior adaptation to motion, when subjects were asked to rate how separate the test windows appeared from the surround, ratings rose with offset not only up to 72° but then further up to 180°. In experiment 3, which probed the range of offsets between 72° and 180°, segregation ratings were again higher for 180° than for 90°, but peaked at 166° offset, whereas MAE strength peaked at 72° offset. In summary, both MAE strength and judged segregation vary with the relationship between the test stripes and the surround. However, the former appears to depend more on size of offset or phase shift between the test and surrounding stripes, whereas the latter appears to depend more on the length of black/white border at the edge of the test window.

◆ **The quantised degrees of freedom in images and visual codes**

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Several classical results in signal processing and information theory can be summarised by the statement that the information contained in continuous, band-limited signals (such as images) is in fact quantised. Despite the apparent denseness of such signals, the information they contain can be completely enumerated as a countable list of 'quanta'. Five familiar examples which have influenced the visual sciences are:

1. Nyquist's sampling theorem: A continuous, band-limited signal can be completely represented by a discrete set of samples.

2. Hartley's principle: The number of degrees of freedom in a signal of duration T and bandwidth W is at most $2WT$.

3. Gabor's logons: The information diagram for a signal has a quantal grain structure, whose smallest 'atoms' of independent data define a nonorthogonal expansion basis using complex-valued wavelets.

4. Shannon's channel coding theorem: A continuous communication channel can transmit continuous information at a maximum rate (as measured in bits s^{-1}) specified by, among other things, its signal-to-noise ratio.

5. Logan's theorem: For bandpass signals whose bandwidth is no greater than one octave, their zero-crossings alone (a finite set of points) completely specify the waveform (excluding AM signals) up to a scale factor.

In addition to these classical coding insights, strongly nonlinear ideas such as vector quantisation exploit the fact that only a tiny fraction of possible image structures actually do occur in real images, so it is more efficient simply to nominate the types that do occur (by matching to a finite discrete codebook) than to code for all possible ones. For the visual sciences, the legacy and influence of these insights about quantised degrees of freedom extend to: optical quality in relation to retinal sampling; understanding 2-D receptive-field profiles; limits of perceptual uptake; explanations of illusions and isomeres; and modelling the efficiency of visual codes in terms of image compression and recognition. The above family of classical results is briefly reviewed and applied to a contemporary problem in pattern recognition and computer vision, in which high-confidence visual recognitions of personal identity are achieved in real time simply by detecting a failure of statistical independence in mathematically encoded iris patterns. The decision environments created thereby have a decidability (or detectability, d') index exceeding 11.

◆ **Visual perception and the higher-order structure of psychophysical stimuli**

7 M G A Thomson (Division of Vision Sciences, Aston University, Birmingham B4 7ET, UK; e-mail: M.G.A.Thomson@aston.ac.uk)

One of the goals of visual psychophysics is to determine a representation which relates the perceptually significant structure of visual stimuli to their physical properties. A useful representation would work equally well for both classical experimental stimuli (bars, gratings, etc) and 'natural' stimuli but has so far proved elusive. For example, there has been much debate over the relative importance of low and high spatial frequencies in bar detection/perception, and the roles of Fourier amplitude, phase, and orientation in natural-image perception/discrimination are still unclear. Higher-order statistical image measures have, however, met with some success in predicting psychophysical results for both classical (Klein and Tyler, 1986 *Journal of the Optical Society of America A* **3** 868 – 879) and natural (Thomson and Foster, 1997 *Journal of the Optical Society of America A* **14** 2081 – 2090) visual stimuli. The work reported here dealt with third-order statistics: this is the lowest-order global measure sensitive to both amplitude and relative phase. Computational techniques such as phase randomisation, phase quantisation, and phase – amplitude hybridisation were used to distort a variety of classical and natural psychophysical stimuli. The visual appearance of these distorted stimuli was then related to changes in their 3rd-order structure. The results illustrate the potential value of adopting these higher-order physical measures, and are discussed in terms of likely sensory representations.

◆ **How amblyopic vision uses phase and amplitude information in natural images**

8 C A Parraga, G M Kennedy, D J Tolhurst (Department of Physiology, University of Cambridge, Downing Street, Cambridge CB2 3EG, UK; e-mail: djt12@cam.ac.uk)

As many as 5% of the population may suffer from amblyopia, a condition in which vision is impaired in one eye without obvious pathologies of the eye or visual pathways and cannot be corrected by refractive means. Unfortunately, simple laboratory or clinical tests of visual performance may not always reflect the full nature of this disability. Our objective was to identify the real extent of the visual disability of amblyopia using stimuli related to everyday visual tasks. A modified two-alternative forced-choice experiment was used to measure sensitivity to changes in

natural images caused by systematic perturbations of the phases or amplitudes of the coefficients in their Fourier spectra (Tadmor and Tolhurst, 1994 *Vision Research* **34** 541 – 554; Thomson and Foster, 1995 *Journal of Physiology* **485** 25P). Experiments were performed on amblyopic subjects with one eye being used at a time. Subjects had to discriminate between test images made by gradually exchanging the phase spectra between two different natural images (five subjects) or by gradually randomising the phase spectrum (seven different subjects). Both kinds of phase perturbation were much less easily detected when the amblyopic eye was used than when the good eye was used. These effects were equally pronounced when the subject has to discriminate between images with different Fourier amplitude spectra (the second seven subjects).
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◆ **Simplifying images**

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Many schemes for simplifying images have been proposed; the most notable, based on progressive Gaussian blurring, may be achieved either by 'viewing' the image through apertures of increasing size or by running the diffusion equation $L_t = L_{xx} + L_{yy}$ (where the subscripts indicated differentiation with respect to time t and position x, y). Other simplification schemes can be cast only in the equation form and not in the aperture form. For example, mean curvature flow (MCF) simplifies an image by moving isophotes at a speed proportional to their curvature; in equation form, $L_t = L_{vv}$, where v is in the direction tangent to the isophote. Recently, Guichard and Morel (1996, Ceremade Technical Report #9335) proved that MCF could be cast as an aperture scheme but only if the apertures were of infinitesimal size and applied iteratively to progressively simplify the image. They proved that MCF is equivalent to iterated infinitesimal (i.i.) median filtering and they noted the parallel with the well-known fact that Gaussian blurring is equivalent to i.i. mean filtering. This suggested a generalisation that has now been proved: i.i. mode filtering is equivalent to the evolution scheme $L_t = L_{vv} - 2L_{ww}$ (where the v is as before and w is in the gradient direction). With i.i. mode filtering, unlike i.i. mean filtering or i.i. median filtering, the image stops changing before it becomes constant-valued: instead, the endpoint is a mosaic of constant regions separated by discontinuities. This result may explain why a similar formula, $L_t = L_{vv} - 3L_{ww}$, proposed by Gabor (1965 *Laboratory Investigations* **14** 801 – 807) is image-enhancing.

◆ **Automatic face representation for unfamiliar-view face recognition**

10 D B Graham, N M Allinson (Department of Electrical Engineering and Electronics, UMIST, Sackville Street, PO Box 88, Manchester M60 1QD, UK; e-mail: danny@sound.ee.umist.ac.uk)

Experiments have shown that there are viewpoint dependences which affect the nature of human face recognition. These dependences support the model that humans represent faces as a set of 2-D images which are interpolated between and extrapolated beyond during the recognition process. As faces belong to a specific object class we can use our prior knowledge of facial structure to facilitate this interpolation and extrapolation.

We describe an eigenspace manifold for the automatic representation and recognition of pose-varying faces. We show that the distribution of faces in this manifold allows us to determine an efficient representation which we can then use to characterise faces in the manifold. Faces are characterised by estimating their appearance at novel viewpoints with the use of knowledge gained from other faces undergoing the same positional change. We show how the degree of representation affects recognition performance, and contrast these results with previous results obtained by using the same characterisation with a manual representation.

Finally we draw parallels between our system and reported human behaviour including some neurophysiological evidence for view-specific face representation.

◆ **Multiple orientation-selective mechanisms for line-target detection**

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Observers can detect a line element differing in orientation from a background of uniformly oriented line elements rapidly and effortlessly. This kind of efficient target detection is thought to involve the early or preattentive stages of visual processing (Treisman, 1985 *Computer Vision, Graphics, and Image Processing* **31** 156 – 177). The level of performance depends both on the angle between the target and background elements and on the orientations of the background elements themselves (Foster and Ward, 1991 *Proceedings of the Royal Society of London B* **243** 75 – 81). In an extended psychophysical study, threshold values of the angle between target and background elements were obtained as a function of the orientation of the background ele-

ments. An analysis of these threshold functions suggested the involvement of distinct groups of orientation-selective mechanisms: coarse-scale and medium-scale mechanisms whose preferred orientations were spaced on average at angles of about 90° and 35° – 50° respectively in the frontoparallel plane, and which had common alignments over observers; and also fine-scale mechanisms whose preferred orientations were spaced on average at angles of 10° – 25°, but whose alignments varied randomly from observer to observer, possibly reflecting individual variations in neuronal sampling characteristics. Increasing effective display duration produced a shift in activity from coarser-scale to finer-scale mechanisms, a result consistent with the notion that the visual system applies a process of limited refinement in detecting the orientations of lines in scenes.

◆ **12 Orientational anisotropy in line-target detection with and without a gravitational reference for orientation**

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When observers detect a uniquely oriented line element ('target') among uniformly oriented line elements ('nontargets'), detection performance depends on element orientation (Treisman and Gormican, 1988 *Psychological Review* **95** 15 – 48; Foster and Ward, 1991 *Proceedings of the Royal Society of London B* **243** 75 – 81). When displays of line elements are presented briefly, the orientation increment threshold (the difference between nontarget and target orientations that is required for effective detection) is generally lower with vertical or horizontal nontargets than with tilted nontargets. Thus, the variation of orientation increment threshold with nontarget orientation is periodic with a period of about 90°. Does this orientational anisotropy depend on the observer's use of the direction of gravity as a reference for orientation? In an experiment to address this question, observers viewed briefly presented displays of line elements while sitting (so that gravity could be used as a cue defining the vertical in stimulus displays) and while supine (lying horizontally, face upwards, so that gravity provided no such cue). Twenty line elements of length 1 deg visual angle were presented in a circular field of diameter 20 deg visual angle. Nontarget orientations were in the range 0°, 5°, ..., 175° from the vertical. The difference between nontarget and target orientations was varied adaptively. Stimulus displays lasting 40 ms were followed by a blank interstimulus interval lasting 180 ms or less and then a random-line mask. With both sitting and supine observers, orientational anisotropy in thresholds was found. So, it appears that the orientational reference frame for early visual processing can be defined without gravitational information, by retinocentric coding or by awareness of the body axis.

◆ **13 Grouping by proximity or similarity?: competition between the Gestalt principles in vision.**

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A study is reported of the nature of the psychological processes that underlie the Gestalt principles of grouping by proximity and grouping by similarity. Similarity was defined relative to the principles of grouping by common colour and grouping by common shape. Subjects were presented with displays comprising a row of seven coloured shapes and were asked to rate the degree to which the central target shape grouped with either the right or left flanking shapes. Across the displays the proximal and featural relationships between the target and flankers were varied.

These ratings reflected persuasive effects of grouping by proximity and common colour: there was only weak evidence for grouping by common shape. Nevertheless, both common colour and common shape were shown to override grouping by proximity, under certain conditions. The data also show that to understand how the Gestalt principles operate, it appears necessary to consider processes that operate within and between groups of elements that are initially identified on the basis of proximity. Whether such groups survive further analysis depends critically on the featural content of the constituent elements.

◆ **14 The spatial-frequency tuning of visual contour integration**

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We examined the mechanism subserving visual contour detection and particularly its tuning for the spatial frequency of contour components. We measured the detection of contours composed of Gabor micropatterns within a field of randomly oriented distractor elements. Distractors were randomly assigned one of two spatial frequencies and elements lying along the contour alternated between these values. We report that the degree of tolerable spatial-frequency difference between successive contour elements is inversely proportional to the orientation difference between

them. Spatial-frequency tuning (half-width at half-height) for straight contours is around 1.3 octaves, but for contours with a 30° difference between successive elements drops to around 0.7 octaves. Integration of curved contours appears to operate at a narrower bandwidth. Much orientation information in natural images arises from edges, and we propose that this narrowing of tuning is related to the reduction in interscale 'support' that accompanies increasing edge curvature.

◆ **Contributions of parvo and magno signals to cortical responses: selectivity limits.**

15 J J Kulikowski, A G Robson (Visual Sciences Laboratory, Mill/G.126, UMIST, PO Box 88, Manchester M60 1QD, UK; e-mail: ymum21@umist.ac.uk)

In a series of studies we have established that low-contrast, low-spatial-frequency gratings selectively activate parvo/magno streams. Responses to the onset of chromatic (isoluminant) gratings are sustained and parvo-like, whereas responses to coarse achromatic (luminance modulated) gratings are transient and magno-like. In this study we further investigate the contrast-dependence of selective stimuli by comparing human visual evoked potentials (VEPs) with VEPs, field potentials, multi-unit and single-unit activity in macaque monkey.

Comparison of VEP responses to a grating presented on–off and reversed in contrast can provide an index of parvo/magno involvement: responses to low chromatic contrast are sustained, but at higher contrast transient components are generated. Isoluminant stimuli can elicit transient-type field potentials which represent residual magno activity. Conversely, the higher the achromatic contrast the greater the asymmetry between on and off components reflecting nontransient activity. Thus 'selective' stimulation of a mechanism is revealed by its relative response amplitude with respect to the activity of another mechanism.

Temporal tuning of the reversal response is a stricter test of selectivity. Low-pass is characteristic of parvo activity and bandpass tuning reveals transient-type magno responses. Isoluminant red/green gratings generate low-pass VEPs only up to a contrast increment of 0.1 (above this contrast, magno contribution becomes significant and temporal tuning becomes bandpass). Thus reversal presentations of higher contrasts should be checked for selectivity.

These observations are consistent with single-unit recordings in macaque striate cortex: recorded responses are sustained (low-pass) only for cells responding to low chromatic contrast, and transient (bandpass) only for cells sensitive to low achromatic contrast. Cells with higher contrast thresholds are common and have intermediate responses, consistent with recent demonstrations of dual parvo/magno inputs to some chromatic cells (Vidyasagar, Kulikowski, and Dreher, Australian Neuroscience Meeting, January 1998).

POSTERS

◆ **First-order and second-order coding of orientation: evidence from the tilt aftereffect**

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We used luminance-modulated (LM) and contrast-modulated (CM) gratings to test (a) whether a second-order tilt aftereffect (TAE) exists, and (b) whether LM adaptation can induce an aftereffect on CM gratings and vice versa—a crossover effect. Gratings were 1 cycle deg^{-1} with contrast set at a fixed multiple of individual subject thresholds (8 × threshold for adapters, 5× and 8× for test gratings). Adapters were tilted ±15° from vertical; carrier pattern was 2-D static, binary noise with 45% contrast. Initial adaptation was for 3 min, topped up for 2 s between 150 ms test presentations. The experiment was controlled by an interleaved staircase procedure that measured the TAE by nulling it, hence making a tilted test grating appear vertical. In a single-adaptation condition, subjects adapted and tested to LM or CM gratings. In two double-adaptation conditions, the LM and CM gratings were superimposed at opposite orientations ('plaid') or at the same orientation ('compound grating'). With CM adaptation and CM test we found a second-order TAE, of similar magnitude to the first-order TAE. A crossover TAE (from LM to CM, or CM to LM) was also found. These findings can be interpreted in terms of a two-stage model of orientation coding (Anderson and Georgeson, 1997 *Perception* **26** supplement, 122), in which cue-specific filters (LM or CM; stage 1) are later integrated.

◆ **Linear time-varying receptive fields explain complex-cell behaviour**

17 M A Garcia-Perez (Departamento de Metodologia, Facultad de Psicologia, Universidad Complutense, Campus de Somosaguas, 28223 Madrid, Spain; e-mail: psmet04@sis.ucm.es)

Unlike simple cells, complex cells in mammalian visual cortex appear to function as nonlinear mechanisms lacking a structured receptive field (RF), and different complex cells display a variety of mutually inconsistent behaviours. Current complex-cell models postulate nonlinear interactions between multiple simultaneous afferents, but none explains the variety of complex-cell behaviours. We have explored an alternative scheme where these afferents are sequential rather than simultaneous, with a sequence that repeats cyclically over time. A cell receiving

afferents this way can be described as if its spatial RF changes shape cyclically over time. Different time-varying RFs arise when the number of afferents, their individual spatial RFs, and/or their sequence varies; and we present simulation results showing that they exhibit all reported varieties of complex-cell behaviour. Our results suggest a common linear functional description for simple and complex cells. Nonlinearities are not required to explain complex-cell behaviour.

◆ **Spatial probability summation for detecting four patches of grating**

18 T S Meese, C B Williams¶ (Division of Vision Sciences, Aston University, Birmingham B4 7ET, UK; ¶ McGill Vision Research Centre, Department of Ophthalmology, McGill University, 687 Pine Avenue West, H4-14, Montreal, Quebec H3A 1A1, Canada; e-mail: t.s.meese@aston.ac.uk)

When components of a compound pattern stimulate different visual mechanisms, psychophysical performance typically improves by a small amount consistent with probability summation. In spatial vision, compound stimuli have been made from (a) components with different spatial frequencies or orientations, and (b) gratings with variable spatial extent [Graham, 1989 *Visual Pattern Analysers* (Oxford: Oxford University Press)]. In (a) the number of components in the compound is usually less than four, and in (b) full psychometric functions are rarely, if ever, shown, and interpretation is difficult because sensitivity is not always uniform across the stimulated region. We overcame these previous limitations in the following way. Using a 2AFC technique and the method of constant stimuli, we measured psychometric functions for detecting (i) single 3.75 deg circular patches of 1 cycle deg^{-1} grating centred on each of four corners of an imaginary square surrounding the fixation point, and (ii) a compound in which the four grating patches were presented simultaneously. The centres of the patches were 4.24 deg from the fixation point and the sine-phase gratings were windowed by a raised cosine function to remove sharp luminance borders. Stimulus duration was 100 ms. Individual psychometric functions were derived from between 1600 and 2000 trials and the four component-functions were combined probabilistically, producing excellent predictions for the four-patch compound. These results are consistent with probability summation between four independent detectors sensitive to one of each of the four stimulus patches.

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◆ **A new slant on the tilt aftereffect: orientation aftereffects on global perception of heterogeneous line-segment textures**

19 H L O'Donnell, J E Raymond (School of Psychology, University of Wales, Bangor, Wales LL57 2DG, UK; e-mail: h.l.odonnell@bangor.ac.uk)

After viewing a row of obliquely oriented lines (inducer), observers commonly report that a row of vertically oriented lines appears tilted in the opposite direction to the previously viewed inducer. This is known as the tilt aftereffect (Appelle, 1972 *Psychological Bulletin* **78** 266 – 278) and is thought to reflect adaptation or fatigue processes of orientation-selective visual neurons. We have previously shown that orientation sensitivity can be quantified with the use of a texture coherence paradigm similar to that used to study sensitivity to global motion in random-dot kinematograms. Using heterogenously oriented line-segment textures, we obtained global orientation thresholds by determining the minimum percentage of coherently oriented line segments (amidst randomly oriented 'noise' lines) required for just correct global orientation judgments. We asked whether pre-exposure to 100% coherently oriented textures would cause alterations to orientation sensitivity consistent with the tilt aftereffect. Since analogous effects in motion can be produced with very brief exposure to inducers (Raymond and Isaak, 1998 *Vision Research* **38** 579 – 589), we asked whether global orientation aftereffects could also be produced with brief inducers. We presented observers with a 200 ms texture patch (inducer) composed of short line segments oriented horizontally or vertically. After 200 ms, a similar but partially coherent texture (test) was presented for 180 ms. The percentage of coherently oriented segments in the test patch was varied from trial to trial and observers reported the global orientation of both inducer and test textures. Mean orientation coherence thresholds were significantly elevated when test orientations matched that of the inducer and were reduced when test and inducer were mismatched. These data demonstrate that viewing briefly presented, homogeneously oriented textures dramatically changes subsequent global orientation sensitivity to similar, partially coherent textures depending on the orientation relationship between them.

◆ **20 Blur discrimination in the chromatic and luminance domain**

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When a red – green sinusoidal grating is presented to observers with normal colour vision, observers usually report that the sinusoidal grating looks more like a square wave than a sine wave. In contrast, a sinusoidal luminance grating of the same spatial frequency is perceived veridically as a sine wave. This phenomenon was first noted by Helmholtz, and has been reported by others (eg Mullen, 1982 *Journal of Physiology* **332** 14P), but to our knowledge it has so far not been studied systematically.

We investigated a phenomenon related to chromatic sharpening, namely blur discriminability, in the various colour directions. We measured blur thresholds for square-wave gratings modulated either along the red – green, luminance, or yellow – blue colour directions. We used a 2IFC procedure to assess the amount of blur tolerated. One interval contained the square-wave stimulus and the other contained a blurred square-wave stimulus. We asked the subjects to identify the interval which contained the square-wave stimulus. Stimulus blur was varied by convolving the square-wave grating with a Gaussian mask of varying standard deviations. Blur thresholds were defined as 80% correct response. Blur thresholds for red – green and luminance stimuli were very similar (approx. 1 min of visual angle). These results are consistent with the idea that the luminance and red – green channels have similar spatial properties. The blur thresholds for yellow – blue were much higher (between 2 and 8 min of visual angle) than for the other two directions. A more robust understanding of human spatiochromatic image processing may lead to more efficient image-compression techniques.

◆ **21 No use for rose-coloured glasses: A study on the effect of colour on transient system activity with implications for dyslexia research**

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Results from recent psychophysical studies have been interpreted to suggest that activity in transient/magnocellular pathways is enhanced by short-wavelength blue light (eg Williams et al, 1991 *Vision Research* **31** 2017 – 2023). Based on the premise that many dyslexic children suffer from a transient system deficit, such results have formed a theoretical basis for remedial work into dyslexia utilising coloured overlays, lenses, and text. The current study used normal readers and was designed to explore the proposal that transient system activity is increased by short-wavelength light and attenuated with longer-wavelength light. The study adopted metacontrast designs, with the use of coloured masks in light and dark ambient conditions, a Turnus apparent motion task on coloured backgrounds, and two measures of visual latency: temporal order judgement and reaction time, with coloured targets. The results demonstrated that colour had little or no differential effect on either the magnitude or speed of transient system activity, other than a decrease in some instances with red light as predicted by physiological research. However, the predicted pattern of results was demonstrated when contrast rather than colour was manipulated in a final metacontrast study. The results suggest that conclusions regarding the differential effects of wavelength on transient system activity may be premature, possibly reflecting a colour/contrast confound. However, as the current studies were conducted on normal readers, one cannot eliminate the possibility that dyslexic readers may receive a beneficial effect of colour on reading, either as a result of some sort of visual anomaly in colour processing and/or in reducing visual discomfort.

◆ **22 Depth perception from disparity of contrast envelopes: sorting the facts from the artifacts**

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In previous work we showed that stereo depth perception for Gabor patches can exploit the disparity of the carrier (first-order disparity) and the disparity of the envelope (second-order disparity) (Applied Vision Association Meeting, Dundee, April 1997). We also modelled the interaction and combination of these two cues (*Perception* **26** 1337, abstract 29). We consider here the possibility that second-order stereo depends upon vergence movements, or is an artifact of distortion products that introduce first-order information about the contrast envelope. Reducing the presentation time from 300 to 150 ms had little or no effect on depth estimates for horizontal Gabor patches, suggesting that vergence is not important. Depth estimates obtained at peak contrasts of 32%, 8%, and 4% were all very similar. This rules out the compressive distortion hypothesis, because such distortion decreases as the square of contrast and so would be negligible at low contrasts.

We then investigated what cues in the contrast envelope were being used for depth perception, by presenting horizontal Gabors and filtered noise patches with correlations of +1 and −1 between the eyes. Depth perception was possible, though much more variable, for the negatively correlated patches that contained no matchable first-order features. With −1 correlation there was a bias

to respond 'back' more often, equivalent to approx $\frac{1}{4}$ cycle shift of disparity for the Gabors and $\frac{1}{2}$ cycle for the filtered noise. When envelope cues are weak, unmatched features may act as half-occlusion cues [Shimojo and Nakayama, 1994 *Vision Research* **34** 1875 – 1881; Anderson, 1994 *Nature (London)* **367** 365 – 368] that drive the percept back so that the response is consistent with a surface seen behind an aperture.

◆ **Representational momentum and the human face**

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Faces are complex objects. One dimension of this complexity that is often ignored, at least in respect to processing facial identity, is the fact that faces move. That is, when we smile, speak, or gesture approval, our faces change shape. How do such nonrigid transformations influence the way we perceive and represent specific faces? Does motion simply add noise, or could a transforming face actually enhance processing in some way?

Thornton and Kourtzi (1997 *Investigative Ophthalmology & Visual Science* **38** 1004) recently reported performance advantages in a sequential identity-matching task when the first image of a face was a short video clip versus a single still frame. The current work explores whether such advantages might arise owing to the creation of what Freyd (1987 *Psychological Review* **94** 427 – 438) has termed dynamic mental representations. Evidence for these structures has come mainly from representational momentum studies in which the final position or configuration of a transforming object is misremembered as being further forward in the direction of motion or change.

Can we find evidence for similar memory distortions when video clips of facial expressions are used? That is, when shown a dynamic smiling or frowning face, will participants misremember the stopping point as being more intense than the true stopping point? Results indicate no evidence for such forward memory bias. Rather, a consistent bias back towards the starting point of the video sequence was observed, suggesting that face-specific dynamic constraints may be overriding more general representational factors (eg motion anticipation) during performance of this task.

◆ **Temporal processing of spatial alignment information across gaps**

24 S J Waugh (Division of Vision Sciences, Aston University, Birmingham B4 7ET, UK; e-mail: S.J.Waugh@aston.ac.uk)

The effects of exposure duration on alignment thresholds for separated lines were investigated. Alignment thresholds for equally visible lines (ie lines a constant multiple above contrast detection threshold) separated by 1.5 deg, were measured for different exposure durations (15 – 1000 ms). This condition was interleaved with those where the stimulus was closely followed by spatial noise masks. Alignment thresholds for equally visible stimuli presented without a postmask improved with increasing exposure duration as a power function with an exponent of approximately -0.1. However, when the stimulus was closely followed by an appropriate spatial mask, thresholds improved as a power function with an exponent close to -0.5. Experiments did not show a significant change in the spatial scale characteristics of the most effective mask across exposure duration. The improvement in alignment thresholds over time is most likely a result of a square-root temporal integration process occurring for alignment calculations made between separated targets. [This work was supported by the ARC of Australia (F79340109 and A49531427).]

◆ **Contrast-modulated and luminance-modulated masking as a function of spatial frequency**

25 **and phase.**

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Previous studies have shown that a low-spatial-frequency contrast-modulated grating (beat), composed of two high-spatial-frequency sinusoids, severely masks the detection of a sinusoid at the beat frequency (Henning, Hertz, and Broadbent, 1975 *Vision Research* **15** 887 – 899). This finding could suggest that channels tuned for low and high spatial frequencies are not completely independent. Alternatively, the masking could arise as a result of an early nonlinearity injecting a distortion product at the beat frequency. If so, the effects of masking by a beat should be similar to those of masking by a 'real' grating at the same frequency. Here, we explore the effects of masking by a beat and a 'real' grating on the detection of test gratings as a function of both spatial frequency and phase.

Contrast thresholds were measured for a range of test spatial frequencies (0.25 – 4.0 cycles deg^{-1}) in the presence of a masking grating. The mask was either (a) a contrast-modulated grating with a beat frequency of 1 cycle deg^{-1} and components of 8 and 9 cycles deg^{-1}, each with a contrast of 20%, or (b) an 8 cycles deg^{-1} sinusoidal grating of 20% contrast plus a 1 cycle deg^{-1} grating of 3% contrast. The phase of the test grating was randomised at the start of each trial.

Under some conditions the effects of masking by beats and 'real' gratings were similar. Specifically, both the beat and the 'real' grating produced robust elevations of contrast threshold about the beat frequency (see also Smallman and Harris, 1995 *Perception* **24** supplement, 127). However, not all the data lend support to the simple distortion product hypothesis: the detection of test gratings in the presence of a real masking grating is dependent on phase, but detection is phase-independent when masked by a beat of the same frequency.

◆ **Motion in depth and nonrigid motion of subjective contours**

26 M J Wright (Department of Human Sciences, Brunel University, Uxbridge, Middx UB8 3PH, UK; e-mail: Michael.Wright@brunel.ac.uk)

With the aid of computer animation techniques it is demonstrated that a Kanizsa square can be made to rotate in depth, or advance and recede. The square is seen as a surface moving in front of the background dots. The subjective contours of a Kanizsa square rotating in depth can appear slanted or tilted in depth even without stereoscopic cues. The effect depends upon using perspective projection. If perspective cues are removed from the rotating square, the percept becomes ambiguous, and it can be seen either as a square rotating in depth or as a flat rectangle undergoing nonrigid motion (squashing and stretching). Replacing either the inducing dots or the background with an equiluminous random texture almost completely abolishes the subjective contours when stationary, but they reappear when the square is in motion.

However, a rotating Kanizsa square composed entirely of second-order motion contours (accretion and deletion of texture) does not show contour completion over a textured background. It is concluded that motion and perspective can give rise to subjective surfaces slanted or tilted in depth, and to nonrigid as well as rigid surfaces. The effects are as strong as or stronger than with stationary figures.

◆ **Recognition of faces and facial expressions in central and peripheral vision**

27 R Nemeth, M J Wright, A Green (Department of Human Sciences, Brunel University, Uxbridge, Middx UB8 3PH, UK; e-mail: Robert.Nemeth@brunel.ac.uk)

Ten subjects performed a forced-choice identification of stationary 512×512 pixels 12-bit grey-scale images of ten famous faces (five male and five female film stars) presented for 1 s in central vision and at four eccentricities along the horizontal meridian. The magnification of the peripheral stimuli was increased in accordance with published M-scaling data for contrast sensitivity by varying the viewing distance as follows: 0 deg = 5 m; 3 deg = 2.5 m; 10 deg = 1 m; 20 deg = 0.61 m; 40 deg = 0.27 m. It was found that recognition decreased strongly with eccentricity despite the scaling. Performance also decreased in progressively degraded images (256×256, 128×128, 64×64, and 32×32 resolution binary images) but there was no significant interaction between eccentricity and resolution: thus the steep decline of performance in the periphery does not depend on the high spatial frequency or low contrast content of the face image. A further seven subjects performed forced-choice identification of five emotional expressions under the same experimental conditions: absolute performance in terms of total errors made was worse in this task, but the slope of the decrease with eccentricity was similar (see also Wright and Bentley, 1990 *Perception* **19** 270–271). It is concluded that the recognition of facial identity and facial emotion is limited by visual processes which decrease with eccentricity more steeply than contrast sensitivity.

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