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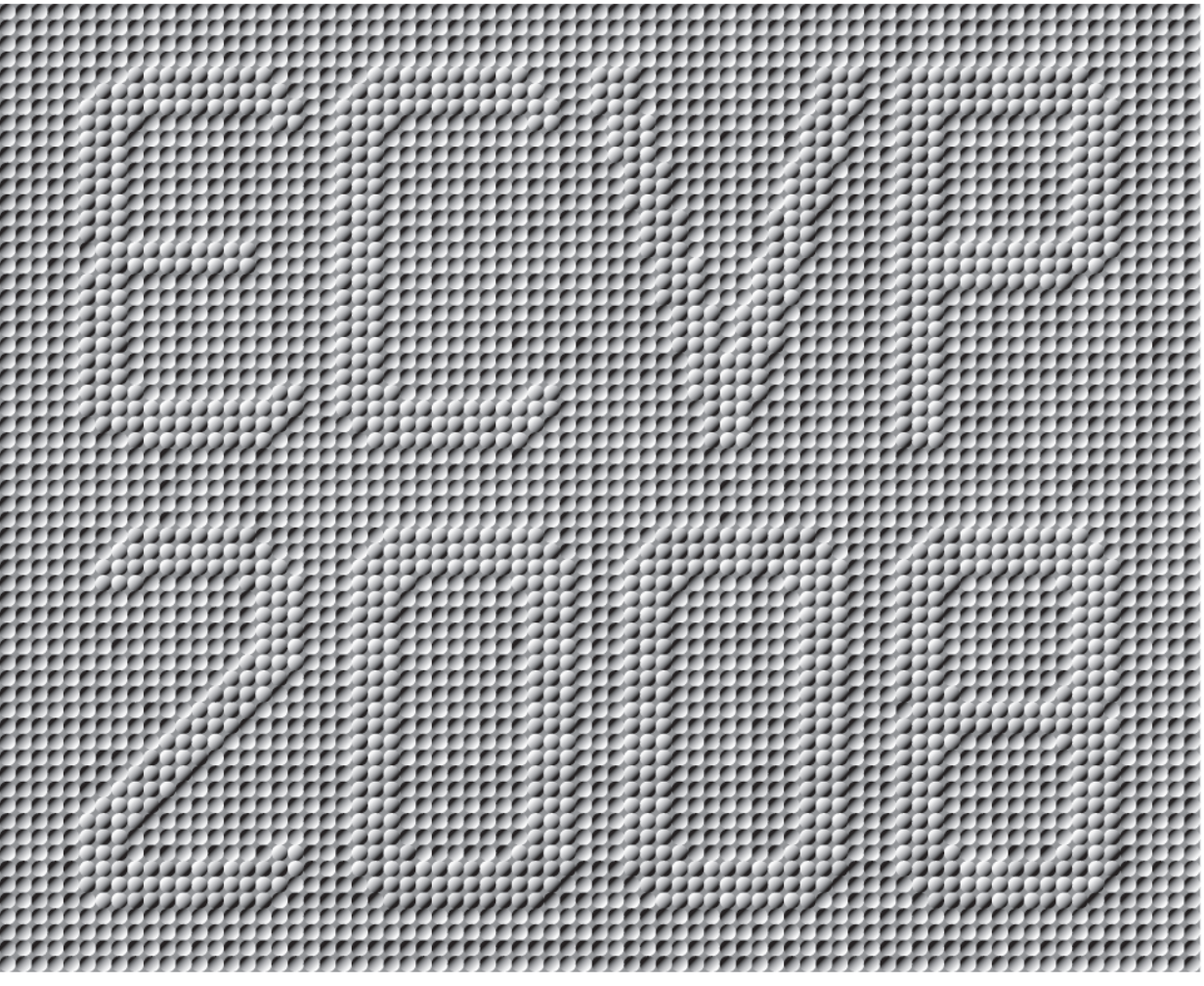

31st European Conference on Visual Perception

Utrecht, 24-28 August 2008

Abstracts

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Thirty-first European Conference on Visual Perception
Utrecht, The Netherlands
24 – 28 August 2008

Abstracts

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1979 Noordwijkerhout (NL)
1980 Brighton (GB)
1981 Gouvieux (F)
1982 Leuven (B)
1983 Lucca (I)
1984 Cambridge (GB)
1985 Peñiscola (E)
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2002 Glasgow (GB)
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2006 St Petersburg (RU)
2007 Arezzo (I)

ECVP '08 Abstracts

Sunday

THE PERCEPTION LECTURE

◆ **Exploring motion in depth with the dichoptiscope**
I P Howard (Centre for Vision Research, York University, Toronto, Canada; e-mail: ihoward@cvr.yorku.ca)

I have constructed an instrument that provides independent control of all cues to motion in depth. I call it the dichoptiscope. A conventional stereoscope combines disparate 2-D images. The dichoptiscope modulates the disparity of a real 3-D object, leaving accommodation and motion parallax normal. Two identical 3-D image objects are viewed through 45° mirrors to form a binocular object. Each image object moves in depth along a track within arm's reach. Vergence (absolute disparity) is controlled by changing the angle between each track and the midline. Internal relative disparity is controlled by rotating the image objects in opposite directions as they move along the tracks. External relative disparity is controlled by adding a stationary object. Looming is controlled by the velocity of motion or by using radial stimuli that do not loom. I have used the instrument to investigate the relative strengths of these cues to motion in depth. Perceived motion in depth was indicated by the tracking motion of the unseen hand. Looming was the dominant cue but changing vergence was an effective cue when looming was neutralized. Constancy of the perceived 3-D shape of an object requires that we scale relative disparity by perceived distance. I am now using the dichoptiscope to investigate the stimulus factors that allow a person to achieve depth constancy in an approaching object. I will report whatever results I have obtained by the time of the conference.

Monday

ORAL PRESENTATIONS

BINOCULAR PROCESSING

◆ **A common factor underlying binocular rivalry and dichoptic masking**
D H Baker, E W Graf (School of Psychology, University of Southampton, UK; e-mail: d.h.baker@soton.ac.uk)

When incompatible images are shown to the two eyes, two empirical phenomena are observed: monocular detection thresholds are elevated (dichoptic masking) and the perceived image changes over time (binocular rivalry). It has recently been shown [van Boxtel et al, 2007 *Journal of Vision* **7**(14.3)] that these two phenomena have similar perceptual dynamics when images are presented successively. Here, we report a common underlying factor between rivalry and dichoptic masking during simultaneous presentation. Using orthogonal Gabor patches (2 cycles deg^{-1}) we measured threshold elevation for dichoptic masking, as well as the mean dominance duration of binocular rivalry, in a group of forty-one subjects. Both threshold elevation and dominance durations varied substantially across observers, and were highly correlated ($r = 0.44$, $p < 0.01$) such that stronger dichoptic masking was associated with longer dominance durations. Within subjects, we also varied the angle between dichoptic Gabors, producing a similar pattern of results. These findings are accounted for by a single computational model in which the weight of interocular suppression determines both threshold elevation and dominance durations.
[Supported by BBSRC grant no BB-E012698-1.]

◆ **Illusory size changes influence the tuning of spatial coding interactions**
D H Arnold, A Birt, T S A Wallis (School of Psychology, The University of Queensland, Australia; e-mail: darnold@psy.uq.edu.au)

Images of the same physical dimensions on the retina can appear to represent different sized objects. One reason for this is that the human visual system can take viewing distance into account when judging apparent size. Sequentially presented images can also prompt spatial coding interactions. Here we show, using a spatial coding phenomenon (the tilt after-effect) in tandem with viewing distance cues, that the tuning of such interactions is not simply determined by the physical dimensions of retinal input. Rather, we find that they are contingent upon

apparent size. Our data therefore reveal that spatial coding interactions in human vision are modulated by processes involved in the determination of apparent size.
[Supported by a Discovery Project Grant awarded to DHA by the Australian Research Council.]

◆ **Sound induces binocular rivalry alternations**
A Parker, D Alais (Department of Psychology, University of Sydney, Australia; e-mail: amandap@psych.usyd.edu.au)

Binocular rivalry occurs when different images are presented to each eye. Rather than contriving a fusion of the inputs, the percept of such stimuli alternates between the discrepant images. Transient visual events can induce rivalry alternations (Kanai et al, 2005 *Perception* **34** 803 – 822), suggesting that processes more distributed than those implicated in binocular combination are involved. Here we demonstrate that transient induced alternations (TIAs) are not limited to visual transients but occur with stimuli presented in the auditory modality. The cross-modal induction of TIAs is evidence against a purely visual mechanism underlying rivalry alternations. Auditory TIAs persist at higher presentation frequencies than visual TIAs; therefore TIAs are not gated by the temporal limits of vision. The role of expectation in producing visual and auditory TIAs is important, supporting the role of attention in the effects reported. Experiments showing brief sounds increase the likelihood of flash suppression provide consistent results. The physical energy of the transient auditory stimulus (eg frequency spectrum) is inconsequential, ruling out a low-level explanation for TIAs.

◆ **Neural and optical constraints on stereoacuity**
B N S Vlaskamp, G Y Yoon¶, M S Banks (School of Optometry, University of California at Berkeley, USA; ¶ Department of Ophthalmology, School of Medicine and Dentistry, University of Rochester, USA; e-mail: vlaskamp@berkeley.edu)

The finest spatial variation that can be perceived from stereopsis is 2 – 4 cycles deg^{-1}, more than 10 times lower than the finest perceptible luminance variation. Why is this limit to stereopsis so low? Banks et al (2004 *Journal of Neuroscience* **24** 2077 – 2089) argued that spatial blur caused by filtering in the visual front-end limits stereoacuity. We tested the hypothesis that blur induced by optical defects of the normal well-focused eye limit performance. We re-measured stereoacuity after minimizing higher-order aberrations with phase plates and after eliminating chromatic aberrations by presenting stimuli under monochromatic light conditions. These measures greatly improved image quality: in one observer, they yielded up to a 7-fold increase in monocular luminance contrast sensitivity. We then measured the finest detectable sinusoidal depth corrugation with normal and improved optics. Despite the substantial image improvement with phase plates and a monochromatic stimulus, stereoacuity was not improved. Thus, the eyes' optics do not seem to limit stereoacuity. Rather the limit is the smallest neural mechanism that subserves disparity estimation.

◆ **Fechnerian sensory scaling: a test of the intrinsic constraint model**
F Domini, C Caudek¶ (Department of Cognitive and Linguistic Sciences, Brown University, USA; ¶ University of Florence, Italy; e-mail: Fulvio_Domini@brown.edu)

In a recent paper, MacKenzie et al (2008) matched the perceived depth of half-cylinders defined by disparity to half-cylinders defined by motion information for two simulated depths and attributed to the IC model (Domini et al, 2006 *Vision Research* **46** 1707 – 1723) the following prediction: The JND count, defined as the difference between two simulated depths divided by the (constant) JND, should be equal for both motion-only and disparity-only stimuli. They conclude that their findings do not conform to the predictions of the IC model. Such conclusion is flawed. In the present study we show that, if the JND count is correct, then the empirical data is compatible with the hypothesis that two depth-matched pairs of stimuli are separated by equal numbers of JNDs. These results are consistent with the predictions of the IC model and support the hypothesis that there is a strong link between perceived depth and depth discrimination. We will also discuss the implications of these results for the MWF theory of depth-cue integration.

◆ **Signal-to-noise ratio and not simulated depth predicts perceived 3-D structure from stereo and motion stimuli**
C Caudek, F Domini¶ (University of Florence, Italy; ¶ Department of Cognitive and Linguistic Sciences, Brown University, USA; e-mail: Caudek@unifi.it)

To recover absolute depth in terms of a Euclidean inverse-projection model of 3-D shape perception, scaling parameters like absolute distance and object rotation are required to scale the information provided by binocular disparities and retinal velocities. In the psychophysical literature, however, large and systematic departures from veridical perception have been reported

for each cue shown in isolation, suggesting that these scaling parameters are poorly estimated by human observers. Here we contrast two theories of 3-D shape perception. The inverse-geometry theory predicts that two stimuli are perceptually matched when they simulate the same depth. The intrinsic constraint theory (Domini, Caudek, & Tassinari, 2006) predicts that the signal-to-noise Ratio (SNR) of velocity and disparity signals is the best predictor of human performance. In this study, we found support for the second theory since observers reported that (i) perceived depth was equal for stimuli having the same SNR but different simulated depths; (ii) perceived depth was different for stimuli with different SNR magnitudes but same simulated depth.

LOW-LEVEL PROCESSES OF ATTENTION AND MODELLING

◆ **Modelling visual search for a target against a 1/fb continuous textured background**

A D F Clarke, P R Green¶, K Emrith, M J Chantler (School of Mathematics and Computer Science, Heriot Watt University, Edinburgh, UK; ¶ School of Psychology, Heriot Watt University, Edinburgh, UK; e-mail: alasdair.clarke@macs.hw.ac.uk)

We present synthetic surface textures as a novel class of stimuli for use in visual search experiments. These are created from surface height maps with 1/fb properties, which are rendered to give images that strongly resemble surfaces of natural materials such as stone. These textured images have certain advantages over both photographs of natural scenes and the arrays of abstract discrete items commonly used in search studies; they appear naturalistic, yet are fully parameterised and controllable. As there is no semantic information present, these images are ideal for testing models of low-level processes in the control of visual attention. The difficulty of the search task can be modified by changing the parameters of the surface and the target. Experimental results show that the Itti–Koch saliency model fails to replicate the sensitivity of human observers to elongated indentations in a surface when they are oriented close to the direction of illumination. We present results from an alternative model of visual search on such surfaces based on Gabor filters.

◆ **Feature-based visual attention: the probabilistic account**

B T Vincent (School of Psychology, University of Dundee, UK; e-mail: b.t.vincent@dundee.ac.uk)

The deployment of visual attention is a topic of much debate. While 'high level' factors surely have a role, it is firmly established that simple visual features can influence attention in specific ways. Currently, the best account of human performance in visual search tasks is provided by signal detection theory: however, despite its success, I describe how its assumptions limit its robustness, sometimes resulting in suboptimal predictions. I present a Bayesian account and predicted performance for 2AFC visual search tasks. Based on probabilistic representations of target and distractor feature properties, the account is simple yet provides a good explanation of multiple visual search effects caused by manipulation of: display duration; set sizes; target/distractor similarity; distractor variability; and retinal eccentricity. By constructing a generative model we gain insight into how the visual properties of targets and distractors affect visual search performance. This supports the emerging probabilistic account which asserts that visual attention is deployed in an approximately optimal manner.

◆ **Uncertainty and selective attention**

E Vul, N Kanwisher (Brain and Cognitive Sciences, Massachusetts Institute of Technology, USA; e-mail: evul@mit.edu)

'Visual attention' selectively allocates resources to visual input. We consider tasks requiring selective short-term storage for subsequent report (eg, crowding, attentional blink, etc). In these tasks subjects must detect the spatiotemporal co-occurrence of potential targets with a cue, while performance is limited by uncertainty about the spatiotemporal locations of cues and targets. The solution to this inference under uncertainty is a probability distribution over items. Do people represent these probability distributions in short-term memory? In our tasks, subjects make multiple responses on every trial. We can evaluate properties of the representations underlying responses on any given trial via conditional report distributions. Multiple responses on one trial are independent and identically distributed, indicating that these responses are functionally equivalent to samples from a probability distribution. Further experiments show that conscious access, like responses, is also limited to one sample at a time. We describe implications for crowding, illusory conjunctions, partial cued report, and graded ('attentional gate') versus all-or-none ('Boolean map') theories of attention.

[EV was supported by an NDSEG fellowship.]

◆ **A neural implementation of a Bayes optimal sensory motor transformation in a visual search task**

J M Beck, W J Ma, V Navalpakkam¶ (Brain and Cognitive Sciences, University of Rochester, USA; ¶ Klab, Caltech, USA; e-mail: jbeck@bcs.rochester.edu)

Human performance in search for a tilted target among vertical distractors is well described by signal detection theory (SDT) or saliency-based models, both of which utilize reasonable but ad-hoc assumptions and computations. Here, we develop a fully Bayesian model of this visual search task and study the detection of a target among distractors, where target and distractor features are drawn from arbitrary, but known, distributions. This model (i) reproduces behavioural effects such as set size effects, target-distractor similarity, and distractor heterogeneity; (ii) explains behaviour in complex search conditions, eg flanking distractors. A neural implementation of this model requires a code which represents probability distributions and neural operations which perform probabilistic computations such as evidence integration, marginalization, and maximum-likelihood decoding. We then show that a biologically plausible population of Poisson-like neurons representing relevant features provides such a code. This is accomplished by demonstrating that biologically plausible operations such as linear combination, quadratic nonlinearities, divisive normalization, and attractor dynamics are sufficient to construct Bayes-optimal motor commands on a trial by trial basis.

◆ **On an elementary definition of visual saliency**

M Loog (Faculty of Electrical Engineering, Mathematics, and Computer Science, Delft University of Technology, The Netherlands; also Department of Computer Science, University of Copenhagen, Denmark; e-mail: m.loog@tudelft.nl)

Various approaches to computational modelling of bottom-up visual attention have been proposed in the past two decades. As part of this trend, researchers have studied ways to characterize the saliency map underlying many of these models. In more recent years, several definitions based on probabilistic and information or decision theoretic considerations have been proposed. These provide experimentally successful, appealing, low-level, operational, and elementary definitions of visual saliency (see eg, Bruce, 2005 *Neurocomputing* **65** 125 – 133). Here, I demonstrate that, in fact, all these characterizations provide essentially the same measure of saliency. Moreover, where the original formulations rely on empirical estimates of the underlying probability density of low-level pre-attentive features, I show that saliency can be expressed as a closed-form solution based on purely local measurements and, surprisingly, without the need to refer back to previously observed data. Furthermore, it follows that it is actually not the statistics of the visual scene that would determine what is salient but the low-level features that probe the scene.

[Supported by Netherlands Research Organization and Research Grant Program, University of Copenhagen.]

◆ **Attention improves orientation selectivity in human visual cortex**

J F M Jehee, D K Brady, F Tong (Department of Psychology, Vanderbilt University, Nashville, TN, USA; e-mail: janneke.jehee@vanderbilt.edu)

Does attending a spatial location only strengthen neural responses in corresponding regions of the human visual cortex, or does it also result in additional information processing about the attended features at that location? We used fMRI in combination with pattern-based analyses to address this question. Subjects performed an attention-demanding orientation discrimination task on either one of two laterally presented gratings. Analyses revealed much stronger BOLD responses for attended stimulus locations than unattended locations in early visual areas. To test whether this also improved information available about the attended features at these locations, we used a pattern-based analysis to decode the presented stimulus orientation from cortical activity in these regions (Kamitani and Tong, 2005 *Nature Neuroscience* **8** 679 – 685). We found significantly better decoding performance in the attended condition as compared to the unattended condition in areas V1, V2, and V3. We conclude that attention not only results in enhanced cortical responses in early visual areas, but also improves the orientation selectivity of these responses when analysed at a population level.

[Supported by The Netherlands Organisation for Scientific Research (to JJ) and NIH grant R01 EY017082 to (FT).]

POSTERS

ANALOGOUS CONCEPTS IN HAPTICS AND VISION

◆ **Different haptic working memory stores for length and roughness?**
A L Kaas, S Ritzkowski¶, M C Stoeckel§ (Faculteit der Psychologie, Universiteit Maastricht, The Netherlands; ¶ Biologische Fakutät, Georg-August-Universität Göttingen, Germany; § Centre for Functional MRI of the Brain (FMRIB), University of Oxford, UK; e-mail: a.kaas@psychology.unimaas.nl)

There is some evidence that different neural substrates support tactual macro- and microspatial judgments. The latter was found to rely crucially on somatosensory cortex, whereas the former depended on visual cortex (Merabet et al, 2004 *Neuron* **42** 173 – 179). We investigated whether these differences also affect haptic working memory (WM) decay functions, by varying interstimulus interval (ISI) and visual interference during delayed macrospatial (length) and microspatial (roughness) discrimination. Subjects discriminated length or roughness of two parallelepipeds that were presented for 3 s with an ISI of 1, 3 or 8 s. In half of the trials, a visual letter detection task was presented in the ISI. We found that length discrimination with visual interference dropped close to chance level for ISIs of 8 s, while performance remained stable after unfilled ISIs. Visual interference and ISI did not affect roughness discrimination accuracy. These findings suggest shared resources for length WM and visual letter detection, whereas haptic WM for roughness might use a different pathway.

◆ **Intermanual transfer of haptic curvature aftereffects depends on the manner of touching**
B J van der Horst, A M L Kappers (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: b.j.vanderhorst@phys.uu.nl)

Aftereffects have been demonstrated for several phenomena in different modalities. In vision, the occurrence and transfer of aftereffects have extensively been studied for phenomena like colour, curvature and motion. An important reason to establish the transfer of an aftereffect is to obtain a better understanding of the representation of perceived information. In the present study, we applied this concept to the haptic perception of curvature, to determine whether the representation of shape information depends on the manner of touching. Therefore, we investigated the occurrence and transfer of curvature aftereffects in static and dynamic touch. Aftereffects were found for both types of exploration. In static touch, only a small intermanual transfer of the aftereffect was obtained. In contrast, a full transfer was found in dynamic touch. These findings indicate that statically obtained shape information is mainly represented at a unilateral level, whereas dynamically perceived shape is represented at a bilateral stage.

◆ **Lateral occipital cortex reactivation during grasping of haptically-experienced novel objects**
G Kroliczak, S H Frey¶ (Department of Psychology, University of Oregon, USA; ¶ Department of Psychology & Lewis Center for NeuroImaging, University of Oregon, USA; e-mail: gregk@uoregon.edu)

Subdivisions of the lateral occipital complex (LOC) of the visual ventral stream (Malach et al, 1995 *Proceedings of the National Academy of the USA* **92** 8135 – 8139) have been demonstrated to mediate multimodal object recognition (Amedi et al, 2001 *Nature Neuroscience* **4** 324 – 330; James et al, 2002 *Neuropsychologia* **40** 1706 – 1714), and actions based on visual memory (Singhal et al, 2005 *Visual Cognition* **14** 122 – 125). The question remains if LOC subdivisions (LO) would also mediate planning and execution of object-directed grasping. Event-related BOLD fMRI data were acquired from ten right-handed adults during five experimental runs involving haptic exploration of familiar and novel objects, followed by planning and execution of reach-to-grasp movements directed at these objects. Two kinds of LOC localizers were also run. We find that haptic object exploration is mediated only by left LO. In contrast, grasp planning activates only right LO. The suggested encoding-retrieval asymmetry in LOC functioning is further supported by right LO reactivation during novel-object grasping. In sum, object-responsive cortex in the occipital lobe also mediates exclusively haptically-driven prehension.
[Supported by TATRC Pilot Study Funds awarded to GK by Lewis Center for NeuroImaging.]

◆ **A visual but no haptic face inversion effect indicates modality-specific processing differences**
L Dopjans, C Wallraven, H H Bülthoff (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: lisa.dopjans@tuebingen.mpg.de)

In previous experiments, we provided further evidence that 3-D face stimuli can be learnt and recognized across haptic and visual modalities. Our results suggested information transfer across modalities to be asymmetric due to differences in visual versus haptic face processing (ie, configural vs featural). To test this hypothesis, we designed two experiments investigating a visual, haptic and cross-modal face-inversion effect: Experiment 1 used an old/new recognition task in

which three upright faces were learnt visually followed by three visual test-blocks (one with upright and two with inverted faces) and one haptic test-block with inverted faces. We found a strong inversion effect for visually learnt faces (visual-upright: $d' = 2.07$, visual-inverted: $d' = 0.6$, haptic-inverted: $d' = 0.52$). When we exchanged learning and testing modalities in Experiment 2 (haptic learning of upright faces followed by one haptic-upright, two haptic-inverted and one visual-inverted test-blocks), we failed to find an inversion effect for haptically learnt faces (haptic-upright: $d' = 1.45$, haptic-inverted: $d' = 1.75$, visual-inverted: $d' = 1.16$). Whereas visual face processing thus operates configurally, haptic processing seems to rely on featural information.

◆ **The influence of haptic perception on pictorial relief**

M W A Wijntjes, R Volcic, J J Koenderink, A M L Kappers (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: M.W.A.Wijntjes@phys.uu.nl)

Although a photograph only possesses 2-D information, the visual system is able to interpret depth that relates to the depth of the original scene. However, this depth map suffers from ambiguities inherent to the transformation of the 3-D world to the 2-D photograph. Mathematically this ambiguity can be resolved by an affine transformation of the depth map. We studied the difference between subjective depth maps between observers who could only see a photograph of the 3-D stimulus, and observers who could also touch the stimulus. We found that the similarity, expressed in depth map correlations, is higher when haptic information is available. This means that the 3-D representations were more alike within the haptic group. We also found that haptic information makes the relief more 'stretched' in the depth direction. Our results indicate that haptics can partly disambiguate visual perception.

[Supported by the Netherlands Organisation for Scientific Research (NWO).]

◆ **A characteristic 'dipper function' for bimodal and unimodal visual and tactile motion discrimination and facilitation between modalities**

M Gori, G Mazzilli¶, G Sandini, D Burr¶ (IIT, Italian Institute of Technology, Genoa, Italy; ¶ Dipartimento di Psicologia, Università degli Studi di Firenze, Florence, Italy; e-mail: monica.gori@unige.it)

We measure bimodal and unimodal visual and tactile velocity discrimination thresholds over a wide range of base velocities and spatial frequencies. The stimuli were two physical wheels etched with a sinewave profile that was both seen and felt, allowing for the simultaneous presentation of visual and haptic velocities, either congruent or in conflict. Stimuli were presented in two separate intervals and subjects reported the faster motion in 2AFC using visual, tactile or bimodal information. We found an improvement in the bimodal thresholds well predicted by the maximum likelihood estimation model and not specific for direction. Interestingly, both bimodal and unimodal thresholds showed a characteristic 'dipper function', with the minimum at a given 'pedestal duration'. The 'dip' occurred over the same velocity range at all spatial frequencies and conditions. Most interestingly, a tactile pedestal facilitated a visual test and vice versa, indicating facilitation between modalities and suggesting that the thresholding of these signals occurs at high levels after crossmodal integration.

◆ **The achievement of object constancy across depth rotation for unimodal and crossmodal visual and haptic object recognition**

R Lawson, H H Bülthoff¶ (School of Psychology, University of Liverpool, UK; ¶ Max Planck Institut für biologische Kybernetik, Tübingen, Germany; e-mail: rlawson@liv.ac.uk)

We investigated whether achieving object constancy across depth rotation was similar for visual (V) versus haptic (H) inputs by testing unimodal (VV, HH) and crossmodal (VH, HV) sequential object matching. We presented 60 white, hand-sized, plastic object models comprising 20 pairs from similarly-shaped categories (bath/sink; pig/dog, key/sword) and a midway morph (eg, half-bath/half-sink) between each pair. These objects were placed at fixed orientations behind an LCD screen that was opaque for haptic inputs and clear for visual presentations. A 90° rotation from the first to the second object on a trial impaired people's ability to detect shape changes in all conditions except HV matching. Task difficulty was varied between groups by manipulating shape dissimilarity on mismatch trials. For VV matches only, task-irrelevant rotations disrupted performance more when the task was harder. Viewpoint thus influenced both visual and haptic object identification but the effects of depth rotations differed across modalities and for unimodal versus crossmodal matching. These results suggest that most view change effects are due to modality-specific processes.

[Supported by the Economic and Social Research Council (RES-000-27-0162).]

◆ **Adaptation and contrast effects in haptic perception of hardness**
W M Bergmann Tiest, A M L Kappers (Helmholtz Institute, Universiteit Utrecht, The Netherlands; e-mail: W.M.BergmannTiest@phys.uu.nl)
In vision, adaptation and contrast effects are well-known. For example, the perceived luminance of a surface is influenced by its background. Here, similar effects are investigated in the haptic perception of object hardness. Subjects had to adapt to either a stimulus presented to one hand, or to stimuli presented to both hands. They were then presented with two stimuli in either hand and they were asked to indicate which one was the harder. In this way, a shift in perceived equal hardness was measured. With two-handed adaptation, a very large shift was found, while with one-handed adaptation to a hard stimulus, the effect was very small. Adaptation to a soft stimulus had an intermediate effect. These results can be explained either by a contrast effect with a magnitude that depends strongly on the stimulus hardness, or by a combination of two mechanisms which can either amplify or extinguish each other. One of these mechanisms might be due to muscle fatigue, while the other is analogous to the luminance contrast effect.
[Supported by the Netherlands Organisation for Scientific Research.]

ATTENTION AND RELATED ISSUES

◆ **How does the duration of target presentation affect object substitution masking?**
A Gellatly, M Pilling (Department of Psychology, Oxford Brookes University, UK; e-mail: agellatly@brookes.ac.uk)
Object substitution masking (OSM) is said to occur when a brief target is presented either simultaneously with a spatially distinct mask (such as four dots or a ring) that outlasts it, or with the mask having both delayed onset and offset (DiLollo et al, 2000 *Journal of Experimental Psychology: General* **129** 481 – 507; Enns, 2004 *Vision Research* **44** 1321 – 1331). Reporting of some feature of the target is worse in these 'trailing mask' conditions than when the mask offsets simultaneously with the target, this difference giving the measure of OSM. OSM is thought to arise during competitive interactions involving higher and lower cells in the visual system responding to onset of target and mask. We will report experiments showing that OSM can be obtained with targets presented for some hundreds of milliseconds rather than being briefly flashed as in all prior OSM studies known to us. We then go on to investigate similarities and differences in degree of masking between OSM obtained in this fashion and in the more usual fashion.

◆ **Sequential dependence in multi-stable perception**
A Pastukhov, J Brain (Cognitive Biology, Otto-von-Guericke University Magdeburg, Germany; e-mail: alexander.pastukhov@ovgu.de)
A hallmark of multi-stable perception is that dominance times are distributed stochastically and are sequentially independent. Here we report that multi-stable perception looses these characteristics when dominance periods of one percept are systematically shortened. We presented an ambiguous rotating ring intermittently, interrupting the display shortly after each perceptual reversal. Occasionally, however, the display continued until a second reversal. As a result, several successive onsets were consistently dominated by the same percept: consistent onset sequence (COS). Over the course of a COS, dominance times reverted progressively towards the overall mean, presumably reflecting rise or decay of adaptation. Within COS, successive dominance times were significantly positively correlated (corr. coeff. = 0.26 – 0.29). Over all presentations, as well as between COS, sequential dependence was marginal. These observations suggest that multi-stable perception is not a 'memoryless' renewal process, as had long been supposed. Rather, sequences dominated by the same percept show strong evidence of a memory between successive percepts. We hypothesize that long-lasting memory states play a pervasive role in multi-stable perception.

◆ **Proprioceptive adaptation while walking does not require attention**
T A Brandwood, S K Rushton, C Charron¶ (School of Psychology, Cardiff University, UK; ¶ School of Engineering, Cardiff University, UK; e-mail: brandwoodta@cardiff.ac.uk)
Adaptation to spatial errors produced by optical prisms has been shown to be dependent on the amount of attention an observer has available during exposure to the distortion (Redding and Wallace, 1985 *Perception & Psychophysics* **37** 225 – 230). We investigated the effect of attention on adaptation and trajectory when walking directly towards a target whilst wearing prisms. Participants walked between targets twenty times while performing a mental arithmetic (hard, medium, or low difficulty) task. Proprioceptive, visual and total shift were calculated. We found that visual and total shift were independent of attention. In contradiction to the original work on adaptation, we found that most proprioceptive adaptation took place when participants were given the most difficult secondary task to complete. Moreover, significant differences existed in the

amount of adaptation to left vs right displacing prisms. We consider the results with reference to differences in walking trajectories taken by participants completing the different tasks and discuss possible applications of prism adaptation in the rehabilitation of navigation problems in patients with visual neglect.

◆ **Similarities between attentional attraction by familiarity singletons and abrupt onsets**
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Evidencing attentional attraction by singletons defined by long-term familiarity should have consequences for models of early visual processing. We used an allo-cue paradigm combining a spatial pre cuing by a familiarity singleton during 80 ms and a subsequent change detection task. We varied the spatial congruency between the familiarity singleton (a familiar shape between unfamiliar ones or the reverse) and the colour change of a cross. Results evidenced an attraction by familiarity singletons. However when change occurred at the opposite position of the one cued by the singleton, an enhancement relative to uncued conditions (all familiar or unfamiliar items in the first display) was observed in these incongruent trials. On the other hand, incongruent changes occurring at 90° of the cued position actually induced a classical cost. This study replicates, but here with a familiarity singleton, the improvement of detection capacities in the diametrically opposite position of the cued location already evidenced by Tse et al (2003 *Psychological Science* **14** 91 – 99) using abrupt onsets as spatial cues.

◆ **Peripheral mislocalization with successively presented stimuli: experimental and modeling evidence for a dynamic field account**
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When observers were asked to localize the peripheral position of a flashed probe with respect to a previously presented comparison stimulus, they tended to judge it as being more towards the fovea than the comparison stimulus. Experiments revealed that the mislocalization only emerged when comparison stimulus and probe were presented successively, not when they were presented simultaneously. In addition, the mislocalization decreased with larger interspaces between stimuli and it was reversed with stimulus onset asynchronies above 400 ms. Modeling the data with a dynamic field model revealed further evidence for locally working interactions of excitatory and inhibitory mechanisms, which can account for other mislocalizations as well (Fröhlich effect, flash-lag effect, representational momentum).

◆ **Top – down strategy affects learning of visual context in visual search**
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Visual search performance is facilitated when participants repeatedly experience the same search array (contextual cueing). Contextual cueing is evidence that visual context, such as an association between a target location and a distractor configuration is implicitly learned, and guides spatial attention to the target location (Chun and Jiang, 1998 *Cognitive Psychology* **36** 28 – 71). Recently, Lleras and von Mühlenen (2004 *Spatial Vision* **17** 465 – 482) found that contextual cueing is affected by participants' search strategy (ie, passive or active search), and only the passive search led to the cueing effect. However, it is unclear whether participants' strategy would affect learning of the context or use of the learned context. In this study, the same set of the search arrays was consistently utilized, while participants were required to switch the strategy between the different sessions of the experiment. The results showed that the cueing effect occurred only when participants passively searched for the target in the first session, and suggest that participants' strategy would affect learning of the context, but not use of the learned context.

◆ **AB magnitude is affected by physical similarity between targets and distractors**
F K Chua (Department of Psychology, National University of Singapore, Singapore; e-mail: fkchua@leonis.nus.edu.sg)

In an RSVP procedure, two targets (T1, T2) are embedded among distractors and presented sequentially at the same location. The attentional blink (AB) refers to phenomenon in which T2 is poorly identified if it appears between 200 – 600 ms after T1. One influential account of the AB is that processing demands of T1 cause the AB. Specifically, when the distractors (especially, the object trailing T1) are drawn from the same set as T1 (eg, all are letters), T1 processing is impeded and the AB occurs. In a set of experiments in which the distractors were systematically manipulated, we show the following: (a) the T2 locus is perhaps even more crucial in determining the AB magnitude; and (b) the physical similarity between T1 and the trailing distractor(s) is

more important. These results are interpreted as evidence that the AB is caused not so much by processing difficulties but from the delay in attentional disengagement from the T1 locus.
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◆ **Spatial control of attention in depth**
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It has recently been shown that the spatial precision of attentional control is influenced by image-level characteristics, such as differences in colour. The aim of the present study was to explore whether the spatial control of attention is also modulated by the perceptual organization of a scene based on depth. In a variant of the attentional-walk task, participants were stereoscopically presented with a dense circular array of discs that could appear in front and/or in back of the horoptor. The task of the participants was to shift their attention from one disc to the next disc of the same depth. In the homogeneous condition all discs were presented at the same depth plane, whereas in the heterogeneous condition the discs alternated between the front and back depth planes. Performance accuracy was higher in the heterogeneous than in the homogeneous condition, which suggests that participants were able to limit the allocation of attention to items within a perceptually grouped plane in depth.

◆ **Orientation-specific adaptation to mentally generated lines**
H M Mohr, N S Linder, R Sireteanu (Institut of Psychology, Johann Wolfgang Goethe University, Germany; e-mail: hmohr@em.uni-frankfurt.de)

The tilt after effect (TAE) is a phenomenon by which, after staring at a pattern of tilted lines, subsequently presented lines appear tilted in the opposite orientation. In this study, we investigated whether a TAE can be obtained after mental imagination. In a first experiment, the subjects ($N = 30$) were asked to generate tilted lines mentally, after which they had to decide psychophysically on the orientation of physically presented lines. In a second experiment, the effects of adaptation were tested with functional magnetic resonance imaging ($N = 12$). Results: Subjects showed a significant TAE after imagining the adapting lines. We also found evidence for bilateral neuronal adaptation in areas V3/V3A-B after mental imagery. We conclude that he influence of mental imagery on visual perception and the activity of neurons in visual areas provide evidence for a coding of mental images similar to perception. It could be speculated that the mental imagery of tilted lines is based on top-down modulation from prefrontal cortex that first hits extrastriate areas.

◆ **Invisible images can leave stronger afterimages than visible images**
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After removal of a visual stimulus observers may experience a negative afterimage, an illusory image with identical contours as the previously viewed image, but of opposite polarity. Afterimages arguably arise due to adaptation of cells activated during presentation of the original stimulus. Here we study afterimages of stimuli that are perceptually suppressed during binocular rivalry. Surprisingly, our results indicate that images that do not reach awareness due to rivalry suppression can leave a stronger afterimage than the same images when they are consciously perceived. We account for our findings by positing that perceptually suppressed stimuli cause stronger adaptation in polarity sensitive cells than in polarity insensitive cells. This can explain our findings in a way that is analogous to previous accounts of the influence of attention on afterimage formation. Finally, we show that the effect of rivalry suppression on afterimage formation depends strongly on the spatial frequency of the inducing stimulus, which reconciles our results with previous studies that reported weakening of afterimages due to perceptual suppression.

◆ **Free condition selection: the choice is ruled by attention**
J Palix, C Brandner (Institute of Psychology, University of Lausanne, Switzerland; e-mail: julie.palix@unil.ch)

A new visual search paradigm was imagined to isolate endogenous components of visuo-spatial shifts of attention. Each stimulus consisted in the simultaneous presentation of four comparable arrays in the four corners of a screen, each compounded of two types of elements. Participants ($N = 21$) were instructed to select one of the four arrays while maintaining a central fixation point, and press a response key once they had determined the most predominant element in it (RT_{stim}). Two additional phases followed each display, controlling both visuo-spatial (RT_{space}) and feature (RT_{feat}) abilities. Despite the task difficulty (mean $RT_{stim} = 2192$ ms ± 192), performances

reached 85%. Type and number of elements did not affect RT_{stim}, but their location did. Indeed, a significant left visual field preference (57% of choice) was noticed, with correspondences in RT ($p = 0.005$; $RT_{stim} - LVH = 2139$ ms, $RT_{stim} - RVH = 2245$ ms). Interestingly, this advantage significantly transferred in both successive control RTs, particularly in RT_{feat}. Taken together, our results suggest that free decision is under the control of attention.

◆ **Effects of attention and depth order on Troxler effect**

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Troxler effect (peripheral fading) is influenced by voluntary attention to peripheral targets (Lou, 1999 *Perception* **28** 519 – 526) as well as by depth ordering between the targets and distractors (Hsu et al, 2006 *Vision Research* **46** 1973 – 1981): the selectively attended stimuli and the stimuli perceived farther in depth tend to disappear from peripheral vision faster following steady fixation. It remains possible that (i) attention tends to be spontaneously drawn to stimuli perceived farther in depth, and (ii) selective attention can override depth order in affecting the Troxler effect. To investigate these possibilities, we factorially manipulated selective attention (via instruction) and depth order (via binocular disparity) between two sets of peripheral discs, and measured frequency and latency of the Troxler effect that occurred to each set. Additive effects of these two factors were obtained, with the influence of the selective attention exceeding that of the depth order. Thus, no support for either of the hypotheses has been found.

◆ **Impairment of controlled attentionnal processing after irradiation of posterior fossa tumor: an fMRI study**

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Brain differences activation between twelve young adults and one patient (14-year-olds) treated for a cerebellar tumor 4 years ago were examined during an attentional task. Participants had to detect the presence of a target among distractors in two situations. In the pop-out condition, target differed from the distractors by both form and color, and search is parallel and automatic. In the conjunction condition, as the target shared the colouror the form with the distractors, the search is serial and controlled. Three set sizes were used (3, 15, or 24 distractors). Functional magnetic resonance imaging (fMRI) and behavioural indicators (RT) were used to evaluate automatic and controlled attentionnal processing. The results indicated that automatic attentional processing was unaffected in the patient (RT did not increase with set size) but the neural network was larger than for the control group (including areas in the temporal, parietal and frontal lobes). Controlled processing involved a more frontal network in controls, and was selectively impaired in patient, with additional regions involved.

◆ **Retinotopic mapping of the human visual cortex: magnetic field strength comparison 3 Tesla vs 7 Tesla**

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Retinotopic mapping fMRI-data obtained at a magnetic field strength of 7 Tesla were evaluated and compared to 3 Tesla acquisitions. Portions of a phase reversing circular checkerboard were stimulated during T2*-weighted echo planar imaging to obtain eccentricity or polar angle maps according to established retinotopic mapping techniques. In two subjects 25 slices parallel to the calcarine sulcus were acquired at 7 and 3 Tesla every 2 s for three different voxel sizes of 2.5^3, 1.4^3, and 1.1^3 mm^3. After motion and distortion correction, the fMRI signals were Fourier analysed, correlated with the stimulus fundamental frequency, and projected to the flattened representation of T1 weighted images acquired at 3 Tesla. The obtained retinotopic maps allowed for the identification of visual areas in the occipital cortex. The mean coherence in V1 increased with magnetic field strength and with voxel size. At a field strength of 7 Tesla the occipital cortex can be sampled with high sensitivity in a short single session at high resolution aiding a detailed description of the visual areas.

◆ **Gaze-contingent human – computer interaction in view of the Midas-touch problem**
M Zoellner, H Koesling, K Essig¶ (CRC 673 Alignment in Communication [¶ Faculty of Technology], Bielefeld University, Germany; e-mail: mzoellne@techfak.uni-bielefeld.de)
Gaze-contingent user interfaces appear to be a viable alternative to manual mouse control in human-computer interaction. Eye movements, however, often occur involuntarily and fixations do not necessarily indicate an intention to interact with a particular element of a visual display. To address this Midas-touch problem, we investigated two methods of object/action selection using volitional eye movements, blinking versus fixating, and evaluated user satisfaction in a typing task. Results show significantly less errors for the blinking method while task completion times do not vary. However, participants rate the fixation method higher for its ease of use and as less tiring. In general, blinking appears more suited for sparse, non-continuous input (eg ticket machines), whereas fixating seems preferable for tasks requiring more rapid, continuous selections (eg virtual keyboards). We also demonstrate that the quality of the selection method does not rely on efficiency measures (eg error rate, response time) alone. User satisfaction must definitely be taken into account as well to ensure user-friendly interfaces.
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◆ **Search with naturalistic stimuli: using a low-level visual difference model to predict search efficiency**
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Visual search efficiency varies as a function of both target – distractor and distractor – distractor similarity (Duncan and Humphreys, 1989 *Psychological Review* **96** 433 – 458). When searching for targets in naturalistic scenes a reliable prediction of search efficiency is hard to achieve because it is difficult to quantify the degree of similarity between image elements. Using metrics which predict image differences reasonably well (visual difference predictors, or VDPs) (Parraga et al, 2005 *Vision Research* **45** 3145 – 3168), we can attempt to predict search performance in scenes containing natural objects. The current study examines observer's visual search efficiency for natural objects while manipulating factors such as the visual similarity between the target and scene and distractor heterogeneity. Observer reaction times were modelled with neural-networks, the inputs of which were the VDP's predictions of visual similarity. This resulted in reliable predictions of search efficiency. A post-hoc examination of the neural-net activation patterns enabled reconstruction of the original Duncan and Humphreys's prediction of search efficiency as a function of target – distractor and distractor – distractor similarity.
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◆ **Emotional information modulates the temporal dynamics of visual attention**
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Studies using dwell time paradigm show that identification of the first target impairs the subsequent target identification at short stimulus onset asynchronies (SOA). It has been argued that there is a reciprocal interaction between emotion and attention. Based on this prospective, study explores the dependence of attentional dwell time on emotional information. Two experiments were conducted using dwell time paradigm, in which two successive targets are presented at different locations with a variable SOA. In the first experiment, the first target was an emotional schematic face (happy/sad) and the second target was a digit (2/5). The order of stimulus presentation was reversed in the second experiment. There was a main effect of emotion and SOA in both the experiments. In the first experiment, digit identification (as second target) preceded by happy face was better than sad face. In second experiment, happy face was identified better than sad face (as a second target). The result show that attention dwell time is dependent on emotional content of the stimuli.

◆ **The effects of perceptual load on adaptation to task-irrelevant visual motion**
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When observers perform a word classification task in the centre of the visual field, adaptation to peripheral, irrelevant motion decreases as task demands increase (Rees et al, 1997 *Science* **278** 1616 – 1619). Here we investigate the effects of perceptual load on adaptation to task-irrelevant visual motion when the task-relevant and irrelevant features are colocalized. Observers viewed an adaptation stimulus comprising an expanding pattern of dots of four isoluminat colours. During adaptation, observers performed either a motion or a colour discrimination task under conditions of high or low perceptual load. The magnitude of motion aftereffects (MAE)

was measured for each task condition. The MAE was not modulated by task-relevant feature (colour/motion) or perceptual load. Our results suggest that the visual system cannot ignore task-irrelevant visual motion and that the attentional resources are allocated to that feature even under the condition of high perceptual load.
[Supported by EPSRC Grant: EP-D039916-1.]

◆ **Exploitation of common regularities in natural environment increases our contrast sensitivity for target detection**
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Spatiotemporal regularity, co-linearity and co-circularity are common regularities in visual environment. The prior knowledge of the probability structure of these regularities could be informative for efficient visual system. We explored to what degree different regularities influence our contrast sensitivity for target detection. The dynamic stimulus sequence comprised four short bars appearing consecutively towards the fovea, followed by a target bar with varying contrast; we systematically measured human contrast detection performance of the briefly presented target as the function of statistical structure and predictability of the stimulus sequence. The results illustrated that both contrast sensitivity and reaction time for target detection was facilitated by predictable spatiotemporal stimulus structure. Consistent with natural image analysis that co-linearity is a stronger statistical feature than co-circularity, the facilitation in target detection was more evident for predictable stimulus sequence following co-linear path than co-circular path. As response bias and uncertainty reduction could not fully account for our observation, it seems that our brain is aware of and uses these common regularities to interpret incoming visual signals.

◆ **Attentional capture by sound is task dependent**
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When performing a visuospatial discrimination task, an irrelevant auditory cue is able to capture visual spatial attention. Some studies have shown that attentional capture by an irrelevant auditory cue can be suppressed by endogenously focusing visual attention prior to the presentation of cue and target. In contrast, others have shown opposite results. We have investigated whether this discrepancy is due to the use of different types of visual tasks. In our study participants performed both a spatial and a symbol discrimination task. Prior to the presentation of the target an auditory noise burst was presented. When attention was unfocused, we observed attentional capture by the auditory cue in both the spatial and symbol discrimination task. When attention was focused in advance to a location in space, however, attentional capture occurred in the spatial discrimination task but not in the symbol discrimination task.

◆ **The owl cam: ego-centred assessment of visual behaviour in free-viewing barn owls**
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The owl cam—a wireless miniature camera mounted on the head of a barn owl (Ohayon et al, 2007 *Biological Cybernetics* **98** 115 – 132)—provides exciting perspectives towards visual behaviour in birds. Since eye movements are virtually absent in barn owls, the camera's view remains aligned with the owl's gaze, enabling precise analysis of observed objects. Objects of interest are fixed with respect to the image coordinate frame and can be recovered from a simple visual search task. Video images of subsequent recordings can then be analyzed with reference to the informational content of the fixated locus. Moreover, the owl cam provides information about idiosyncratic head movements, observed when owls attend to or follow static and moving visual targets. In addition to the description of the methodological approach, we present here results from a set of experiments under different visual conditions: visual search in reduced (experimental) and complex (natural) environments, the characteristics and possible role of head movements prior to target selection, and attentional mechanisms underlying visual localization.

BINOCULAR VISION AND SPATIAL LOCALISATION

◆ **Many human observers lack extrinsic local sign**

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'Local sign' as introduced by Lotze is an ambiguous term. One aspect is the topological structure of the visual field, another its projective and metrical structure, yet another one its relation to the external world. 'Internal local sign' refers to the topological structure. A likely mechanism was suggested by Helmholtz, it might even be developed in utero. Projective and metrical structure may be developed via eye movements, but are independent of optical projection. 'External local sign' refers to the association of retinal locations with the mutual directions of visual rays. Likely mechanisms were suggested by Berkeley, they depend on experience with the physical environment. The visual rays diverge from the anterior nodal point of the eye, subtending a conical sheaf with a semi top angle of about 90°. We have found that many observers ignore this divergence and commit systematic errors of up to 100° in estimates of parallelity of external objects. They apparently lack external local sign and refer orientation to the local visual ray.

◆ **Telestereoscopic viewing within prehension space: initial effects and short-term visual adaptation**

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Helmholtz designed the original telestereoscope in 1857. This optical device enhanced binocular disparity and required vergence to fuse on close objects, by mean of an arrangement of mirrors optically increasing interpupillary distance. A pre-exposure, exposure, post-exposure design was used to study the disturbance of egocentric depth perception of light emitting diodes induced by telestereoscopic viewing and subsequent visual adaptation for various distances. Egocentric distance to target was assessed by open-loop pointing. Cues for target distance during exposure period were restricted to oculomotor cues. Results showed a compression of visual space during exposition as required vergence was increased, but perceived distances were greater than distances specified by the vergence angle. After the telestereoscope was removed subjects exhibited a target overreaching aftereffect, obtained after a ten minutes exposure, in absence of any cognitive cue. Adaptation was found to be partial, consisting in a positive bias constant over all targets distances. Large inter-individual differences were observed. We hypothesize the distance aftereffect to be derived from changes in absolute level of tonic vergence.

◆ **Binocular summation of colour and luminance contrast targets with spatial and temporal interocular phase differences**

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Binocular sensitivity is higher for matched than mismatched colour and luminance targets, indicating the involvement of specialized binocular mechanisms. Mismatched contrast reversing binocular targets can be described equally well by a mismatch in temporal or spatial phase. The current experiment aimed to isolate binocular spatial and temporal mechanisms for colour and luminance. Binocular summation was measured for contrast reversing Gabor targets with interocular spatial and temporal quadrature phase differences and compared them to matched and mismatched binocular summation values. Stimulus contrast was modulated along the achromatic, L-M and S cone axes. Contrast thresholds for three subjects were determined using a two interval forced choice task. Binocular summation values (binocular sensitivity divided by monocular sensitivity) for colour and luminance quadrature stimuli were between those for matched and mismatched stimuli. Binocular summation was marginally higher for spatial quadrature than temporal quadrature. The results are consistent with binocular mechanisms that sum luminance and colour contrast across space and time with the output proportional to the degree of spatiotemporal binocular correlation.

◆ **Predicting distortions of perceived depth when a scene changes size**

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Cue combination rules have often been applied to the perception of surface shape but not to judgements of object location. Here, we used immersive virtual reality to explore the relationship between different cues to distance. Observers viewed a virtual scene and judged the change in

distance of an object presented in two intervals, where the scene changed in size between intervals (by a factor of between 0.25 and 4). Biases in this depth matching task could be predicted from a weighted combination of the 'physical' matched distance and a 'relative' matched distance (proportional to the expansion of the scene). We determined the predicted weights by measuring thresholds for detecting a change in object distance when there were only physical cues (vergence and absolute motion parallax) or only relative cues (physical distance remained constant). The data were well fit by the predictions, including when the scene layout was altered which changed the thresholds for each type of cue.

◆ **Vergence errors during short fixations between disparity vergence step responses**
J Hoormann, S Jainta, W Jaschinski (Institut für Arbeitsphysiologie, Dortmund, Germany; e-mail: hoormann@ifado.de)

While fixation disparity, the vergence error for stationary fusion stimuli, is conventionally tested in optometry with subjective nonius methods, only few studies described the inter-individual distribution of fixation disparity based on objective eye movement recordings. We measured objective fixation disparity in a group of nineteen subjects who performed a series of disparity-induced convergent step responses and corresponding backward steps towards baseline vergence of 6 deg. We analysed fixation disparity assumed when vergence had returned to baseline (1450 ms after disparity stimulus offset). In this condition of non-forced vergence, fixation disparity is free of adaptation to the actual vergence state. The resulting objective fixation disparity had a group mean (SD) of 3 (43) min of arc; test retest correlations of 0.9 confirm reliable individual differences between 85 min of arc underconvergent and 60 min of arc overconvergent. Concurrent subjective estimations were weakly correlated with and smaller than objective fixation disparity. This discrepancy may have implications on retinal correspondence and the size of Panum's fusion area.
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◆ **Does reaction time depend upon perceived or retinal stimulus size?**
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Size constancy is a property of the visual perceptual system that can keep relatively constant the perceived size of an object despite the size of the retinal image. The relationship between size and reaction time (RT) is well known: RT is faster in response to larger than smaller stimuli. The two studies reported here aimed to verify whether this effect depends upon retinal or perceived stimulus size. In Experiment 1, we found that the larger stimuli were responded to faster than the smaller ones even when they were positioned at a different distance so as to subtend the same retinal image. Clearly, this effect can be attributed to size constancy affecting RT. In Experiment 2, the role of size constancy cues was removed by using a pinhole for stimulus viewing. As a consequence, RT depended on stimulus retinal size. In sum, these results demonstrate that simple RT reflects perceived rather than retinal size.

◆ **Accommodation mediates the difference between objective and subjective measures of the convergence step response**
S Jainta, J Hoormann, W Jaschinski (Individual visual performance, Institut für Arbeitsphysiologie, Germany; e-mail: jainta@ifado.de)

Measuring vergence eye movements with dichoptic nonius lines (subjectively, psychophysically) leads usually to an overestimation of the vergence state. In a mirror-stereoscope, we estimated convergence with nonius lines flashed at 1000 ms after a disparity step-stimulus ($N = 6$); for comparison, we made objective recordings (Eyelink II). We presented two stimuli: a vertical line and a DOG-pattern (difference-of-Gaussians). For 180 min of arc vergence steps, the subjective measures revealed a larger final vergence response; for the vertical line this overestimation was 20 min of arc, while it was significantly smaller (12 min of arc) for the DOG. For 60 min of arc step-responses no overestimation was observed. Additionally, we measured accommodation (Handy-Ref): accommodation changed more for the DOG-pattern relative to the line-stimulus; this increase correlated with the decrease of subjective – objective difference in vergence ($r = -0.80$, $p = 0.05$). Both, no overestimation for small steps and a weaker one for the DOG-pattern, reflect lesser conflicting demand on the coupling of accommodation and vergence under forced-vergence; consequently, sensory compensation is reduced and subjective and objective measures tend to agree.
[Supported by DFG (Ja 747,4-1).]

◆ **Modulation of binocular integration by anisometropia in normal observers**
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The neurophysiological mechanisms underlying anisometropic amblyopia in humans remain unknown. To better understand the suppressive interaction under anisometropic conditions, pattern-reversal visual evoked potential (VEP) was examined in eight normal observers for whom anisometropia was induced by converging lenses (+3.25 D). Reversal checkerboardhe analysis of latency and amplitude show significant reduction of integration in anisometropic condition. These effects indicated significant binocular facilitation in normal condition and binocular suppression in anisometropic condition. Intriguingly, no significant difference was found between the amplitude of the binocular-refracted condition and the amplitude of the anisometropic condition. Overall, this study supports the notion that binocular deficits observed in anisometropic amblyopes are associated with a cortical suppression of the emmetropic eye over the ametropic eye.

◆ **Complexity and position effects on binocular rivalry**
M Bignotti, C Lentini, A Facchin, R P O'Shea¶, R Daini (Department of Psychology, Università degli Studi di Milano-Bicocca, Milan, Italy; ¶ Department of Psychology, University of Otago, Dunedin, New Zealand; e-mail: macroleon@hotmail.it)
During binocular rivalry, two incompatible images presented dichoptically spontaneously alternate in visual awareness. This phenomenon is mainly explained by bottom-up mechanisms. To investigate top–down processes, we manipulated stimulus complexity and spatial position, which should not modify binocular rivalry according to eye and V1 competition hypotheses. Twelve observers pressed buttons to track their experience of rivalry. In Experiment 1, we showed rival stimuli differing in complexity: simple (oriented gratings, coloured circles, shapes) and complex (grouped elements and objects). We found slower alternation rates for complex stimuli. In Experiment 2 we divided the stimuli along their vertical symmetry axes, then made one half of one stimulus the same as the corresponding half of the other, yielding rivalry in one visual field and fusion in the other. We found different rivalry rates in the left and right visual fields for simple stimuli but not for complex stimuli. The results of both experiments are consistent with a contribution of high-level mechanisms to binocular rivalry.

◆ **Visual space anisotropy for percieved size and distance**
O Toskovic, D Todorovic¶ (Department of Psychology, Faculty of Philosophy, Kosovska Mitrovica and Laboratory for Experimental Psychology, Faculty of Philosophy, Belgrade; ¶ Laboratory for Experimental Psychology, Faculty of Philosophy, Belgrade; e-mail: otoskovi@f.bg.ac.yu)
In previous research we showed that in darkness, physically shorter vertical distances are seen as equal to physically longer horizontal distances. The aim of the present research was to investigate whether, according to the size-distance invariance hypothesis, the same regularity can be found for size estimates. In the first experiment fourteen participants had the task to equalize the perceived distances of three stimuli in three directions (horizontal, tilted 45°, and vertical). In the second experiment sixteen participants had the task to estimate the perceived sizes of three stimuli in the same three directions. Participants in both experiments performed estimates while sitting on the floor, in a dark room, wearing special glasses in order to prevent the subjects' eye movements. For distance estimates we found such differences between three directions, that as the head tilts upwards, the perceived space is being elongated, which coincides with earlier results. On the contrary, for size estimates we found no difference between the three directions, which contradict to the size-distance invariance hypothesis.

◆ **Depth perception following monocular fusion of two images with a squinting eye**
S I Rychkova, J Ninio¶ (Eye Microsurgery Clinic of S Fyodorov, Irkutsk, Russia; ¶ Laboratoire de Physique Statistique, Ecole Normale Supérieure, Paris, France; e-mail: rych.sv@mail.ru)
Some strabismic patients with inconstant squint can fuse two images and experience lustre with a single eye, one image projecting on the fovea, the other projecting on a second sensitive zone of the retina (Rychkova and Malychev, 2007 *Perception* **36** Supplement, 71). Here, 13 stereograms were tested on thirty subjects able to fuse monocularly. Relief was often perceived, mostly on the fixated image. Camouflaged rectangles above or below background could not be detected, while their explicit counterparts were well separated in depth from the background. Camouflaged continuous surfaces (hemispheres, cylinders) were perceived as bumps or hollows, without detail. Slanted bars were mostly interpreted as frontoparallel near or remote bars. The direction of perceived depth was not clearly related to the disparity sign, and could vary with the presentation distance. The depth effects reported here might be the signature of some intermediate stage in

stereopsis, in which a coarse correspondence between two images is established, but the conversion of the disparity field into a depth map is still very crude.

◆ **Multimodal localization in medial posterior parietal cortex: fMRI and TMS evidence**
S Teng, D Whitney (Center for Mind and Brain/Department of Psychology, University of California, Davis, USA; e-mail: steng@ucdavis.edu)

Prior neuroimaging studies (Bushara et al, 1999 *Nature Neuroscience* **2** 759 – 766; Weeks et al, 1999 *Neuroscience Letters* **262** 155 – 158) have implicated posterior parietal cortex in spatial auditory and visual processing. We conducted two fMRI experiments investigating visual and auditory localization. In these experiments, subjects performed 5AFC visual and auditory localization tasks using flickering Gabor patches (visual) and pink-noise sound bursts (auditory). An analysis identifying the brain regions with the greatest spatial selectivity revealed a site in medial parietal cortex that exhibited the most spatially selective responses. To elucidate a possible causal role in perceptual localization, we repeated the experiment using auditory stimuli and rTMS at 1 Hz over that site. We found that sensitivity to the locations of auditory stimuli was reduced compared to control sites, as measured by hit rate and d' after stimulation. The stimulated site was medial to previously identified auditory localization regions in parietal cortex. Stimulating this region selectively disrupted localization performance, suggesting that it plays an active role in spatial localization tasks.
[Supported by Jason Fischer, Kelsey Laird.]

◆ **Interaction between orientation and background in visual acuity and stereoacuity**
A Torrents, J A Aznar-Casanova¶ (Department of Optic and Optometry, Universitat Politècnica de Catalunya, Spain; ¶ Department of Basic Psychology, Universitat de Barcelona, Spain; e-mail: torrents@oo.upc.edu)

Human perception is strongly influenced by the surrounding context in many visual tasks. The majority of previous studies have investigated visual acuity in two-dimensional visual space but little is known about the effect of context and cue integration in depth perception. We have designed several experiments to study the influence of stimulus orientation and background in 2-D and 3-D visual tasks. The experiments have been carried out by volunteer observers and they consisted of judging the alignment of two fine lines (Vernier lines) in frontoparallel plane (2-D) or in depth plane (3-D). To simulate space curvature, we use a concave or convex background grid (Bézier surfaces) behind the Vernier lines. The results revealed a significant interaction between 2-D or 3-D condition and background ($F_{3,33} = 7.8$; $p < 0.002$) in the observer's precision. Furthermore, we have found a significant interaction between 2-D or 3-D condition, orientation and background ($F_{6,66} = 3.431$; $p < 0.023$) in the observer's accuracy. In conclusion, we have found an orientation effect but also some influence of the background.

◆ **Stereo transparency in ambiguous stereograms that have potential matches leading to both transparency and non-transparency perceptions**
O Watanabe (Department of Computer Science and Systems Engineering, Muroran Institute of Technology, Japan; e-mail: watanabe@csse.muroran-it.ac.jp)

Transparency perception is one of important problems for the theory of early vision, because this phenomenon raises a fundamental issue of how visual information is represented and detected in the brain. Therefore, the transparency detection mechanism in human stereopsis has been studied intensively. Many experimental studies for stereo transparency used stereograms composed of two random dot patterns with different disparities. Here we investigate the perceptual property of stereo transparency in a specific stereogram generated by overlapping two 'identical' dot patterns in different depths. This stereogram has potential matches leading to a unitary (or non-transparent) surface perception as well as transparency perception, and which surface is perceived in this ambiguous stereogram would reflect the property of the transparency detection mechanism in human stereopsis. The result suggests that the depth perception in this stereogram is affected by the correlation between overlapping patterns within a small area the width of which was about 0.5 deg; this size was approximately equal to the receptive field sizes of neurons in early visual cortex.

CLINICAL ASPECTS

◆ **Acute local changes in cortical anatomy during visual activity**
A Hernowo, R Renken¶, F Cornelissen (Laboratorium for Experimental Ophthalmology, University Medical Center Groningen, The Netherlands; ¶ Neuroimaging Center, University of Groningen, The Netherlands; e-mail: a.hernowo@ohk.umcg.nl)

Studies have indicated the presence of volumetric changes both in glial cells and the extracellular space during neuronal activity (Sykova and Chvatal, 2000 *Neurochemistry International* **36** 397 – 409;

Dietzel et al, 1980 *Experimental Brain Research* **40** 432 – 439). In this study, we examined whether such volume changes at the cellular level are translated into changes that can be observed at the scale of the cerebral cortex. Two subsequent T1-weighted anatomical MRI scans were obtained in eight subjects. During the first scan, the subject was viewing a 6.5 min movie of natural scenery; during the second scan, the subject had his eyes closed (rest). The acquired cortical scans were subsequently analyzed using voxel-based morphometry. Comparing cortical anatomy during viewing vs rest revealed no detectable volumetric changes in the grey matter of visual cortex. However, such volumetric changes were observed in the anterior cingulate cortex and bilaterally in the insulas. These results suggest that acute volumetric changes at the cellular level related to neuronal activity can result in macroscopically detectable changes in cortical anatomy.

◆ **Prevalence and early detection of CVI in children born prematurely**

C J A Geldof, M Dik, M J de Vries (Royal Visio, National Foundation for the Visually Impaired and Blind, The Netherlands; e-mail: christiaangeldof@visio.org)

Cerebral visual impairment (CVI) represents visual impairments caused by damage of the visual system beyond the optic chiasm (Frebel, 2006 *British Journal of Visual Impairment* **24** 117 – 120). Relationships between damage in those visual processing areas (occipitoparietal and periventricular) and impaired scores on tests of visual perception are identified (Fazzi et al, 2004 *Brain Developemnt* **26** 506 – 512). Children born prematurely are known to be at risk for brain abnormalities in regions involved in visual processing (Inder et al, 2005 *Pediatrics* **115** 286 – 194). However, prevalence numbers of CVI among children born prematurely are still unknown. The aim of this research will be to establish a prevalence number and validate signal items for early detection of CVI. A cohort ex-preterm children will be fully screened at the age of 5 years using tests for lower (visual sensory) as well as higher (visual processing) visual functions. The data will be retrospectively correlated to the scores of signal items (indicating dorsal- and ventral processing and visual attention) from earlier follow-up ages.

◆ **Temporal aspects of grapheme-colour synaesthesia**

M J van der Smagt, S M Heringa, T C W Nijboer (Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands; e-mail: M.J.vanderSmagt@fss.uu.nl)

Several studies have demonstrated the synaesthetic colour experience to both facilitate and impede performance, depending on task demands. Colour perception is generally viewed as a relatively slow process. We thus investigated the influence of high temporal frequency signals on number recognition. A 'digital' '8' can be made a '5' by removing its upper-right and lower-left segments, while removing upper-left and lower-right segments creates a '2'. Presentation of the digit (eg '2') was rapidly interleaved with these excluded segments. Lack of temporal segmentation would thus result in a perceived '8'. Alternation rates varied from 10 to 200 Hz. Each 500 ms trial was subsequently masked with luminance noise for 100 ms. In a 2AFC paradigm, synaesthetes and controls judged whether a '2' or a '5' (or in separate blocks a '4' or '7' and '6' or '9') was presented. The distribution of correct responses was shifted slightly towards lower alternation rates for synaesthetes compared to controls. This hints at a lower temporal resolution for synaesthetes, possibly due to interfering (colour) percepts.

◆ **Accuracy of straylight measurement with the compensation comparison technique**

T J T P van den Berg, L Franssen, J E Coppens (Nethetherland Institute of Neuroscience, KNAW, The Netherlands; e-mail: t.j.vandenberg@nin.knaw.nl)

Optical quality of the human eye is limited, not only because of small-angle widening of the point-spread-function, but also because of large angle (>1 deg) light scattering, resulting in retinal straylight, perceived as glare, contrast loss, etc For quantitative measurement of straylight (defined as part of the functional psf) the psychophysical technique of 'compensation comparison' was developed, embedded in the C-Quant instrument. With a small adaptation, this psychophysical technique can also be used to measure the light scattering property of physical scattering samples, to be compared to their scattering measured physically. Using 8 scattering samples, ranging from 0.9 to 2.2 log(s) units [range as found in human eyes is 0.5 to 2.2 log(s)] absolute measurement precision of the C-Quant proved to be about 0.03 log units (SD). Single measurement repeated measures SD is about 0.07 log units, for measurements on these physical models as well as on the eye itself. The repeated measures SD corresponds closely to the predictions derived from maximum likelihood estimation.

COLOUR AND BRIGHTNESS

◆ **Age- and gender-dependent contrast sensitivity in C57BL6 mice**

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Mice have become a central research subject in neuroscience, especially due to the availability of mutants. Many tests have been developed to quantify the way a mutation affects brain function and behaviour. Vision often plays an important role in these tests. Should a mouse with a low visual acuity participate, it won't perform well and this suboptimal behaviour can be misinterpreted as a learning- or motor-problem. A good test of the visual acuity is required to rule out that acuity affects the behavioural test. We present a novel way to measure visual acuity in mice. By recording how the gain of the optokinetic reflex (a gaze stabilization reflex) decreases as sinegrating stimuli become harder to perceive, we do not only investigate behaviour at the threshold of perception but quantify the whole range of the visual system instead. Using this sensitve new approach we find differences in visual acuity between male and female C57BL6 mice as well as age related changes in acuity that could not be detected with earlier tests.

◆ **Perceptual video quality assessment by means of colour perception and short term memory behaviour**

C C Oprea, R M Udrea, I Pirnog, D Vizireanu (Faculty of Electronics, Telecommunications and Information Technology, University Politehnica of Bucharest, Romania; e-mail: cristina@comm.pub.ro)

Human perceptual experience can be characterized with far better results following a cognitive style analysis. This work proposes a novel approach in the subjective video quality estimation, trying to incorporate into a video quality metric the colourperception mechanism and the short term memory behaviour. Video dynamics is also a very important human factor in video quality assessment and the metric includes a content dynamism analysis stage. Multimedia content can be more or less appealing for human subjects, depending on the human perceptual systems ability to analyze, synthesize and assimilate visual stimuli. Beside the visual system, which is also responsible for the colourperception, in the assessment process there is also involved a short memory system which retains impressions about precedent video frames and projects a part of those impressions upon the current frame. We integrated both proposed methods into a more complex full-reference video quality metric. The result is an estimate for the subjective quality level. The metric performances proved to be better in several types of common distortions.

◆ **Neural basis of categorical perception of colour**

D Högl, A Franklin¶, M Fahle (Centre for Cognitive Science, Department of Human Neurobiology, University of Bremen, Germany; ¶ Department of Psychology, University of Surrey, UK; e-mail: dhoegl@uni-bremen.de)

Categorical perception (CP) of colour makes discrimination easier, more accurate, or faster for two colours that cross a category boundary than two colours from within the same category, even when physical differences are equated. We examined the neural basis of CP across the blue–green category boundary using behavioural and functional MR methods. Participants performed a variant of the n-back working memory task and judged whether a briefly presented stimulus was identical (same) or different to the preceding one. Blocks of stimuli contained either within- or between-category stimulus change while brain activation was recorded using functional MRI. Consistent with previous behavioural findings on CP, between-category discrimination was faster and more accurate than within-category discrimination. Neuroimaging data revealed correlations of the effect, with slight differences in activation for within- and between-category blocks, primarily in language-specific areas. The findings suggest that categorical perception of colour may indeed involve verbal labelling.

◆ **Deep adaptation under motion induced blindness conditions**

F Caetta, A Gorea¶ (Paris Descartes University, Paris, France; ¶ Paris Descartes University & CNRS, Paris, France; e-mail: f.caetta@gmail.com)

Low-level (eg Troxler-type) accounts of motion-induced blindness (MIB) (ie the transient phenomenal disappearance of highly visible stimuli when superimposed on a moving background) have been rejected based on a number of incompatible observations. Still, the adaptation dynamics during MIB has not been tested directly. We assessed the brightness of the MIB target over a 1 min adaptation period using a matching technique under moving, static and absent background conditions. The first two entailed an about equally abrupt brightness drop of $\sim$73% and 70% to a steady state (excluding the target disappearance lapses) within $\sim$5 s, significantly faster than under the absent background condition (67% in $\sim$13 s). The detection thresholds of this same target for the three background configurations (during target's visible phases) were

equal after 2 s adaptation and reached after ~10 s a plateau ~1.7 times higher for the moving than for the remaining two backgrounds. Taken together, the two experiments strongly suggest that a deeper adaptation state is at least one of the main causes of MIB.

◆ **Verbal information modulates the colour space in working memory**
T Ikeda, N Osaka (Department of Psychology, Graduate School of Letters, Kyoto University, Japan; e-mail: ikeda.psy@gmail.com)

Many colour discrimination studies indicate that the colour memory is linked to colour category and not based on the uniform colour space. Categorical perception is shown when cross-category discrimination is easier than equivalent within-category discrimination, and several studies have suggested that this is mediated by verbal information. However, the influence of verbal information on broader range of colour including focal colour is unclear. We examined the colour space represented in working memory and the influence of verbal information on category. The stimuli were varied at even intervals only in hue (green – blue, including both focal colours in Japanese) according to the CIELUV colour space. Memory discrimination was measured using a successive matching task with 5 s ISI. In addition, we introduced three types of concurrent interference task; none, verbal, and visual. With none and visual interference, recalled colour shifted toward its own focal colour. However, with verbal interference, the shift was not observed. The result implies that verbal information may change the uniform colour space into the categorical space.
[Supported by KAKENHI from JSPS.]

◆ **Chromatic global motion processing: the effect of colour polarity**
J Martinovic, A Ruppertsberg¶, S Malek§, M Bertamini, S Wuerger (School of Psychology, University of Liverpool, UK; ¶ Department of Optometry, University of Bradford, UK; § Department of Psychology, University of Halle-Wittenberg, Germany; e-mail: jasnam@liv.ac.uk)

Global motion integration mechanisms can utilise both parvocellular and koniocellular chromatic information. But are these mechanisms selective to colour polarity? To test this, we employed isoluminant random-dot kinematograms (RDKs) that contain a single colour or two different colours. Single-colour RDKs consisted of local motion signals with either a positive or a negative S cone or L-M component, while in the two-colour RDKs half the dots had a positive and the other half a negative S cone or L-M component. We measured colour contrast thresholds for these two types of RDKs for three different dot densities (50, 100, 200 dots). We report two main findings: (i) the dependence on dot density is the same for all colours (+S, −S, +LM, −LM), (ii) thresholds for single and two-colour RDKs did not differ significantly. This is consistent with the hypothesis that mechanisms underlying global motion integration do not utilise the polarity (sign) of the colour contrast, relying instead on unsigned contrast when integrating across local chromatic signals.

◆ **What do colour-blind people really see?**
M Hogervorst, J Alferdinck (Human Interfaces, TNO Human Factors, The Netherlands; e-mail: maarten.hogervorst@tno.nl)

Various models have been proposed (eg Walraven and Alferdinck, 1997; Brettel et al, 1997 *Journal of the Optical Society of America A* **14** 2647 – 2655) to model reduced colour vision by colour-blind people. It is clear that colour-blind people cannot distinguish certain object colours that appear different to people without colour-blindness: such objects are depicted by the colour blindness visualization models in the same colour. However, which colours are perceived is not clear. Here, we propose a model that uses the colour statistics of the environment along with the remaining colour information to estimate the underlying object colours. For different types of colour-blindness we show that the underlying colours can be estimated quite well. Likewise, colour-blind people may—consciously or unconsciously—use the colour statistics to obtain a good estimate of the underlying object colour. In a similar way, colour statistics may be used to promote colour constancy.

◆ **Effects of surround similarity on brightness and lightness matches performed with double-decrement and double-increment stimuli**
M E Rudd (Howard Hughes Medical Institute, University of Washington, USA; e-mail: mrudd@u.washington.edu)

Brightness matches performed with double-decrement stimuli exhibit both contrast and assimilation effects over different ranges of the surround luminance (Rudd and Zemach, 2007 *Journal of the Optical Society of America A* **24** 2134 – 2156). Here I show that these opposite-sign induction effects are part of a larger pattern in which brightness depends on the degree of similarity of the target and match surrounds: a new result. Specifically, target brightness is proportional to

the squared difference in either the (i) luminances (in log units), or (ii) widths, of the target and match surrounds. The surround similarity effect was also observed in a lightness matching experiment involving double-increment stimuli when the observer was instructed to think of the target and match stimuli as surfaces belonging to a single global illumination framework. The effect was absent when the observer was instructed to think of the target and match stimuli as belonging to separate local frameworks. These results have implications both for theories of lightness perception based on grouping principles and theories based on the principle of edge integration.

◆ **Chromatic diversity of art paintings under light-emitting diodes**
P D Pinto, J M M Linhares, S M C Nascimento (Department of Physics, University of Minho, Portugal; e-mail: ppinto@fisica.uminho.pt)

The type of illumination used in museums influences critically the visual impression of art works because their appearance is determined by the spectral profile and intensity of the illumination. The aim of this work was to estimate computationally the chromatic diversity perceived by normal observers when viewing paintings under two types of white light-emitting diodes (LED). Hyperspectral images of eleven oil paintings were collected at the museum and the chromatic diversity under illuminant D65 and two white LED lights (LXHL-W02 and LXHL-W03 from the Luxeon® with CCT of 5500 K and 3300 K, respectively) was estimated by computing the representation of the paintings in the CIELAB colourvolume, segmented it into unitary cubes, and by counting the number of non-empty unitary cubes. It was found that chromatic diversity obtained with LXHL-W02 and LXHL-W03 was, on average, about 8% higher and 15% lower than with illuminant D65, respectively. The result suggests that LED light sources with high CCT may be suitable for museum illumination.

◆ **Orientation-specific contextual modulation of the fMRI BOLD response to luminance and chromatic gratings in human visual cortex**
J S Mcdonald, K J Seymour, M M Schira¶, B Spehar¶, C W G Clifford (School of Psychology, University of Sydney, Australia; ¶ School of Psychology, University of New South Wales, Australia; e-mail: scottM@psych.usyd.edu.au)

We used fMRI to investigate orientation-specific centre–surround effects in visual cortex. The brain of four subjects were scanned at 3T while performing a demanding dimming task at fixation. Stimuli consisted of a 'test' annulus and an 'inducing' region. Five stimulus blocks were presented: test only; inducer only; parallel test and inducer; orthogonal test and inducer; and blank (fixation only). In Experiment 1 the test annulus contained a luminance-modulated grating; in Experiment 2 an isoluminant red–green grating. Each 16-second block contained 16 different stimulus orientations. Parallel and orthogonal blocks differed in the relative orientation of test and inducer, but not the distribution of absolute orientations. Percent-signal change analysis indicated significantly lower BOLD activation in response to gratings with parallel versus orthogonal surrounds across the early retinotopic areas of visual cortex. This difference increased up the visual hierarchy for luminance stimuli, but not chromatic stimuli. The data are consistent with orientation-specific lateral interactions beyond V1 that are selective for the colour/luminance composition of the surround.
[Supported by grants to CWGC from the Australian Research Council and The University of Sydney.]

◆ **Hue discrimination and post-receptoral mechanisms**
T Hansen, K R Gegenfurtner (Department of Psychology, University of Giessen, Germany; e-mail: Thorsten.Hansen@psychol.uni-giessen.de)

Hue discrimination has been traditionally investigated by measuring detectable differences between wavelengths. Here we investigate hue discrimination in a physiologically meaningful colour space. Discrimination thresholds were measured for thirty-two observers along the cardinal axes and along intermediate axes in the isoluminant plane of the DKL colour space. Hue discrimination was best along the cardinal axes and worse along intermediate axes, in particular for magenta. Measuring discrimination thresholds at 36 chromatic directions spanning the full colour circle revealed that the thresholds at the cardinal and intermediate axes defined minima and maxima of a smooth discrimination curve. An exception was the quadrant with reddish/orange/yellow colours were discrimination was generally good. Interestingly, the colours of various edible fruits lie in this quadrant, which is also the quadrant with the largest number of basic colour categories. The results suggest that chromatic discrimination is determined both by low-level neuronal preferences for the cardinal directions, and more high-level factors such as the ecological validity of particular colours and the perceptual distance between colour categories.

◆ **Gradient-induced depth and glow: similar processes?**
U Leonards, C P Benton, N E Scott-Samuel (Department of Experimental Psychology, University of Bristol, UK; e-mail: ute.leonards@bristol.ac.uk)
Luminance gradients can encode both depth and luminosity, but the relationship between these features remains unclear. We used the glare effect stimulus (Zavagno and Caputo, 2001 *Perception* **30** 209 – 222) to address this issue: This stimulus consists of four orthogonal luminance gradient inducers (I), abutting a central target square (T) to form a cross, and four background corner squares (B). Keeping T and I constant at three different levels, B was varied between maximum luminance (same as T maximum value of I) and minimum luminance (same as minimum value of I). In separate experiments, the same participants judged T luminosity (as either reflecting or self-luminous) or depth of stimuli (Is and T in front or behind B), using a method of constants. Both luminosity and depth thresholds showed linear relationships between background and inducers, in agreement with earlier findings for luminosity. However, luminosity thresholds were consistently lower than depth thresholds, suggesting that separate mechanisms underlie the luminosity and depth perception induced by luminance gradients.

EYE, HAND AND BODY MOVEMENTS

◆ **'Does my step look big in this?'**
A Vale, J Buckley¶, D Whittaker, D Elliott (Vision Science [¶ School of Engineering], University of Bradford, UK; e-mail: a.vale@bradford.ac.uk)
We investigated whether the horizontal vertical illusion makes a step riser look bigger, thereby leading to subjects increasing their toe elevation when stepping up. From two walking step lengths away, twenty-one subjects (age 28.2±8) were asked to judge the height of a raised surface covered with two configurations of the horizontal – vertical illusion [horizontal grating on front surface, vertical grating on top (H – V); and reversed (V – H)]. Subjects then negotiated the raised surface under binocular and monocular conditions. Toe trajectories were analysed using an 8 camera Vicon motion analysis system. Subjects perceived step height to be larger in the V – H configuration (mean increase binocular 4.3±10 mm, monocular 6.1±9.7 mm, $p < 0.05$) and in response toe elevation was greater for V – H, compared to H – V under both visual conditions (binocular 6.9±8.5mm, monocular 5.4±7.5mm, $p < 0.01$). These findings indicate that not only does the step riser look big in the V – H illusion but their perception drove subsequent toe clearance of the step riser. Perception and action appeared linked.

◆ **Oculomotor distractor effect without retinotectal inputs**
A Bompas, P Sumner (School of Psychology, Cardiff University, UK; e-mail: bompasa@cardiff.ac.uk)
The retinotectal pathway to the superior colliculus has been held responsible for evoking reflexive oculomotor plans. Consistent with this, stimuli invisible to this pathway (S-cone stimuli) have been reported not to cause the oculomotor distractor effect (Sumner et al, 2002 *Current Biology* **12** 1312 – 1316). However, such stimuli do produce other supposedly low level oculomotor phenomena, such as express saccades and gap effect, and automatically capture attention. Here we investigated the factors that may lead to this apparent discrepancy in chromatically-driven oculomotor effects. We obtained a reliable S-cone distractor effect by making our distractors appear distinct from the background of spatio-temporal luminance noise, as new objects. We also tested the hypothesis that S-cone stimuli, processed more slowly than other signals, would benefit from a head-start to compete with luminance-defined targets. Interestingly, presenting distractors 40 ms before the targets reduced the effect for both luminance and S-cone signals. Our results show that the distractor effect does not rely exclusively on the retinotectal route and suggest the involvement of higher level mechanisms.
[Supported by the BBSRC.]

◆ **Differential gaze behaviour towards sexually preferred and non-preferred body images**
C L Hall, T Hogue, K Guo (Department of Psychology, University of Lincoln, UK; e-mail: chhall@lincoln.ac.uk)
The pattern of our eye movements associated with image exploration is sensitive indices of our attention, motivation, interest, and preference. To examine whether a person's gaze pattern to body images can reflect his/her sexual preference, we compared eye scanning patterns of young heterosexual male and female participants while viewing photos of clothed male and female people aged from birth to 60-year-olds. Our analysis showed that male participants demonstrated similar gaze pattern to non-age-matched body pictures regardless of gender; age-matched female pictures, however, elicited distinctive gaze pattern with chest and waist/hip region attracting more fixations, longer viewing time and more likely to be inspected at early stage of exploration.

Female participants, interestingly, directed more attention at the upper body on female images in comparison to male images, but this difference was not age-specific. The results suggest that the difference in cognitive processing of preferred and non-preferred body images can be manifested in eye scanning patterns. Eye tracking, hence, holds promise as a potential sensitive measure for sexual preference particularly in males.

◆ **A negative test of the sensorimotor dissociation with saccades perturbed by close to threshold distractors**

C Tandonnet, P Cardoso-Leite, D Rider, A Gorea (Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS, Paris, France;
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In a dual task participants first made a saccade toward a suprathreshold target presented on the extinction of the fixation point and then decided whether a close to threshold distractor ($d' \sim 2$) displayed on 50% of the trials was present/absent. Distractors were displayed for 17 – 80 ms at $\pm 5^\circ$ from fixation on the horizontal meridian. Targets were presented at 10° eccentricity either on the same meridian and side as the distractor (Experiment 1) or on the vertical upper meridian (Experiment 2). Distractor – target stimulus onset asynchrony (SOA) was -80 ms or 0 ms (ie distractor first or concurrent with target; Experiment 1) or -100 ms (Experiment 2). In Experiment 1, saccade endpoints were shifted toward the distractor ('global effect') only on trials entailing perceptual Hits for both SOAs. In Experiment 2 the curvature of saccades (but not their endpoints) was biased toward the distractor, once again only on Hit trials (suggesting an excitatory rather than inhibitory perturbation). The data provide further evidence that the motor program is unaffected by 'invisible' (missed) stimuli.

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◆ **The shape and development of oculomotor inhibition revealed by saccade trajectory modulation**

E Mcsorley (Department of Psychology, University of Reading, UK;
e-mail: e.mcsorley@reading.ac.uk)

Selecting a stimulus as the target for a goal-directed movement involves inhibiting other competing possible responses. The state of inhibition of the competing motor response to the distractor at the time of saccade initiation can be seen by examining oculomotor trajectories. Individual saccades may initially deviate either toward or away from a distractor as a function of saccade latency with shorter-latency saccades deviating toward and longer-latency saccades progressively deviating away. Here we extend this by investigating the development of oculomotor inhibition of distractors presented at different spatial locations. Targets were presented with distractors presented at various locations: 10, 20, 30, 60 and 120 angular degrees from the target. The deviation of saccade trajectories arising from the presence of distractors was measured. A fixation gap paradigm was used to manipulate latency independently of the influence of competing distractors. Shorter-latency saccades deviated toward distractors and longer-latency saccades deviated away from distractors at all spatial locations. However, differences were found in the time course of this shift in saccade trajectory deviation.

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◆ **Delayed control of fixation durations: experiment and model**

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Across different tasks, eye movements are used to investigate cognitive processes. The direct control hypothesis assumes that fixation durations reflect processing demands at the fixation location. In a gaze-contingent paradigm, we studied the adjustment of fixation durations to a stepwise change in processing difficulty. Participants searched for a target in an array of symbols. Except for the fixated symbol, all symbols were masked by Xs. Participants scanned the array from left to right; thereby, successively unmasking each symbol. In the middle of a trial, we manipulated processing demands by altering the similarity between the target and distractors. After increasing processing difficulty, we observed an immediate but dispropotionate prolongation of fixation durations. After decreasing processing difficulty, fixation durations remained unchanged during the first fixation. In both conditions, fixation durations on the second symbol matched the new processing needs. Our results show that fixation durations are only coarsely affected by the current fixation location. We suggest a model with indirect and temporally delayed control to reproduce the fixation duration pattern.

◆ **Reading the mind's eye for individual fixations in natural viewing behaviour**
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Visual fixations are important events that reveal information about perception and cognition. Moreover, they can be considered naturally occurring and internally triggered events. Given their relevance for perception and cognition, it is desirable to incorporate them into the design of neuroimaging studies that aim to study cognitive processing in naturalistic conditions. Here, we test whether fixations can be used as event in fMRI, despite that traditional event-related designs require events that are well separated in time. We recorded both gaze behaviour and brain activity while subjects were viewing stimuli composed of both house and face objects (3/3, circularly arranged), under three task conditions (look at houses, look at faces, look at both). Using multivariate analysis, we trained on regional imaging data (house and face selective areas obtained from a localiser experiment). Within-subject testing resulted in classification performance that is well above chance for both task and the inspected object type. Our findings indicate that we can extract meaningful cortical activation patterns using fixations as events.
[Supported by the EU FP6 NEST-Pathfinder PERCEPT- 043261.]

◆ **Differential eye scanning patterns for exploring faces of different species**
K Guo, D Tunnicliffe (Department of Psychology, University of Lincoln, UK; e-mail: kguo@lincoln.ac.uk)
Human behavioural, neuropsychological, and neurophysiological studies have reported differences in perceptual and neural processing of faces of different species (even for those faces sharing similar facial configurations), implying crucial contribution of expertise effect in face processing. Could these differences be manifested in our eye scanning patterns while extracting salient facial information? Here we systematically compared non-pets owners' gaze patterns for exploring faces of humans, monkeys, dogs, and cats with neural facial expressions. Although different face categories induced similar pattern of fixation distribution across key local facial features (ie the eye region attracted the highest proportion of fixations followed by the nose and then mouth regions), the quantitative distribution of fixations within each facial feature and associated scanpath were species-dependent. Specifically, the human eyes tended to attract fewer fixations and were less likely to be inspected at the earliest stage of exploration. Our observation suggests that the eye scanning pattern associated with face exploration is influenced by observer's expertise/experience, but not rigidly constrained by it.

◆ **Dissociating visual and interoceptive rotation during path integration**
L Tcheang, H Bülthoff, N Burgess¶ (Bülthoff Department, Max Planck Institute for Biological Cybernetics, Germany; ¶ Institute of Cognitive Neuroscience, University College London, UK; e-mail: ltcheang@gmail.com)
Path integration in darkness is classically thought to be accomplished using interoceptive information. Here we examine the contribution of visual input to the accumulation of rotational information during path integration of a return to origin task, in a fully immersive virtual environment. Nine paths that varied in turn angle and number of turns were used. Path length was approximately constant across trials. During walking the outward legs of a path, a mismatch was introduced between actual rotation and the perceived rotation of a rich virtual environment, which could be increased or decreased. The return leg of the path was performed without vision. The mismatch trials were interleaved with two control conditions; one where vision matched interoceptive information exactly on the outward paths, and one without any visual input. Sixteen subjects (balanced across gender) were tested and a mixed ANOVA analysis showed a significant effect of the visual manipulation. Return directions were consistent with the direction of the visual manipulation suggesting a strong visual component to this 'path integration' task.
[Thanks to Naima Laharnar for help with data collection.]

◆ **Brain activity during manipulating task with different levels of difficulty**
M Ohmi, M Kondo (Department of Psychoinformatics, Kanazawa Institute of Technology, Japan; e-mail: ohmi@his.kanazawa-it.ac.jp)
The performance of manipulating task depends on levels of difficulty of the task. We measured activity on the frontal lobe by the near infrared spectrometer (NIRS) to investigate brain mechanism underlying the manipulating task. Levels of difficulty of the task were managed by instructing participants to clip out drawings with various complexities and to use dominant or non-dominant hand. Averaged brain activity of ten undergraduate participants was higher when they cut more complex shapes. The result showed brain activity on the frontal lobe area

enhanced during more difficult manipulating task as we expected. However, brain activity was not significantly higher when participants used non dominant hand. It is inconsistent with implicit expectation that brain on the frontal lobe area becomes more active during unused manipulating task. This inconsistency could be because NIRS can only measure brain activities of cerebral cortex at limited depth from the skull. Future research with using another non-invasive system should be necessary.

◆ **Neural correlates of audiovisual biological motion and speech processing**
S Wuerger, G Meyer, R Rutschmann¶, M Greenlee¶ (School of Psychology, University of Liverpool, UK; ¶ Department of Psychology, University of Regensburg, Germany; e-mail: s.m.wuerger@liverpool.ac.uk)

Behavioural data suggest that the processing of audiovisual speech and biological motion signals may be subserved by specialised processing centres. We conducted an fMRI study to investigate which areas are involved in the processing of auditory (A), visual (V), and audiovisual (AV) speech, biological motion and scrambled (meaningless) signals. In a localiser experiment we identified areas that responded to unimodal (A,V) and bimodal (AV) stimuli. Conjunction analysis showed that the pSTS and premotor areas bilaterally responded strongly to speech and biomotion but less to scrambled motion signals. Audiovisual interactions (AV $>$ A $+$ V were seen in parietal/occipital sulcus, the superior frontal sulcus and the anterior STS. Subsequently, a region-of-interest analysis was performed using consistent and inconsistent audiovisual stimuli. We find significantly increased activity in the STS for inconsistent AV stimuli than for matching auditory and visual signals.

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◆ **Oculomotor scanning behaviour in visual feature search with graded target – distractor-similarity**
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We conducted a visual feature search experiment in which we varied the target – distractor similarity in four steps, the number of items (4, 6, and 8), and the presence of the target. By recording eye movements, we analysed scan paths particularly with regard to re-fixations and re-inspections, fixation durations, the number, and the length of saccades. Our results show more re-fixations and re-inspections in trials with higher target – distractor similarity. Re-fixations were more frequent in target-present trials, whereas for re-inspections the contrary occurred. Furthermore, we found that the fixation duration as well as the number and length of saccades depended on the target – distractor similarity. The pattern of re-fixations and re-inspections suggests that recurrent item visits are more a sign of uncertainty in perceptually identifying the target than of amnesic search. The results on fixation durations, number, and length of saccades support theories that assume an attentional focus variable in size according to task demands, and a variable attentional dwell time. Moreover, they generalize previous findings from conjunction search to the feature search realm.

◆ **Low-level sustained accommodative/vergence loads, eyestrain and trapezius muscle activity**
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The relationship between oculomotor effort, eyestrain and neck and shoulder activation during strenuous near work remain unclear. Different levels of oculomotor load were accordingly induced while the ensuing trapezius muscle activity was measured with bipolar surface electromyography (EMG). Symptom free volunteers and asthenopic patients were instructed to focus on a high-contrast fixation target placed either close to the age-appropriate near point of accommodation or at distance. Optical lenses in combination with different target distances were used to elicit contraction/relaxation of the ciliary and/or extraocular muscles in four different stimulus conditions. The levels of load actually obtained and the resulting oculomotor functioning, trapezius and orbicularis oculi EMG levels were quantified in parallel. The results show that five minutes sustained accommodation/vergence, aimed at overcoming a -3.5 D blurred high-contrast target presented at near, was strongly coupled with a bilateral increase in trapezius muscle activity. It is concluded that sustained accommodation/vergence at near might represent a risk factor for trapezius muscle myalgia and particularly so in the presence of an uncorrected visual error.

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MOTION PERCEPTION AND TEMPORAL ISSUES

◆ **The freezing rotation illusion and relative motion**

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A stimulus rotating at constant angular velocity (V_c) in the centre of a background pattern, rotating concentrically in the same direction with a sinusoidally changing angular velocity (V_b), is perceived as stationary ('frozen'), but not when the background moves in opposite direction (http://www.vertigocenter.ch/duersteler/motionIllusion/index.htm). We investigated the relevance of relative velocity (between centre and background) for this illusion. V_c and V_b values were 0, 5, 10 or 15, and 0, 15, 30, or 45 deg^{-1} (constant velocities), respectively. When background and centre moved in the same direction, the freezing effect happened at $V_c = 5$ deg s^{-1} irrespective of V_b. Higher V_c values were underestimated by a fixed amount, also independent of V_b. With stimuli moving in opposite directions V_c was overestimated with the same fixed amount, also irrespective of V_b. This suggests that relative motion between centre and background generates a fixed noise factor, which is substracted from or added to V_c to yield perceived centre velocity, irrespective of the amount of relative motion.

◆ **Patterns of fMRI activity representing perceived direction in apparent motion**

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The so-called 'motion quartet' is an ambiguous apparent-motion stimulus that can be seen either in vertical or horizontal motion. When brain activity is measured with fMRI during switches between subjective states, a number of areas spanning multiple levels of the cortical hierarchy show switch-related activity. The question remains at which of those levels the content of our visual experience is represented, since other factors like attention- and motor-related processes are confounded with pure percept-related activity. In our study, we employed a multivariate approach to fMRI data analysis to classify the perceptual state of the participants from activity patterns in occipital, parietal, and frontal regions. Decoding performance was highest in early visual cortex (~80%, 50% chance level) and also significant in hMT/V5+ (~60%). In addition, some parietal and frontal regions showed above-chance decoding performance. In accordance with previous results from our group, we suggest that high decoding performance in early areas is due to distinct retinotopic patterns of activity produced by the different perceptual interpretations of apparent motion.

◆ **Facilitation of action recognition by motor programs is critically dependent on timing**

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The recognition of body movements might depend on internal simulation of the observed motor behaviour. Some theories have postulated the existence of internal dynamic models that simulate motor behaviour in synchrony with the visual stimulus. This predicts a facilitation of action recognition if the dynamic motor program is in synchrony with the visual stimulus and an impairment of recognition when they are asynchronous. This hypothesis was tested exploiting real-time motion capture within a VR setup, presenting point-light figures executing the same actions as the observers. Visual stimuli were either synchronous with the action of the observer (delay < 40 ms), or presented with time delays (280 and 550 ms). Detection rates were determined in a 2AFC task, presenting the target action embedded in a scrambled mask or the mask alone. Consistent with the hypothesis, we found a significant increase of the detection rate if observers performed the action in synchrony with the visual stimulus. If the visual stimulus was delayed relative to the executed action, instead detection performance was impaired.

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◆ **Ocular following response to sampled motion**

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Nowadays it is common practice in visual experiments to use computer generated stimuli presented on a monitor. We find that the ocular following response (OFR) to a moving random-dot pattern strongly depends on the frame rate of the presented stimulus in the range of 80 to 160 Hz. The strength of the OFR increases approximately linearly with the frame rate, without evidence for saturation. We conclude that the temporal resolution of the presented stimuli might be more

important to oculomotor and motion perception studies than widely assumed. The dependence of OFR strength on frame rate is significantly reduced when using a double-frame stimulus. Our results fit well to motion detection models based on spatiotemporally tuned receptive fields.

◆ **Dissociating the flash-lag effect from the drifting-Gabor displacement effect**
D Linares, A O Holcombe (School of Psychology, University of Sydney, Australia; e-mail: danilinares@gmail.com)

The two most frequently studied effects of motion on perceived position are the flash-lag and the drifting-Gabor displacement effects. To investigate whether these illusions reflect a common underlying mechanism we measured them using similar stimuli. (i) Flash-lag condition: A Gabor patch moved directly towards or away from fixation. Subjects reported its position relative to static landmarks when the fixation point changed color. When the colour change occurred at the time of alignment between the patch and the landmarks, subjects perceived the patch to be offset in the direction of motion. This effect was bigger for motion towards the fovea. (ii) Drifting Gabor condition: Subjects reported the position of the Gabor patch relative to the landmarks when the patch remained stationary but the internal grating drifted at identical speeds as in the flash-lag condition. Subjects perceived a displacement in the direction of motion that was bigger for motion away from the fovea. This asymmetry is opposite to that of the flash-lag effect, suggesting that the two illusions tap different mechanisms.
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◆ **A predictive model for the accordion grating illusion**
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The accordion grating (AG) consists of a vertical square-wave grating composed of black and white lines. The illusory effect is induced by self-motion along the line of sight. Observers report a non-rigid expansion or contraction of the middle parts of the pattern in a direction perpendicular to the stripes, for head motion toward and away from the pattern, respectively. We propose here a simple model based on an underlying interaction between motion signals originating from two different motion-processing mechanisms: contour units and end-stopped units. The model makes several predictions that were successfully tested by psychophysical experiments. Moreover, other possible explanations of the illusion, such as the influence of the cortical-magnification factor and the effects of afterimages are discussed and ruled out. Finally, the time course of the propagation of the signals from end-stopped units is demonstrated by the breakdown of the illusion with slow dynamic presentation of the stimulus.

◆ **Development of spatiotemporal receptive field properties of neurons in the rat primary visual cortex**
F Prevost, F Lepore, J P Guillemot¶ (Centre de Recherche en Neuropsychologie et Cognition, Université de Montréal, Canada; ¶ Département de Kinanthropologie, Université du Québec, Montréal, Canada; e-mail: francois.prevost@umontreal.ca)

Although the rat is commonly used for studying the visual system, the development of spatiotemporal receptive field properties of neurons in the primary visual cortex remains relatively unknown. Thus, extracellular single cell recordings were performed in the adult (> 60 days) and 15 – 30 days old Long Evans rat. The response rate of neurons was recorded under anaesthesia. The optimal temporal frequencies significantly differ ($p < 0.01$) between the 27 – 30 days-old rat ($\mu = 2.7$ cycles s^{-1}) and the adult rat ($\mu = 3.5$ cycles s^{-1}), as well as the temporal resolution ($\mu = 7.9$ vs 11.8 cycles s^{-1}, $p < 0.001$) and contrast thresholds ($\mu = 37$ vs 23%, $p < 0.01$). However, the average optimal spatial frequency, spatial resolution and spatial bandwidth are similar for all ages. These results suggest that, soon after eyelid opening, spatial properties of receptive fields in the primary visual cortex are similar to those observed in the adult rat, whereas temporal properties and contrast thresholds evolve during the first post-natal month.

◆ **Errors in direction of motion at short durations depend on stimulus size and eccentricity**
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Human ability to identify the direction of motion of a small, brief visual stimulus that contains fine features is dramatically impaired if static coarser features are added to it. The effect is to reverse the perceived direction of motion. Here we show that the reversal in direction disappears if the stimulus is reduced in size from 2.8 deg to 0.35 deg We also show that if the stimulus is presented within an annular window with small radius (1 deg), errors almost disappear but they

return if the radius is made bigger than 2 deg The errors in motion discrimination can be explained by a model of motion sensing in which the signals from fine-scale and coarse-scale sensors are subtracted [Serrano-Pedraza et al, 2007 *Journal of Vision* **7**(12.8) 1 – 14]. Errors in the model occur when the signals in the fine and coarse sensors are approximately balanced. The errors disappear when stimulus size is reduced because the reduction in size reduces differentially the response of the sensors tuned to coarse scales.
[Supported by the Welcome Trust.]

◆ **Spatially specific distortions of perceived simultaneity following adaptation to audiovisual asynchrony**
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Perception of audiovisual simultaneity is strongly affected by recent experience. Adaptation to asynchronous stimulus pairs (eg, vision leading sound) causes the physical temporal offset between the stimuli required for perceived simultaneity [the point of subjective simultaneity (PSS)] to shift in the direction of the adapting asynchrony. To investigate the spatial specificity of this aftereffect, observers adapted concurrently to 120 ms asynchronous audiovisual pairs presented at two different spatial locations (left and right of midline). The polarity (ie visual- or auditory-lag) of the adapting asynchrony was either congruent or incongruent across locations. If asynchrony adaptation is mediated by a unitary mechanism that generalises across space, concurrent adaptation to equal and opposite audiovisual asynchronies ought to null, resulting in minimal effect on perceived simultaneity at either location. In contrast to this prediction, incongruent adaptation produced shifts in PSS in opposing directions, the magnitude of which was comparable to that obtained with congruent adaptors. These findings indicate that adaptation to audiovisual asynchrony can recalibrate perceived simultaneity in a spatially specific manner.
[NWR and PVM are supported by the Wellcome Trust.]

◆ **Crossmodal effects of a single auditory tone on multiple visual events**
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We investigated whether one auditory tone crossmodally affects multiple visual events. A multiple stream/bounce display was employed which consists of two disk-pairs tracing orthogonal (45/135 deg) trajectories at equal speeds, and coinciding at a central fixation point. In Experiment 1, we manipulated the temporal offsets between the coincidences of the disk-pairs (0 – 250 ms) by staggering motion onset between the pairs. A brief tone, synchronous with the first coincidence, was presented on half the trials. Observers judged whether all disk-pairs appeared to bounce or not. The tone promoted bounce percepts in both disk-pairs in spite of increasing offsets. However, it is possible that perceived bouncing in the first disk-pair per se promoted bouncing in second. Experiment 2 ruled out this possibility by eliciting reliable bouncing in the first motion sequence without a transient sound (Kawachi et al, 2008 *Vision Sciences*). Results showed that transient free bouncing in the first coincidence did not promote bouncing in the second. We conclude that one auditory tone alters the perception of multiple visual events.
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◆ **Perceiving the direction of walking**
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This study investigates the range of directions within which observers perceive someone walking towards them (hereafter called self-range). In each trial, either an animation clip or a stationary image of a CG-generated, adult-size walker was projected on a screen. The animation resembled treadmill walking; arms and legs moved but the whole body did not move through space. Viewing distance was 2 m. Direction of movement was varied by 3 deg steps. The stimulus was presented for 1.0, 0.5, or 0.25 s. Observers judged whether the walker was moving towards them (hit) or not (miss), and self-range was measured in terms of the standard deviation for hit distributions. There was no effect of duration. The self-range for moving stimuli (5.3 deg) was significantly larger than for stationary stimuli (6.0 deg). The results were replicated with a similar self-range (6.1 deg) by using 18-point biological motion stimuli. These results indicate that in the absence of global motion, local motion of arms and legs contributes to the perception of walking directions.

◆ **Anticipation of gravitational force alters perception of average speed**
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Several studies have found that observers apply an internal model of gravity when intercepting a free falling object. Here we test a possible influence on discriminating average speed. In a 2×2 design with repeated measurements we varied display orientation (normal, inverted), replay direction (forward, backward) and speed (between 80% and 120% in 11 steps) of a 50 frames s^{-1} digital recording of a falling object. Fifteen naive observers attended a training block followed by ten test blocks giving 110 observations per condition. In each trial the observer had to decide whether a clip of 1.6 s contained motion that was faster or slower than real-world motion. For each observer and condition we determined the point of subjective equality (PSE) and just-noticeable difference. In an analysis of variance on PSE replay direction and the interaction between replay direction and display orientation was highly significant. Although observers clearly apply some vector representation of gravitational force to de/accelerating objects, this internal model alone does not accurately predict average speed perception.

◆ **Crowds or photographs of crowds? Visual search through moving or static objects**
N E Scott-Samuel, U Leonards (Department of Experimental Psychology, University of Bristol, UK; e-mail: n.e.scott-samuel@bris.ac.uk)
The dynamic displays previously used in visual search have typically not contained low-level motion signals, but rather involved random relocation of elements. Our subjects searched for a target Gabor patch, differentiated from surrounding distractors by its carrier orientation (target/distractor difference varied between 4 and 32 deg), in two display types: static (stationary elements) or moving (elements smoothly translating in different directions at 3.3 deg s^{-1}). A target was always present, and subjects responded twice on each trial: firstly to indicate that they had found the target, at which point all elements were masked and the reaction time recorded; secondly to identify the target location. For easily identifiable targets (large orientation difference), search functions were similar for static and moving stimuli: both were efficient (shallow gradient with short intercepts). However, for less easily identifiable targets (small orientation difference), static and moving search differed: the former became less efficient, but retained short intercepts; for the latter only intercepts rose. These data present a challenge for existing search models.

◆ **Levelt's propositions generalized for bistable structure-from-motion: common computational mechanisms of visual rivalry**
P C Klink, R van Ee¶, R J A van Wezel (Department of Functional Neurobiology [¶ Department of Physics] & Helmholtz Institute, Utrecht University, The Netherlands; e-mail: P.C.Klink@uu.nl)
Binocular and perceptual rivalry are two types of visual rivalry stimuli that are often used to study the neural mechanisms of visual awareness. Computational models of binocular rivalry are typically tested against a set of experimentally established rivalry characteristics. Levelt's four propositions for binocular rivalry are highly cited as such critical tests to which any model of binocular rivalry should comply. Given this dominant role, it is remarkable that perceptual rivalry has never been tested against these propositions. Here we generalize Levelt's four propositions to make them applicable to perceptual rivalry. We propose that visual competition should be defined to occur between percept probabilities rather than between stimulus strengths. Using this new definition and a bistable structure-from-motion sphere stimulus, we demonstrate that perceptual rivalry complies with (analogues of) all Levelt's binocular rivalry propositions. Our findings imply that perceptual rivalry is produced by active cross-inhibition between neural populations with computational principles similar to those present in binocular rivalry, justifying a generalization of computational models over perceptual and binocular rivalry.

◆ **A computational model of temporal segmentation and the perception of phantom contours**
P T Goodbourn, J D Forte (School of Behavioural Science, University of Melbourne, Australia; e-mail: patrickg@unimelb.edu.au)
The timing of events can influence spatial segmentation. Neighbouring regions flickering asynchronously at a high temporal frequency appear identical, but the visual system signals a 'phantom contour' between them. Using psychophysical procedures, we determined the spatial limitations of this form of temporal segmentation across the visual field. These limitations correspond closely to receptive field diameters of neurons in primary visual cortex (V1), and are also consistent with the spatial limitations of motion detection. Here, we propose a computational model in which the neural signal for phantom contours originates from individual neurons with receptive fields that are space-time separable, like those mapped in cat and macaque V1.

Similar units are also employed in the first stages of models for the perception of local motion. The correspondence between theoretical models of temporal segmentation and motion perception in the human visual system, as well as psychophysical evidence that they have similar spatial limitations, support the notion that these processes are mediated by a common neural substrate situated in early in visual cortex.

◆ **The perception of temporal regularity across modalities**
S Quinn (Department of Psychology, University of Stirling, UK; also Istituto di Neuroscienze del CNR, Pisa, Italy; e-mail: s.c.m.quinn@stir.ac.uk)

The ability to discriminate temporally regular from irregular patterns was investigated. Participants judged which of two intervals, each presenting a sequence of flashed gratings, contained a temporally regular pattern. In the target patterns, flashed gratings were regularly spaced in time. The other pattern contained a sequence of flashes with the same duration, but with irregular intervals between gratings. Both patterns were then interleaved with a further irregular sequence of tones. The second study involved the same temporal features as above, but the target flashes were replaced by tones and the interleaved sequence contained flashed gratings. Discriminating the auditory and visual targets was possible when they are presented alone and when the auditory pattern contains interleaved flashes. When the visual pattern contained interleaved tones the regular target became more difficult to detect. These findings reinforce previous evidence that the auditory domain leads vision in perceiving timing between events (Morein et al, 2003 *Cognitive Brain Research* **17** 154 – 163; Stekelenburg and Vroomen, 2005 *NeuroReport* **16**).
[Supported by the British Academy: No. SG-49664.]

◆ **Emotion biases which you see in a bistable motion pattern**
M K Suzuki, N Kitagawa¶, A Koizumi§, M Kashino¶ (Department of Pharmacology, Tohoku University School of Medicine, Japan; ¶ NTT Communication Science Laboratories, NTT Corporation, Japan; § Graduate School of Humanities and Sociology, The University of Tokyo, Japan; e-mail: suzukim@sal.tohoku.ac.jp)

Recent studies reported that emotional states can modulate visual spatial attention; a positive/negative mood enhances global/local spatial processing. However, it is unclear if emotion only affects scope of attention or also affects other visual phenomena involved in global/local visual processing. This study examined the influence of a happy/sad mood on global/local motion processing using a bistable plaid pattern. After the mood induction, participants viewed the plaid pattern created by superimposing two gratings with different orientations for three minutes. The participants indicated that the plaid pattern was either perceived as two surfaces sliding in different directions (component motion) or as a single plaid pattern (pattern motion). The participants in the happy mood induction reported longer durations of the component motion than those in the sad mood induction. These results suggest that a positive mood enhances the perception of motion segregation, while a sad mood leads to the perception of coherent motion. Our results are discussed in terms of how emotional states modulate various aspects of global/local visual processing.
[MKS was supported by a JSPS Research Fellowship for Young Scientists.]

◆ **Pulfrich-like effects under monocular viewing**
R Taya, Y Ohashi¶, W Ehrenstein§ (Graduate School of Humanities and Sciences, Okayama University, Japan; ¶ Department of Pre-elementary Education, Sanyo Gakuen College, Japan; § Leibnitz Research Center for Working Environments and Human Errors, University of Dortmund, Germany; e-mail: taya@cc.okayama-u.ac.jp)

A disc swinging in the frontoparallel plane appears to move elliptically in depth when viewed binocularly with an attenuating filter placed over one eye (Pulfrich effect). Here we present experimental evidence based on five observers (two experienced, three naive) for Pulfrich-like effects occurring under monocular viewing conditions. A swinging disc that alternated in lightness (white/gray at 5 Hz) on a computer screen appeared to move elliptically in depth. This phenomenon became even more prominent with higher alternation rates of up to 45 Hz, when the lightness fluctuation was hardly perceived. Monocular Pulfrich-like effects were also obtained for a swinging bar that alternated in orientation (vertical/tilted at 5 Hz). Thus, monocular depth effects may result from a swinging target that alternates between different states (white/gray, vertical/tilted), irrespective of whether these states appear to be fused or not. Though binocular viewing contributes, no doubt, much to depth perception, monocular viewing seems to substitute most of its function.

◆ **Transparency and temporal aspects of illusory-surface perception probed with Poggendorff configuration**
Q Wang (Graduate school of Information Systems, University of Electro-Communications, Japan; e-mail: wang@is.uec.ac.jp)

Transparency and temporal aspects of illusory surface perception (ISP) were investigated with the probing method of Poggendorff configuration (PMOPC). The occurrence of Poggendorff illusion could probe opaque surface perception [Wang et al, 2004 *Perception* **34** Supplement, 187; 2005 *Japanese Journal of Applied Physics* **43**(1A/B) L11 – L14]. Probe lines (PL) and testing illusory surface (TIS) with partially opaque and partially transparent composed Poggendorff configuration. The discrepancy of probe lines (DOL) was diminished when PL were located from the opaque part to transparent part of TIS. To investigate temporal properties of ISP, PL was displayed continuously and testing opaque illusory surface was displayed periodically with various duration and interval time. The duration time for sustained perception of DOL and interval time for obliterating DOL needed >300 ms and >2200 ms. We inferred that they were the reflection of the formation and required time for genesis and decay of ISP. Transparency and temporal aspects of ISP could be effectively explored with PMOPC, and PMOPC could be expected to reveal formation mechanism of surface perception.

OBJECTS, FACES AND SHAPES

◆ **Effects of threat perception on visual mental rotation performance**
A Csatho, F Tey¶, G Davis¶ (Institute of Behavioral Sciences, University of Pecs, Hungary; ¶ Department of Experimental Psychology, University of Cambridge, UK; e-mail: arpad.csatho@aok.pte.hu)

Optimizing cognitive processes to deal with threats in out environment is of unquestionable adaptive significance, yet laboratory studies of mental processes following threat perception have focused largely on visual attention following threat, to the virtual exclusion of other processes. In two experiments, we have examined the effects of threat perception on mental rotation tasks, in which participants must compare different views of 3-D objects to determine whether they are views of the same or different shapes. The stimuli to be compared were pictures of left and right hands viewed from various viewpoints. In one (allocentric) condition, participants compared one picture of a hand to another picture and to determine whether the pictures were of the same hand or not. In a second (egocentric) condition, the participant determined whether a single hand stimulus was of a left or a right hand. The results demonstrated clear influences of perceived threat on mental rotation performance, though the nature of these influences depended upon axis of rotation, anxiety state and allocentric versus egocentric coordinates.

◆ **Contrasting target visibility and visual awareness in unconscious emotional body perception**
B M C Stienen, B L M F de Gelder (Department of Cognitive and Affective Neuroscience, University of Tilburg, The Netherlands; e-mail: B.M.C.Stienen@uvt.nl)

Many approaches have been used to support the claim that some visual discriminations are still possible in absence of visual awareness. Most noteworthy, this claim has been made concerning nonconscious processing of facial expressions. Metacontrast masking permits to create experimental conditions in which subjective visual awareness and the objectively measured visual discrimination are measured separately (Lau and Passingham, 2006 *Proceedings of the National Academy of Sciences of the USA* **103** 18763 – 18768). We used such a paradigm to investigate perception of bodily expressions without visual awareness. Pictures of bodies expressing anger and happy were used as targets. The mask consisted of compounds of body parts (trunk, 6 arms, and 6 legs in various positions) and were presented at 12 different SOA's varying from -50 to 133 ms. Participants were instructed to categorize the expression of the target body and subsequently to indicate whether they had seen the body or not. The results show that affective stimulus perception without visual awareness is clearly observed for angry bodily expressions and that the effect is modulated by observer characteristics.

◆ **Category conjunction in ultra-rapid visual categorization: an EEG study**
B Dorgau, S Straube, M Fahle (Institute of Human Neurobiology, Bremen University, Germany; e-mail: birthe.dorgau@lycos.de)

The rapid detection of objects in complex visual scenes is essential to guide complex behaviour in a rapidly changing environment. Electrophysiological experiments have demonstrated that categorization can take place within about 150 ms. We investigated whether ultra-rapid categorization is slowed down when a conjunction of categories is required. Behavioural and EEG data were evaluated in a go/nogo task, with stimuli presented for 20 ms. Subjects discriminated based on either one category (animals versus non-animals or ellipses versus squares) or a conjunction of categories (brown animals or orange ellipses). Responses were faster and target – distractor

ERPs separated earlier for search after ellipses than after animals. Category conjunction produced ?tws› longer reaction times than the corresponding 'one-category' condition. Accordingly, we observed later target – distractor separation in the ERP for conjunction of ellipses with colour. Surprisingly, this was not the case for the corresponding condition with animals: based on electrophysiological findings we conjecture that subjects here tended to first categorize animals and then judge their colour. Our results indicate that category conjunctions delay ultra-rapid categorization.

◆ **How strong is a car's brand from a visual perspective? Searching for an objective measure**
C C Carbon (Faculty of Psychology, University of Vienna, Austria; also Faculty of Industrial Design, TU Delft, The Netherlands; e-mail: ccc@experimental-psychology.com)

Brands are one of the most valuable assets a company has. Successful branding means fast and accurate recognisability of the brand identity. Brand strength, however, is hard to measure. Several attempts to measure the recognisability of a brand already exist, mainly based on questionnaires and subjective measures. Here, I present an objective measure of visual brand strength based on similarity ratings of blended images of different products representing different brands. Via morphing technique, competing brands are blended in steps of 5%, which participants have to rate by similarity. The stronger the visual recognisability of a brand ie the visual brand strength, the longer it resists overlaid information from competing brands. The BBSI was tested within a simultaneous matching and a recognition task for measuring direct visual and memory-based brand strength demonstrating once again that research on basic research in psychophysics can stimulate applied research and consequently can create concrete applications in form of an objective visual brand strength indicator.

◆ **Recognising the actions of others is as fast as recognising objects**
S de la Rosa, A Chatziastros (Department of Psychophysics, Max Planck Institute for Biologial Cybernetics, Tübingen, Germany; e-mail: delarosa@kyb.tuebingen.mpg.de)

Visual recognition of object, faces, and animals is done with ease and speed (eg Thorpe et al, 1996 *Nature* **381** 520 – 522). Similarly important for human life is the visual recognition of social interactions (the physical interaction of an individual with others). Little is known about social interaction recognition and how it compares to visual object recognition. One prediction is that social interaction recognition, unlike object recognition, requires the recognition of how objects/humans are related to each other (eg, is the arm reached out for hitting or hand shaking?) in addition to the recognition of individual objects/humans. Hence, the visual recognition of social interactions might take longer. Here we compared the time course of visual object and social interaction recognition. We measured the presentation time thresholds to recognise static images depicting objects or social interactions with 80% certainty. We found the same presentation time thresholds for object and social interaction recognition. We conclude that social interaction recognition is as fast as object recognition.

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◆ **Attractiveness of faces of different age**
E Nikitina (Institute of Psychology, Russian Academy of Sciences, Moscow, Russia; e-mail: e.nikitina@psychol.ras.ru)

The colour photos of newborns, 7-year-old children, and 20-year-old students were used as stimuli. The observers were asked to categorize sex and estimate attractiveness level of each face. The experiment showed the high concurrence of observers' judgments of attractiveness of stimuli faces. Unlike the experiments with adult faces, no correlations was found between attractiveness and level of sex expression in faces. Girls' faces were estimated as more attractive than boys' faces in all ages. The images of girls (and newborn and 7-year-old) with probability of sex categorization at about 60% were called the most attractive.

◆ **The (un)usefulness of interactive exploration in building 3-D mental representations**
F Meijer, E L van den Broek¶ (Department of Cognitive Psychology and Ergonomics [¶ CTIT], University of Twente, The Netherlands; e-mail: f.meijer@utwente.nl)

The generation of mental representations from visual images is crucial in 3-D object recognition. In two experiments, thirty-six participants were divided into a low, middle, and high visuospatial ability (VSA) group, which was determined by Vandenberg and Kuse's MRT-A test (1978 *Perception and Motor Skills* **47** 599 – 601). In the experiments, the influence of four types of exploration (none, passive 2-D, passive 3-D, and interactive 3-D) on building 3-D mental representations was investigated. First, 24 simple and 24 complex objects (consisting of respectively 3 and 5 geons (Biederman, 1987 *Psychological Review* **94** 115 – 147) were explored and, subsequently, tested through a mental rotation test. Results revealed that participants with a low VSA benefit from

interactive exploration of objects opposed to passive exploration. This refines James et al's findings (2001 *Canadian Journal of Experimental Psychology* **55** 111 – 120), who reported a general increased performance with interactive as compared to passive exploration. Our results underline that individual differences are of key importance when investigating human's visuospatial system or visualisation techniques.
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◆ **Early visual areas anticipate load and location; the fusiform gyri differentiate task demands and grapheme status**
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Functional specialization and flexibility to changing task demands are key characteristics of visual processing. Using magneto-encephalography (MEG) we studied pre-stimulus and evoked activity while subjects classified letters and pseudo-letters into prearranged response categories. Each response category consisted of a letter and a pseudo-letter, but in one task variation, classification was according to global stimulus shape (shape task) whereas in the other fine shape distinctions were relevant (identity task). The identity task increased pre-stimulus bilateral V1 activity and evoked larger responses in the right fusiform gyrus (FG) between 150 and 350 ms after stimulus onset. Implicit grapheme selectivity was restricted to the left FG, between 300 and 400 ms after stimulus onset. The results demonstrate that early visual areas can organize their activity according to expected task demands and predicted stimulus location. Furthermore, the results differentiate the dynamics of functional specialization for graphemes in the left FG from the evoked effects of task-dependent fine shape processing in the right FG.

◆ **A dynamic face-inversion effect**
I M Thornton, E Mullins, K Banahan (Department of Psychology, School of Human Sciences, Swansea University, UK; e-mail: i.m.thornton@swansea.ac.uk)
The face-inversion effect (FIE) refers to increased response times or error rates for faces that are presented upside-down relative to those seen in a canonical, upright orientation. Here we report that this FIE can be greatly amplified when observers are shown dynamic, rather than static faces. In two experiments observers were asked to assign gender to a random sequence of un-degraded, static or moving faces. Each face was seen both upright and inverted. For static images, this task led to little or no effect of inversion. For moving faces, the cost of inversion was a response time increase of approximately 100 ms. Importantly, this slowing occurred in the presence of form cues, cues that when shown statically, led to much faster responses. In control experiments, a difference between static and dynamic inversion was not observed for whole-body stimuli or for human-animal decisions. These latter finding suggests that the processing of upside-down movies is not always more difficult for the visual system than the processing of upside-down static images.

◆ **A computational model for shape classification**
J D Wilder, J Feldman, E Briscoe, M Singh (Cognitive Psychology, Rutgers University New Brunswick/Piscataway, USA; e-mail: jdwilder@ruccs.rutgers.edu)
We created a computational model for the representation of 2-D shapes, allowing shapes to be classified into broad natural categories, such as 'animal' or 'leaf'. Many shape models make implicit assumptions about the shapes in the environment that are not based on real-world measurements. To better connect shape theory to real-world shapes, we collected shape statistics from databases of leaf and animal shapes. An extension of the probabilistic shape framework of Feldman and Singh (2006 *Proceedings of the National Academy of Sciences of the USA* **103** 18014 – 18019) was used to construct probabilistic 'prototypes' corresponding to natural shape categories. These prototypes were then used for classification via the identification of the prototype most likely to have generated a given shape. The classification process depends on the topology of a shape's skeletal structure as well as the skeleton's metric properties, both of which are modeled probabilistically. The model effectively classifies novel shapes, and its performance also corresponds closely to data collected from human observers. The model enhances our understanding of the computational processes underlying natural shape classification by the human visual system.
[Supported by DGE 0549115 IGERT: Interdisciplinary Training in Perceptual Science.]

◆ **Crowding shows that faces have parts and bodies do not**
K A Tillman, M Araki, D G Pelli (Department of Psychology and Neural Science, New York University, USA; e-mail: katharine@nyu.edu)
Crowding provides an operational test for whether an object is recognized by parts or as a whole. If an object has parts for recognition, those parts must be isolated, separated by at least the observer's critical spacing, in order for the object to be identified. Martelli et al [2005, *Journal of Vision* **5**(1.6) 58 – 70] showed that faces are like words: both are recognized by parts. Here we use an emotion-recognition task to ask whether bodies are like faces. We use a staircase procedure to measure the threshold size for identifying the emotion (happiness, sadness, fear, anger, or disgust) conveyed by a body posture silhouette or face photograph. We compute 'complexity' as the ratio of this threshold object size and the size of the smallest 'isolation field' (based on critical spacing) in that region of the visual field. Complexity $\leqslant 1$ indicates holistic recognition, while complexity > 1 indicates recognition by parts. We replicate Martelli et al's finding that faces are recognized by parts (complexity $= 3.6 \pm 1.0$). Surprisingly, we find that bodies, unlike faces and words, are recognized as wholes (complexity $= 1.0 \pm 0.3$).
[Supported by National Eye Institute grant R01-EY04432 to DGP.]

◆ **Larger feature alphabets can improve object recognition even with simpler visual words**
M Lillholm, L Griffin (Department of Computer Science, University College London, UK; e-mail: m.lillholm@cs.ucl.ac.uk)
Responses of V1 simple cells allow encoding of an image using an alphabet of feature 'letters'. We have investigated how such encodings perform when used in the representation of visual 'words', such as drive V4 cells. We have experimented with three alphabets computable by V1: quantized local orientation (8 letters); type of local image symmetry (7); and symmetry type and orientation (23). We have evaluated these alphabets using three different schemes of decreasing spatial complexity—templates, histograms and presences—for encoding visual words. Our evaluation is based on performance in a model of feed-forward object recognition in natural images. Performances are assessed at scheme-optimal patch size. All alphabets perform equally well using templates. The symmetry type and orientation alphabets perform less well with histograms and presences. The combined symmetry and orientation alphabet performs best with presences and has the best overall performance. We conclude that more complex feature analysis at the letter stage can give better performance even with simpler analysis at the word stage.

◆ **How are frontal, mid-profile, and profile faces processed? Evidence from eye movements**
M Bindemann, A M Burton, C Scheepers (Department of Psychology, University of Glasgow, UK; e-mail: markus@psy.gla.ac.uk)
Faces are seen in different poses. Across viewpoints, facial features such as the eyes and ears may or may not be present and their appearance can vary in some fundamental ways. The ability to process different viewpoints is therefore crucial for all tasks with faces. Despite this, psychological research has focussed on the perception of frontal faces. This study provides a step towards understanding how different face views are processed, by measuring eye movements to frontal, mid-profile, and profile faces. Overall, the majority of fixations were directed at the eyes, and to a lesser extent also at the nose and mouth, independent of the viewpoint of a face. However, changes in viewpoint induced qualitative shifts in the sampling behaviour of facial landmarks, particularly immediately after stimulus onset. This pattern reflects a tendency to look at the centre of a face when it is first located within the visual field, rather than specific features, but viewpoint also affects the extent to which different features are encoded at subsequent stages.

◆ **Object bias of perceived gaze direction: Robustness to head orientation**
T Nagai, S Kita (Department of Psychology, Kobe University, Japan; e-mail: nagai@stu.kobe-u.ac.jp)
This study examines the object bias that the perception of another person's gaze direction is biased toward an object near the place at which he/she gazes. Unlike previous studies, this study focuses on the effect of head orientation on the object bias by introducing the condition that the gazer's head is skewed to the observers. In the present experiment, consistence of the object bias was examined in four conditions of head orientation and six conditions of object state (existence or nonexistence of the object and its location). The observers estimated the horizontal location of the gaze direction of a person in the static picture shown in the monitor. Results confirmed the object bias that estimated gaze direction was biased toward the object compared with the no-object condition. Quantitative consistence was obtained that almost the same amount of object bias was shown in all conditions of the head orientation. Thus we conclude that the object bias has robustness to the head orientation.

◆ **Preference of newborn chicks for face-like configurations: underlying mechanisms and lateralization effects**
O Rosa-Salva, L Regolin, G Vallortigara¶ (Department of General Psychology, University of Padua, Italy; ¶ Centre for Mind/Brain Sciences, University of Trento, Italy; e-mail: orsola.rosasalva@unipd.it)
It is still debated whether newborns' preferential looking toward face-like configurations is determined by the presence of an innate schematic representation of conspecific faces' appearance (CONSPEC), or by the up–down bias (that favours stimuli presenting more high-contrast elements in their upper part with respect to the lower part). In the present work we demonstrated that domestic chicks (visually naive for the arrangement of the internal face's features) show a spontaneous preference for face-like schematic stimuli, regardless of whether these are top-heavy or bottom-heavy configurations. The presence in domestic chicks of an up–down bias per se has also been studied, employing non face-like configurations as experimental stimuli. Lateralization effects underlying face-like stimuli perception and processing have been investigated. Evidences were found suggesting that presenting a face-like configuration to the right hemisphere produces a general facilitation for approaching social objects (for example objects resembling the imprinting stimulus), consistently with a dominant role of the right hemisphere in social cognition and especially in face perception.
[Supported by the EC grant EDCBNL.]

◆ **Quantifying image quality in terms of object recognition performance: the TOD methodology**
P Bijl, M Hogervorst (TNO DSS Human Factors, Human Interfaces, The Netherlands; e-mail: piet.bijl@tno.nl)
We propose a simple and powerful method to assess the quality of imaging systems with a human-in-the-loop: the triangle orientation discrimination or TOD method. Basically, a human observer judges the orientation of equilateral triangle test patterns of various degrees of difficulty using the sensor system under test. The sensor system degrades the image of the test pattern, and the method evaluates the combined effect of all image transformations within the sensor system including the observer. The results are shown to have a close relationship to real object recognition performance. The method has a wide application area and is suitable to characterize sensors from different spectral ranges (eg visual, infrared, X-ray), image enhancement techniques and image artifacts (eg due to compression). In addition to the TOD test method, we propose a vision model that simulates the human observer performing the TOD task. Here we will describe the method, its advantages over existing methods, the validation, the model, and some applications.

◆ **Validating the TOD method with identification of real targets: effects of aspect angle, dynamic imaging and signal processing**
J A Beintema, M A Hogervorst, J Dijk¶, P Bijl (TNO Defensie en Veiligheid, Human Factors, Soesterberg, The Netherlands; ¶ TNO Defensie en Veiligheid, The Hague, The Netherlands; e-mail: jaap.beintema@tno.nl)
How far the eye reaches via camera is quantifiable and modeled with the TOD (triangle orientation discrimination) methodology (Bijl and Hogervorst, 2008 *Perception* **37** Supplement, this issue). For validation and extension purposes, we studied identification of real objects in several conditions. Objects (two-handheld) were recorded at various distances and angles with an under-sampled uncooled thermal imager. Results: (i) The distance for identification at threshold level was closely predicted by the TOD model, using existing scale criteria for two-handheld objects; (ii) effects of aspect angle were large, yet to nearly half extent predictable from contrast and size changes; (iii) sensor motion had no positive effect, (iv) the benefit of DSR (dynamic super resolution) was smaller than expected; (v) performance with local adaptive contrast enhancement equaled that of manual contrast optimization. The relatively poor performance with motion and DSR are probably due to motion smear, since camera speed was higher than in earlier studies. We conclude that the TOD methodology can predict identification distance for real targets. Effects of camera motion magnitude and smear are not modeled yet.

◆ **The aesthetic dimension of the perception of paintings**
S Markovic (Laboratory for Experimental Psychology, University of Belgrade, Serbia; e-mail: smarkovi@f.bg.ac.yu)
This study investigated the structure of aesthetic experience and the relationship of this structure and other dimensions of the subjective judgments of paintings (arousal, hedonic tone, relaxation, and regularity; cf Markovic and Radonjic, 2006 *Perception* **35** Supplement, 88). Aesthetic experience was defined by nine descriptors selected from relevant literature: fascinating, irresistible, unique, eternal, profound, exceptional, universal, unspeakable, and I would like to have this painting. In the experiment subjects judged 24 paintings on nine unipolar

seven-step scales that were made of the descriptors mentioned above. The factor analysis extracted one principal component. Multiple regression has shown that 'arousal' was a significant predictor of aesthetic experience, but the percent of explained variance was relatively low (ca 23%). The prediction of other subjective dimensions was not significant. The results of this study suggest that the aesthetic experience is a unique and relatively independent phenomenon: internally, it is not dividable into components, and externally, it is weakly correlated with the other subjective dimensions of the perception of paintings.

◆ **Classification of cognitive states in face-name association by machine learning from EEG spectrum**

H Takai, T Minami¶, M Kitazaki§, S Nakauchi (Department of Information & Computer Sciences, [¶ Intelligent Sensing System Research Center; § Research Center for Future Vehicle], Toyohashi University of Technology, Japan; e-mail: takai05@bpel.ics.tut.ac.jp)

Can we decode the sense of what one knows from brain signals? A difference in brain activity about feeling-of-knowing (FOK) on face-name associations was investigated by fMRI (Kikyo et al, 2004, NeuroImage 23, 1348-1357). Therefore, we can hypothesize that such difference be detected also in electroencephalogram (EEG) spectrum. In this study we predicted the cognitive states about FOK by classifying EEG spectrum using machine learning method. In the experiment, the subjects conducted the face-name association task based on the recall – judgment – recognition paradigm. We conducted FOK states classification from EEG spectrum using support vector machines. As a result, average predictive accuracy for state of knowledge was about 75%. However, we could not discriminate between the states of recall and FOK. This study suggests that EEG spectrum can be used for accurate estimation of cognitive states by machine learning under proper conditions.

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◆ **The various phases of faces**

V Goffaux (Department of Neurocognition, University of Maastricht, The Netherlands; e-mail: valerie.goffaux@psychology.unimaas.nl)

A hallmark of face processing is that individual features strongly interact over space. Once the face is inverted, spatial interactions are attenuated and mainly local information is extracted. Face inversion effect was recently demonstrated to largely stem from the disrupted processing of the vertical spatial relations organising features (eg eye height) in a given face, suggesting that upright face perception largely relies on the extraction of vertically-oriented information. Here we further investigated the prevalence of vertically oriented information in face and object processing. We measured discrimination performance to upright and inverted pictures of faces and objects. Stimuli were filtered to selectively preserve Fourier amplitude at vertical and horizontal phase orientations. Upright face discrimination showed differential sensitivity across phase angles. This profile did not merely reflect stimulus phase spectrum, since it did not replicate for inverted faces. Object discrimination displayed a significantly weaker advantage for vertical phase information, and was less sensitive to orientation, overall.

◆ **Role of facial expressions and attractiveness on the mere exposure effect**

Y Sakuta, H Ishi¶, S Akamatsu§, J Gyoba# (Faculty of Human Sciences, Waseda University, Japan; ¶ Department of Design and Computer Applications, Miyagi National College of Technology, Japan; § Faculty of Engineering, Hosei University, Japan; # Graduate School of Arts & Letters, Tohoku University, Japan; e-mail: y.sakuta@aoni.waseda.jp)

Previous works have shown that an individual's preference for a particular stimulus object is enhanced when the individual is repeatedly exposed to that object (mere exposure effect). However, how subjective factors such as affective expression or physical attractiveness affect the mere exposure effect has not been discussed enough. In our research we used face images, manipulating facial expressions quantitatively on various dimensions (eg elegant, strong), and compared the preference ratings between the repeated and novel stimuli. Itt was suggested that the patterns of the exposure effect were different according to different expression dimensions. The preference ratings were increased by repeated exposure only on the faces on which 'elegant' expressions were manipulated and that had relatively high attractiveness. Therefore, it is possible that the mere exposure effect is mediated by the expression dimension that relates to elegance or attractiveness of stimuli.

SEGMENTATION AND GROUPING

◆ **Centroid shifts and the illusion of extent**

A Bulatov, A Bertulis, N Bulatova, A Gutauskas (Institute of Biology, Kaunas University of Medicine, Lithuania; e-mail: bulatov@vision.kmu.lt)

Subjects matched spatial intervals of a three-spot stimulus with three pairs of flanking spots forming an interpolated Brentano figure. The spots were 1.5 min of arc in size and of 75 cd m^{-2} luminance, background 0.4 cd m^{-2}. The length of the imaginary wings, and the wing tilt angle were considered as independent variables. For stimulus referent intervals 32, 64, and 96 min of arc in length, the judgment errors as functions of the wing length grew steadily and reached their maximum descending gradually afterwards. The curves were similar in shape, but the maximum values and their positions on the curves increased in a linear manner. The errors as functions of the internal angle of the wings showed symmetrical curves of a near cosine type. The analytical description of the experimental data was related to the centroid bias conception (Morgan et al, 1990 *Vision Research* **30** 1793 – 1810). The experimental curves were fitted with a proposed function describing the perceptual shifts of the stimulus terminators. A good resemblance between the calculated and experimental data was established.

◆ **Simultaneous and backward spatial frequency masking does not alter comparison of spatial frequencies at a distance**

M V Danilova, J D Mollon¶ (Laboratory of Visual Physiology, I P Pavlov Institute of Physiology, St Petersburg, Russia; ¶ Department of Experimental Psychology, Cambridge University, UK; e-mail: dan@pavlov.infran.ru)

If two Gabor patches are presented for 100 ms at arbitrary positions on an imaginary circle of 5 deg radius centered on the fixation point, the threshold for discriminating their spatial frequencies is independent of their separation up to 10 degrees (Danilova and Mollon, 2003 *Perception* **32** 395 – 414). We therefore question models of spatial-frequency discrimination that postulate hard-wired comparator units drawing inputs of opposite sign from the two arbitrary regions of the visual field where the targets fall. However, high-level neurons with receptive fields extending across the midline can integrate from large areas of the visual field and thus could serve as dedicated comparators. To eliminate this possibility, we measured spatial-frequency discrimination in the presence of gabor patches occupying the interior of the imaginary circle and simultaneous with the two targets. This central mask did not alter the shape of the function relating spatial-frequency discrimination to the spatial separation of the targets. This result favours a representation of spatial frequency that does not depend on signals from local comparator units.

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◆ **Feature binding in swarming dot patterns**

G J van Tonder (Laboratory of Visual Psychology, Kyoto Institute of Technology, Japan; e-mail: gvtonder@yahoo.co.uk)

Feature binding is a non-rigid process through which possibly meaningful spatiotemporal ensembles of visual features emerge, such as the Fröhlich effect (Fröhlich, 1923 *Zeitschrift für Sinnesphysiologie* **54** 58 – 78) and flash-lag effect (MacKay, 1958 *Nature* **181** 507 – 508) demonstrate. However, spatiotemporal properties of feature binding processes are not fully resolved. During an outdoors excursion the author witnessed the appearance of illusory 'flashing star' patterns, reminiscent of feature binding effects, in real traveling bee swarms. This prompted a systematic search for the spatiotemporal parameters over which this illusory phenomenon occurs in dynamic displays with pseudo-randomly instantiated swarming dot stimuli. Swarming dots that coincide within this spatiotemporal window are not only grouped into a flashing figural percept, but appears structurally regularized (eg symmetrical), regardless of actual spatial and temporal misalignments between individual dot trajectories. The illusion may reflect prägnanz in local spatiotemporal perceptual grouping. To the best of the author's knowledge, this illusory phenomenon—different from global perceptual grouping in dynamic dot displays—has not been reported before.

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◆ **Identification of everyday objects on the basis of kinetic contours**

K Segaert, G E Nygård, J Wagemans (Laboratory of Experimental Psychology, University of Leuven, Belgium; e-mail: katrien.segaert@gmail.com)

Using kinetic contours derived from everyday objects, we investigated how motion affects object identification. In order not to be distinguishable when static, kinetic contours were made from random dot displays consisting of two regions, inside or outside the object contour. In Experiment 1, dots were moving in only one of the two regions. Objects were identified nearly equally

well as soon as the dots either in the figure or in the background started to move, with a trend for faster identification with figural motion. RTs decreased with increasing motion coherence levels and were shorter for complex, less compact objects than for simple, more compact objects. In Experiment 2, objects were identified when the dots were moving both in the figure and in the background with speed and direction differences between the two. A linear increase in either the speed difference or the direction difference caused a linear decrease in RT for correct identification. In addition, speed and motion differences showed to be additive cues for figure – ground segregation and object identification.

◆ **Crowding in primates: a comparison of humans and macaque monkeys**
L Kiorpes, D Li, M Hagan (Center for Neural Science, New York University, USA; e-mail: lynne@cns.nyu.edu)

Crowding refers to interference by nearby objects or contours with the visibility of a target. Crowding is most pronounced in the visual periphery of typical adult humans but affects foveal vision in amblyopes; its underlying mechanisms are unknown. We are studying crowding in macaque monkeys with the goal of directly studying neural correlates. As a first step, we compared the critical distance of macaque monkeys and human observers on a foveal crowding task. We used a Landolt-C type discrimination: the task was to identify the location of the gap in a Gabor C in the presence and absence of flanking targets (after Hariharan et al, 2005 *Vision Research* **45** 617 – 633). Flanking targets were single Gabors of 80% contrast. Our performance measure was contrast threshold for gap identification as a function of flank distance. Critical distance for humans and monkeys ranged from 2.0 – 2.4 SD (21 – 25 min) with free-viewing. Our data are similar to those of Hariharan et al (2005), and show a similar profile for human and non-human primates.
[Supported by NIH grants EY05864; EY02017; RR00166.]

◆ **Bandwidths of cigars and doughnuts in higher-level spatial vision**
L A Olzak, P J Hibbeler (Department of Psychology, Miami University of Ohio, USA; e-mail: olzakla@muohio.edu)

Olzak and Thomas (1999 *Vision Research* **39** 231 – 235) proposed a model of neural recombination containing two parallel summing circuits. One was specialized to signal orientation information (cigars); the other was specialized to signal texture information (doughnuts). Both followed a nonlinear stage of processing in a common gain control pool. Here we report the results of measuring the gain control pool and the bandwidths of the cigars and doughnuts, using orientation or spatial frequency judgments, respectively. Stimuli were simple or complex luminance gratings designed to stimulate the appropriate pathway. To isolate the gain control pool, we measured how masking by a component that differed widely in spatial frequency or orientation varied with the spatial frequency or orientation of the mask. To isolate summing circuits, we measured the extent to which a configural effect (difference in performance depending on how cues were added) was found, as a function of the orientation or spatial frequency of the second cue. Results showed broad masking pools (1.5 – 2.5 octaves) and relatively narrow summing circuits (< 1 octave).
[Supported in part by NIH grant EY13953 to LAO.]

◆ **Relational representations in the human visual system: evidence from priming with bistable stimuli**
S W Cheadle, M Usher (School of Psychology, Birkbeck, University of London, UK; e-mail: s.cheadle@bbk.ac.uk)

In order to represent a complex scene the visual system must integrate information belonging to the same object, whilst segregating information belonging to different objects. Although a neural representation of the binding relation between object-parts is assumed to exist, its nature is controversial and experimental evidence is lacking. Here we report evidence for the reality of the binding relation of line elements, by showing that a relational representation of bound elements can be primed. Observers were required, first, to view a bistable stimulus, and subsequently had to detect a target rectangle. This target consisted either of previously bound prime elements (ie parts of a single object) or of non-bound prime elements (ie parts of multiple objects). We found that binding of the target-elements induced a strong facilitatory effect (accuracy and reaction times) on target detection. This provides an objective test of perceptual organisation in bistable perception, and demonstrates that the binding of visual elements can be primed by a purely relational representation.

◆ **Oppel – Kundt stimulus with three parts to match**
T Surkys, A Bertulis, A Bulatov, L Mickiene (Biology institute, Kaunas University of Medicine, Lithuania; e-mail: tsurkys@vision.kmu.lt)
An Oppel – Kundt type stimulus has been designed by applying two modifications to the spatial structure of the original figure. The stripes were replaced by spots, and three contiguous spatial intervals were aligned instead of two on the monitor screen. The stimulus pattern turned to a symmetrical figure with two versions of the appearance: either the filled middle interval was flanked by two empty ones or the empty interval was placed between two filled flanks. In experiments with the length matching performance, the symmetrical three-part Oppel – Kundt figure reduced the influence of the left – right asymmetry on the matching errors but required averaged judgements on the perceived equality between two flanking intervals and the central one. The strength of the illusion as a function of the spot number varying simultaneously in the flanking intervals of the three-part figure yielded the curves similar in shape with those obtained by the two-part pattern. Although the maxima values were about 1.4 times greater. Vertical and horizontal orientations of the stimulus provided the same result.

ORAL PRESENTATIONS

BRIGHTNESS

◆ **The nature of lightness-match distributions**
S Zdravkovic, P Milin (Department of Psychology, University of Novi Sad, Serbia; also Laboratory for Experimental Psychology, University of Belgrade, Serbia; e-mail: szdravko@f.bg.ac.yu)
It is common to translate raw lightness matches into log reflectance and to analyse them using parametric statistical methods, assuming that the underlying distribution was normal. This work challenged such assumption. Lightness matches were gathered using Munsell scale and transformed into reflectances and log reflectances. The distribution testing included set of one-sample tests, Bayesian inference and bootstrapping of the Kolmogorov – Smirnov one-sample test. In the case of reflectance data, testing showed that they could be treated as normally and double-exponentially (Laplace) distributed. However no such symmetrical distribution could be assumed for the log transformed reflectance values. There was also a significant difference in distributions of increments and decrements. Our findings suggest that the use of standard, parametric statistical methods should be limited only to reflectance values, where additional methods, suitable for Laplace distributions, could also be used. The data transformed into log reflectance values are no longer symmetrically distributed, so non-parametric techniques should be applied. Otherwise the inferences might not be reliable.
[Supported by the Ministry of Science and Environmental Protection, Republic of Serbia, grant D-149039.]

◆ **Coupled computations of lightness, 3-D shape, and gloss**
B L Anderson, J Kim (School of Psychology, University of Sydney, Australia; e-mail: barta@psych.usyd.edu.au)
The computation of surface properties from images is difficult because 3-D surface shape, illumination, transparent media, and material properties all interact to produce the image. The problem of disentangling these variables has motivated attempts to find computational short-cuts to infer surface properties. It was suggested that the skew of pixel histograms provide information about the lightness and glossiness of surfaces (Motoyoshi et al, 2007). We show that these results reflect spurious correlations between histogram skew, lightness, and gloss in the particular images studied. We demonstrate that images with negatively skewed histograms can appear glossy; that positively skewed histograms can appear matte; that the shifts in apparent lightness provide no evidence for the role of skew in the computation of lightness; and that the correlation between surface gloss and image skew is nonexistent for non-uniform albedo surfaces. We argue that the computations of surface gloss, 3-D shape, and lightness are inherently coupled, and that histogram skew is largely uninformative about surface properties.

◆ **Lightness induction in complex configurations: assimilation, contrast or contrast-contrast**
B Spehar (School of Psychology, University of New South Wales, Sydney, Australia; e-mail: b.spehar@unsw.edu.au)
Although most research on lightness has traditionally focused on contrast effects, the effects of assimilation are more challenging for theories of lightness perception. Recently, several proposals have emerged suggesting that assimilation occurs for a given region when its local contrast is small in comparison to the contrast difference of edges among inducing regions. In this framework, the higher contrast among the inducing edges may partially overcome the lower-contrast

signal associated with the local target edge, causing assimilation to occur. Here we investigate this approach by manipulating the luminance relationships of the target and inducing regions in a number of traditional and novel configurations. Overall, the results suggest no strong regularities regarding the contrast differences between the edges in the surround and the local target edge. The results of adjustment and forced-choice lightness judgments demonstrate that when target luminance is intermediate in luminance to that of inducing regions, all tested configurations produce assimilative effects, regardless of whether the contrast between the inducing regions was high or low.

◆ **The role of adjacency and surroundedness in the effect of depth on lightness**
A Radonjic, A Gilchrist (Department of Psychology, Rutgers University, Newark; e-mail: ana@psychology.rutgers.edu)

We tested whether adjacency is a necessary condition for the coplanar ratio principle. One group of twenty observers viewed the dihedral planes display of Gilchrist (1977 *Science* **195** 185 – 187), with two equiluminant targets, one coplanar and adjacent to an illuminated white background, but seen against the non-coplanar shadowed black background and another coplanar and adjacent to a shadowed black background but seen against the illuminated white background. The lightness difference between the two equiluminant targets (the depth effect) was 4.8 Munsell units. Another group of twenty observers viewed the same display in which each target was moved within its plane away from its coplanar background, appearing to float in front of its retinal background. The depth effect was reversed and yielded 0.7 Munsell units. To test whether surroundedness can substitute for adjacency, we extended each background creating a coplanar, but not adjacent, border surrounding each floating target. While the white illuminated border significantly darkened the target (approximately half as much as adjacency would) the black shadowed border did not have an effect.
[Supported by the National Science Foundation (grant BCS-0643827) and the National Institute of Health (grant BM 60826-02).]

◆ **Classification images for perceived brightness**
I Kurki, T Peromaa, J Saarinen, A Hyvärinen¶ (Department of Psychology, University of Helsinki, Finland; ¶ HIIT, Deparmtent of Computer Science & Department of Psychology, University of Helsinki, Finland; e-mail: ilmari.kurki@helsinki.fi)

Here, we introduce a novel method to estimate the stimulus features that determine perceived brightness, using the classification image (CI) method with a brightness matching task. MOCS with two-interval two-alternative paradigm was used. Subjects judged the brightness of a test stimulus, a circular luminance increment patch (contrast 30%; radius 0.33, 0.67, or 1.3 deg) masked by ring image noise (rms-contrast 10%; radius 0.66 – 2.6 deg) by comparing it to a comparison patch, whose luminance was varied (4 levels). CIs were computed by taking the average of the noise masks judged 'brighter than the standard' and subtracting from it the average of the noise masks judged 'not brighter'. This was done separately for each comparison luminance level. The CI was computed from the average of these sub-CIs. CIs reveal a peak inside the edge of the patch, suggesting that the brightness is largely determined by the edge information. The width of the peak was strongly dependent on the stimulus size, challenging the idea of a fixed brightness 'channel'.

◆ **Consistent grey-level ordering for iso-luminant and iso-saturated colours**
M Bloj, D Connah¶, G Finlayson¶ (Bradford Optometry Colour and Lighting Lab, School of Life Sciences, University of Bradford, UK; ¶ School of Computing Sciences, University of East Anglia, Norwich, UK; e-mail: m.bloj@brad.ac.uk)

If a red and a blue patch, of equal brightness and saturation are presented to participants, would they all assign a darker grey to the blue patch than to the red patch? In our experiments we selected 8 coloured patches in cone-opponent space that lay on a circle in the 20 cd m^{-2} plane, displayed on a calibrated CRT. Using heterochromatic flicker we established for each colour and each of our four participants their corresponding iso-luminant point and by adjustment their iso-saturation setting. Participants were presented (3 times) with all possible 56 pairs of colours and asked to set a grey level for each item in the pair. From the participants' grey settings we were able to recover their individual distance matrix for the 8 colours used. Three observers showed a high degree of inter- and intra-observer repeatability. The resulting distance matrices were roughly symmetrical (distance between AB the same as for BA). Applying multidimensional scaling to the distance matrix showed that the distances were well represented in a 1-D scale.
[Supported by joint EPSRC grants EP E012248 and EP E12159.]

OBJECT MOTION AND OPTIC FLOW

◆ **The robust nature of visual-vestibular combination for heading**
J S Butler, J L Campos, H H Bülthoff (Department Bülthoff, Max Planck Institute for Biological Cybernetics, Germany; e-mail: john.butler@tuebingen.mpg.de)

Passive movement through an environment typically involves a combination of several signals, including, visual and vestibular information. Recently it has been shown that if different sensory signals are spatially or temporally discrepant they may not combine in a statistically optimal fashion; however, this has not been evaluated for visual-vestibular integration. In this study, participants were seated on a Stewart motion platform and judged which of two heading intervals was more to the right. Motion/heading information (displacement, velocity and acceleration) was presented via stereo visual information alone, vestibular information alone or both cues combined. In the combined condition, the visual motion profile and the vestibular motion profile differed, therefore creating a discrepancy between the two signals. Specifically, the vestibular motion consisted of a raised cosine velocity profile, while the visual motion consisted of a constant velocity profile. The results show that visual-vestibular inputs combine in a statistically optimal fashion even if the motion profiles do not correspond.

◆ **Processing times for optic flow patterns measured by the saccadic choice task**
S J Thorpe, H Kirchner, S Crouzet, P Bayerl¶, H Neumann¶ (CerCo, CNRS-University Toulouse 3, France; ¶ Institute of Neural Information Processing, Ulm University, Germany; e-mail: simon.thorpe@cerco.ups-tlse.fr)

When two images are presented simultaneously left and right of fixation, subjects can saccade to the side containing an animal in just 120 – 130 ms (Kirchner and Thorpe, 2006 *Vision Research* **46** 1762). Here we used a similar choice saccade task to estimate processing times for various types of moving dot pattern. Two fields of jittering dots were presented on the left and right, then one or both fields started to move coherently at time 0. In Experiment 1, only one field moved coherently, and that was the target. Mean saccadic reaction times (SRTs) were 260 – 280 ms with minimum values ~90 ms. In Experiment 2, both fields started moving coherently, with either upward vs downward motion or expansion vs contraction. Performance was good when targeting upward or downward motion (accuracy ~86%, and minimum SRT ~200 ms). Interestingly, with expansion vs contraction, performance was much better with expansion as the target (accuracy 92%, mean SRT 246 ms, minimum SRT ~170 ms), suggesting that expansion is a particularly salient stimulus that can be processed very quickly.
[Supported by EU Project Decisions in Motion.]

◆ **Analysing the information about scene structure embedded in optic flow fields**
S Durant, J M Zanker (Department of Psychology, Royal Holloway University of London, UK; e-mail: szonya.durant@rhul.ac.uk)

Optic flow motion patterns can be a rich source of information about our own movement and about the structure of the environment we are moving in. In this work we analyse video sequences generated by physically moving a camera through various visual scenes. We show that the motion signal maps generated by a two-dimensional array of correlation-based motion detectors (2DMD) not only depend on egomotion, but also reflect the geometry present in the visual environment. For each movie sequence we constructed histograms of the directions of motion. Despite the substantial levels of noise affecting the motion signal distributions—attributed to the sparse nature of optic flow and the presence of irregular camera jitter—there are characteristic differences between different environments, such as indoor and outdoor scenes. In particular, common edge orientations in artificial man-made environments accentuate the cardinal motion directions. This approach aims to understand optic flow processing by analysing the statistics of motion signal distributions arising from real-life image sequences.
[Supported by EPSRC grant no. EPC0150611]

◆ **Non-retinotopic motion induced by a Ternus – Pikler display**
M Boi, T U Otto, H Ogmen¶, M H Herzog (Laboratory of Psychophysics, Brain Mind Institute, EPFL, Lausanne, Switzerland; ¶ Center for Neuro-Engineering and Cognitive Science, University of Houston, USA; e-mail: marco.boi@epfl.ch)

Motion processing is usually deemed to rely on retinotopic coordinates. Using a Ternus – Pikler display, we present an instance in which coherent motion of a dot can only be perceived when its position is integrated non-retinotopically. The stimulus consists of a traditional Ternus – Pikler display where three discs are perceived to move back and forth. Within the central disc, a dot is presented at a different position in each frame. The dot appears to rotate within the disc. This rotation is obliterated when the discs are perceived not to move, although the dot is presented at the same retinotopic positions as before. Hence, the perceived motion of the discs

is a prerequisite for the perception of the coherent motion of the dot. These findings challenge models of motion perception based exclusively on retinotopic coordinates and highlight the importance of grouping-based non-retinotopic reference frames in the computation of motion.

◆ **Illusory nonrigid motion of equidistant spokes rotating rigidly with constant speed within a static narrow ellipse in the frontal plane**
W A van de Grind (Helmholtz Institute & Functional Neurobiology, Utrecht University, The Netherlands; e-mail: w.a.vandegrind@uu.nl)

If four mutually perpendicular spokes rotate rigidly with constant angular speed within a narrow static ellipse, the angles between the spokes appear to vary with the phase of rotation. The spokes appear to accelerate and decelerate periodically. This illusory nonrigidity is qualitatively the complement of the nonrigidity of frontal plane motion if a slanted spoked wheel is projected on a frontal screen. Similar accelerations and decelerations can be seen for any number of equidistant spokes and the angular deformations can be seen for three or more. The ellipse might be used as a guide to do an inverse projective mapping of the rotating spokes onto a slanted plane. A projective interpretation is apparently valued more than rigidity. Contrast between the maximum and minimum angle during a revolution is perceptually underestimated for a strongly slanted wheel with rotating spokes. In the illusory case the perceptual deformations are smaller than expected from this baseline, more like a weighted average of the outcome of an inverse parallel projection and a frontal plane interpretation.

◆ **True to form: a reduced role for motion in biological motion**
M Thirkettle, C P Benton, N E Scott-Samuel (Department of Experimental Psychology, University of Bristol, UK; e-mail: m.thirkettle@bristol.ac.uk)

Human perception of biological motion from point-light walker (PLW) displays is often thought to be based upon some special motion-based capacity. Recent evidence, however, suggests that we simply recognize the form of the walker from the configuration of the dots. To address this issue we examined the temporal and spatial limits for successful perception of biological motion, and the impact the periodic variation in form inherent to the PLW has on performance. Thresholds for the successful detection of biological motion from a PLW in the absence of noise were similar to figures for low-level motion detection: approximately 50 ms (duration) and about 12 min of arc (spatial extent). Presenting different segments of gait, thereby exploiting the natural variation in PLW form, significantly affected detection performance and noise mask threshold levels. These variations in performance persisted even when all motion cues were removed from the stimulus. Our results suggest that, while motion may be used for grouping, biological motion is processed primarily through the inherent form in the PLW.

VISUALLY GUIDED HAND AND BODY MOTION

◆ **Walking in circles: the role of visual information in navigation**
J L Souman, I Frissen, M N Sreenivasa, M O Ernst (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: jan.souman@tuebingen.mpg.de)

Common myth has it that people who get lost in unfamiliar terrain end up walking in circles. We tested whether this is true and what role visual information plays. Participants walked for several hours under various conditions of visual information. Their task was to walk as straight as possible in the direction indicated at the beginning of the experiment. GPS was used to register their walking paths. Participants often walked in circles when blindfolded, although only few exhibited a consistent bias in one direction. In a forest, with ample visual information at short distance but few distant landmarks, participants walked in circles with overcast sky. However, with sunny weather they walked perfectly straight. In the Sahara desert, finally, participants only walked in circles during the night when the moon was not visible, but not when either moon or sun was visible. The results suggest that visual information is critical for walking straight. Furthermore, the mere availability of optic flow is not sufficient; participants needed distant landmarks to walk straight.
[Supported by EU project CyberWalk FP6-511092.]

◆ **Dynamics of pursuit and evasion in visually-guided locomotion**
W Warren, J Cohen, C Cinelli (Department Cognitive & Linguistic Sciences, Brown University, Providence, USA; e-mail: Bill_Warren@brown.edu)

The steering dynamics model successfully simulates human locomotor behaviour including steering and obstacle avoidance (Fajen and Warren, 2003 *Journal of Experimental Psychology: Human Perception and Performance* **29** 343 – 362), moving target interception (Fajen and Warren, 2007 *Experimental Brain Research* **180** 303 – 319) and moving obstacle avoidance (Cohen, Bruggeman, and Warren, in preparation). Here we ask whether the model generalizes to interactions between

two pedestrians during pursuit and evasion. Pairs of participants were covertly instructed to pursue or evade each other during walking, yielding five different scenarios: (a) interception, (b) evasion, (c) mutual evasion, (d) mutual pursuit, and (e) pursuit/evasion. Head trajectories were recorded using an inertial/ultrasonic tracking system. Surprisingly, the model accounted for these interactive scenarios quite well, with pursuit predicted by the target interception component and evasion predicted by the component for moving obstacle avoidance. This finding demonstrates the generality of the constant bearing strategy that underlies both components, and indicates that evasion does not require a qualitatively different strategy.
[Supported by NIH R01-EY10923.]

◆ **Visuomotor adaptation without sensory conflict nor sensory alteration**
D Laurent, R Laboissière, A E Priot¶, C Prablanc, C Tilikete (Unit 864, Espace et Action, INSERM, Bron, France; ¶ Institut de Médecine Aérospatiale, Brétigny-sur-Orge, France; e-mail: damien.laurent@inserm.fr)

Performing accurate limb movements requires adjusting mechanisms that continually tune the motor system. Here, we isolate a form of limb motor plasticity close to saccadic adaptation. Subjects reached targets that were turned off at orienting saccade onset, and that reappeared at a new location at limb movement end. By contrast with many reaching adaptation tasks our paradigm maintained a congruency between seen and felt limb position. Awareness and strategies were minimized by progressively increasing target perturbation amplitude. Thus this procedure mimicked unconscious saccadic adaptation paradigms, notwithstanding the lack of saccadic adaptation. Under these conditions adaptation exhibited a robust aftereffect that generalized to a large range of movements within the workspace. We looked for a possible perceptual effect generated by this adaptation, and tested the perceptual evaluation of a visual target location with respect to the exposed unseen limb. The lack of any perceptual shift shows that perceptual conflicts are not necessary for sensorimotor adaptation.

◆ **The influence of visual error reliability on motor learning**
R J van Beers (Department Physics of Man, Helmholtz Institute, Utrecht University, The Netherlands; e-mail: r.j.vanbeers@phys.uu.nl)

Motor learning is driven by movement errors. When a movement error is detected, this error is used to adjust planning of the next movement. For arm movements, vision is a major source of movement error information. How does the adjustment of movement planning depend on the reliability of the visual error signal? Subjects produced series of arm movements to a visual target with their unseen hand. After each movement they received visual feedback about their movement error. The reliability of the error feedback was varied across three conditions. The results show that corrections were made in all conditions, but the autocorrelation of the movement errors differed. Whereas it was strongly positive for unreliable error signals, it approached zero for highly reliable error signals. This suggests that the size of a correction increases with the reliability of the error signal. Using a stochastic model for trial-to-trial motor learning, it is shown that this is the optimal strategy to minimise movement errors in the presence of sensory and motor noise.

◆ **Motor inhibition and on-line control of reaching**
L Vainio (Department of Psychology, University of Helsinki, Finland; e-mail: lari.vainio@helsinki.fi)

Previous research has shown that orientation of graspable objects automatically elicits a motor program. When participants are presented with an object, manual responses are facilitated when the handle of the object is oriented towards the responding hand. The present study investigated inhibitory processes associated with the motor program elicited by an object's orientation. Participants selected the hand of response according to the identity of a graspable object, oriented towards the right or left hand, and then reached towards the location on which the object was presented. Reach initiation times were decreased when the object was oriented towards the responding hand. This positive compatibility effect turned into a negative compatibility effect during reach execution when the object was removed from the display (300 ms after its onset) or the object was replaced with a mask during response initiation. Perturbations in the object's orientation were not observed to influence reach execution times. These results demonstrate that interrupted visually-driven updating of an ongoing reach movement triggers inhibitory responses.

CLINICAL VISION

◆ **Comparison of the effectiveness of visual and phonological treatments for children with SRD**
R E Pye, P M Riddell (School of Psychology & Clinical Language Sciences, University of Reading, UK; e-mail: r.e.pye@rdg.ac.uk)

A variety of treatment programmes have been suggested to help improve reading ability in SRD, also known as developmental dyslexia. While cognitive-level phonological training programmes are favoured, visual treatments for SRD are controversial. In a longitudinal treatment study, we attempted to determine whether visual and/or phonological task performance predicted which children with SRD would benefit from either a phonological or visual treatment. Compared to control children ($N = 73$), SRDs ($N = 63$) did not perform significantly more poorly on predictor tests of vision (motion coherence detection and visual search), but did on tests of phonological awareness. However, when comparing the effectiveness of coloured-lensed glasses to phonological training, with SRD children ($N = 51$), only the visual treatment led to improved reading over an eight-week period. Motion coherence detection threshold improvement over the treatment period correlated with reading improvement in the visual treatment group, but not the phonological or both treatment groups. This demonstrates that remediation of visual deficits using a visual treatment leads to a significant improvement of reading ability.

◆ **Impaired facilitation and suppression in dyslexia during perceptual rivalry**
V Manahilov, P Lee, A Black, K Rychlewska, N Northway, U Shahani (Vision Sciences, Glasgow Caledonian University, UK; e-mail: V.Manahilov@gcal.ac.uk)

We studied the dynamics of perceptual rivalry using a Rubin vase-face image. Non-dyslexics ($N = 8$) and dyslexics ($N = 8$) performed a standard passive rivalry task and tasks requiring attentional control by holding or switching the dominant percept. Dominance durations of both subject groups in the standard passive rivalry task were not significantly different. Non-dyslexics approximately doubled the dominance durations in hold conditions and halved the dominance durations in switch conditions as compared with those in the standard rivalry task. This suggests increased suppression of the non-dominant percept in hold conditions and increased facilitation of the non-dominant percept in switch conditions. Dyslexics, however, showed significantly weaker effects of attentional control: the dominance durations were increased by 43% in hold conditions and reduced by 27% in switch conditions. These findings suggest that dyslexics have reduced abilities to control the facilitative and suppressive processes during perceptual rivalry.

◆ **A what/where visual-to-audtiory sensory substitution fMRI study: can blind and sighted hear shapes and locations in the visual cortex?**
A Amedi, W Stern¶, E Striem, U Hertz, P Meijer§, A Pascual-Leone¶ (Department of Physiology, Faculty of Medicine, The Hebrew University of Jerusalem, Israel; ¶ Berenson-Allen Center for Noninvasive Brain Stimulation, Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, USA; § NXP Semiconductors, High Tech Campus 31, Eindhoven, The Netherlands; e-mail: amir.amedi@ekmd.huji.ac.il)

In sensory substitution devices (SSDs), visual information captured by an artificial receptor is delivered to the brain using non-visual sensory information. Using an auditory-to-visual SSD called 'The vOICe' we find that blind achieve successful performance on object recognition tasks, and specific recruitment of ventral and dorsal 'visual' structures for shape versus localization tasks. Comparable recruitment was observed also in sighted learning to use this device but not in sighted learning arbitrary associations between sounds and object identity. These results support the notion that visual structures can support relevant computations in the auditory modality if subjects can extract relevant information and proper training is applied. We also find using phase locking Fourier Techniques an array of topographic maps which can serve as a basis for such audio-visual integration. These results suggest 'The vOICe' can be useful for blind individuals' daily activities but it also has a potential use to 'guide' visual cortex to interpret visual information arriving from prosthesis.

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◆ **Arm position does not attenuate visual loss in patients with homonymous field deficits**
D T Smith, A R Lane, T Schenk (CNRU, Wolfson Research Institute, Durham University, UK; e-mail: daniel.smith2@durham.ac.uk)

A common consequence of stroke is contralesional visual loss (hemianopia) which clinicians typically regard as irreversible. However, Schendel and Robertson (2004 *Journal of Cognitive Neuroscience* **16** 935–944) reported that a hemianopic patient (WM) experienced significant recovery of vision when the contralesional arm was extended into the blind field. They suggest that stimuli near this arm recruited bimodal neurons whose activity was sufficient to bring the stimulus into awareness. This result has enormous potential therapeutic value but there are

reasons to be cautious about interpreting the data. WM has considerable visual sparing, his visual field was not assessed prior to testing and the original study did not adequately control for criterion-shifts or guessing. We investigated the effects of manipulating arm position on visual loss in five densily hemianopic patients while controlling for these confounds. None of our patients experienced visual recovery in the blind field. We suggest that WMs improvement reflected a spatial bias towards his extended arm and conclude that manipulating arm position is of little therapeutic value to densely hemianopic patients.

◆ **Visual field maps in a subject without an optic chiasm**

S O Dumoulin, Y Masuda, H Horiguchi, R F Dougherty, S Prakash¶, Y J Liao¶, B A Wandell (Department of Psychology [¶ Department of Ophthalmology], Stanford University, USA; e-mail: dumoulin@white.stanford.edu)

Signals from the two eyes cross at the optic chiasm, producing the characteristic hemifield maps in primary visual cortex (V1). We report the V1 map in a subject born without an optic chiasm. The achiasmic subject had normal visual fields but a 1 – 4 Hz nystagmus of about 10deg in amplitude. We measured fMRI responses. To verify the achiasma, we presented full-field checkerboards to each eye, singly. We reconstructed his visual field maps using the population receptive field (pRF) method (Dumoulin and Wandell, 2008 *Neuroimage* **39** 647 – 660). Results. Stimulation of either eye resulted in ipsilateral fMRI signals only, confirming functional achiasma. The pRF method showed that both hemispheres contained a full map of the visual field; ipsi- and contra-lateral visual field maps were topographically preserved but intermixed in V1. In conclusions we can confirm the anatomical diagnosis of achiasma and we found atypical V1 maps. This subject made effective use of his vision, including sports activities and reading. Hence, these highly atypical visual field maps did not prevent basic visual functions.

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Tuesday

ORAL PRESENTATIONS

TEMPORAL STRUCTURING OF ATTENTION AND MEMORY

◆ **Consistency in cue lead times between trials improves performance on discrimination tasks involving transient attention**

A Kristjansson (Department of Psychology, University of Iceland, Reykjavic, Iceland; e-mail: ak@hi.is)

Our visual system clearly likes consistency. Observers respond more accurately to targets in visual search tasks that share properties with previously presented items (Maljkovic and Nakayama, 1994 *Memory & Cognition* **22** 657 – 672). Transient attention is allocated preferentially to parts of cues where targets have appeared on previous trials, irrespective of the absolute location of the cue (Kristjánsson and Nakayama, 2003 *Perception & Psychophysics* **65** 711 – 724). We assessed whether transient visual attention has similar preferences for repetition of cue lead times in a cued discrimination task. Observers performed a cued Vernier discrimination task with brief cues (50 to 200 ms). The critical question was whether performance would be modified if the cue lead times (CLTs) would remain constant between trials or if they changed. The results showed that if the CLTs remained constant performance improved while changes in CLTs from one trial to the next led to worse than average discrimination performance. The results indicate that transient attention prefers temporal regularities, similarly to spatial and featural regularities.

◆ **Modelling the formation of attentional episodes: it's about time**

B Wyble, M Potter, H Bowman¶, M Nieuwenstein§ (Department of Brain and Cognitive Sciences, MIT, Cambridge, USA; ¶ Centre for Cognitive Neuroscience and Cognitive Systems, University of Kent, Canterbury, UK; § Department of Cognitive Psychology, Vrije Universiteit, Amsterdam, The Netherlands; e-mail: bwyble@gmail.com)

A computational model (Bowman and Wyble, 2007 *Psychological Review* **114** 38 – 70) proposes that attention and memory interact to enhance the episodic structure of visual experience by producing an attentional blink. A recent variant of this STST model (eSTST), proposes that the duration of an attentional episode can vary to encompass a series of rapidly presented targets, but a 150 ms break between any two targets elicits a blink of attention to temporally segregate later stimuli. A prediction of this model is counterintuitive; four targets presented in a 400ms chunk (DDTTTTDDD) are better remembered than targets presented as a distributed 700 ms (DTDTDTDTD) sequence. Experimental evidence confirms this prediction with mixed blocks that vary SOA and intervening distractors independently. With a 200 ms separation between target onsets, a blink begins and does not recover. Targets arriving within 100 ms exhibit no blink, with or without intervening distractors. These results support our computational theory describing how the momentary deployment of attention is dictated by the temporal and episodic characteristics of the arrival of task-relevant stimuli.

◆ **A boost and bounce theory of temporal attention**

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What is the time course of visual attention? Attentional blink studies find that the second of two targets is often missed when presented within about 500 ms from the first target, suggesting the existence of capacity limitations or bottlenecks. Earlier studies, however, have reported quite the opposite finding: attention is transiently enhanced, rather than reduced, for several hundreds of milliseconds after a relevant event. Here we present a theory that integrates these contradictory findings. There is no central role for capacity limitations or bottlenecks. Instead, a gating mechanism causes relevant events to trigger excitation, whereas distractors trigger inhibition. The attentional blink occurs because the first target results in the strong enhancement (boost) of the following distractor, which in turn results in strong inhibition (bounce) of subsequent items. The theory explains many findings that are problematic for limited-capacity accounts.

◆ **Limits to the use of iconic memory**

R A Rensink (Department of Psychology, University of British Columbia, Vancouver, Canada; e-mail: rensink@psych.ubc.ca)

Do all visual processes use iconic memory equally well? Search for a given target was carried out on displays that were continually interrupted: After a fixed display time (on-time), the display was blanked for a brief interval (off-time); this was repeated until the observer responded or timed out. The question is whether performance is affected when observers use iconic memory for different fractions of the display cycle. On-times varied between 80 ms and 200 ms; off-times between 120 ms and 240 ms. Results: For detection of a fixed target, search was unaffected by

off-times as long as 240 ms. For detection of a changing target, search proceeded while the stimuli were visible plus an additional 110 ms. After that it was suspended, even though the information was still available in iconic memory. Conclusions: Iconic memory can last at least 240 ms, but some processes (likely those involving feedback loops) cannot use it beyond a limit of 110 ms.
[Supported by Nissan Motor Co., Ltd (Japan) and NSERC (Canada).]

◆ **Reward primes visual search**
C Hickey, J Theeuwes (Department of Cognitive Psychology, Vrije Universiteit Amsterdam, The Netherlands; e-mail: c.hickey@psy.vu.nl)
Adaptive behaviour requires that we deploy attention to behaviourally relevant objects in our visual environment. For this to occur the relevance of stimuli must be quickly assessed, but it is not well understood how this occurs. Generally, we adopt strategies and choose actions that in prior experience have resulted in rewarding outcome, a principle that has been formalized in reinforcement learning theory. Here we demonstrate that visual attention is guided by a similar economic algorithm. We find that covert selection of an object is speeded when its features have been associated with large-magnitude monetary reward in immediately preceding experience, but that selection of the same object is slowed when its features have been associated with less-than-optimal reward. Critically, these biases are not under volitional control; attention is deployed in this fashion when participants are consciously aware that the strategy is detrimental to performance. Reward thus appears to prime visual attention independent of its contribution to cognitive strategy, suggesting that the experience of reward changes responses in low-level visual cortex.

◆ **When meaning matters: the effects of images in decision-making**
N A Peatfield, J Intriligator (School of Psychology, Bangor University, UK; e-mail: psp418@bangor.ac.uk)
Decision-making (DM) has been conceptualised as a rational, and more recently an emotional process, eg Iowa gambling task (IGT) (Bechera et al, 1994 *Cognition* **50** 7 – 15). In the IGT participants choose between two 'good' decks and two 'bad' decks, over time choosing the 'good' more than the 'bad'. Our studies investigate the contribution vision makes in DM and how DM reward/punishment associations can create meaning towards images. We used modified IGTs, with the main difference being the superimposing of meaningful images (eg faces, brands, etc) on the decks. Additionally we used techniques (explicitly and implicitly) to assess the meaningfulness of images and their impact on DM. We found that participants could not ignore meaningful images. In fact, their inclusion could make participants perform irrationally. Furthermore, over the course of the DM procedure neutral images acquire meaning. Results suggest meaningful images overwhelm the somatic markers that might develop during the IGT. We discussed these results in terms of the relationship between, meaning, attention, and emotion.

OBJECTS, FACES AND SHAPES

◆ **Impaired perception of biological motion in prosopagnosia**
J Lange, M Lussanet¶, S Kuhlmann¶, A Zimmermann¶, M Lappe¶, P Zwitserlood¶, C Dobel§ (F C Donders Centre for Cognitive Neuroimaging, Radboud University Nijmegen, The Netherlands; ¶ Department of Psychology [§ Institute for Biomagnetism and Biosignalanalysis], University of Münster, Germany; e-mail: j.lange@fcdonders.ru.nl)
Prosopagnosia is most prominently characterised by a deficit in recognizing familiar faces. The term congenital prosopagnosia (CP) refers to a form of prosopagnosia in which the deficit is present from early childhood on without any apparent brain damages. Since other sensory and perceptual abilities and cognitive functioning seem not or much less impaired, CP is considered to be an exclusive deficit of face processing. Biological motion perception, however, shares a number of similarities with face perception, such as configural processing, the inversion effect, and activation of similar cortical areas. We tested individuals with CP and a matched control group with a test battery of biological motion stimuli, eg silent lip-reading or recognition of point-light walkers. The members of the CP group showed severe deficits in several tasks. These findings demonstrate that CP involves damage to a domain-general mechanism that is not exclusively related to face perception. Thus, the perception of faces and biological motion stimuli may share a common neural network which is impaired in CP.

◆ **Shape-frequency and size aftereffects: same or different mechanism?**
F A A Kingdom, E Gheorghiu, E Witney (McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, Canada; e-mail: fred.kingdom@mcgill.ca)
The shape-frequency aftereffect (or SFAE) is the phenomenon in which adaptation to a sine-wave-shaped contour causes a shift in the apparent shape frequency of a test contour away from that of the adapting stimulus (Gheorghiu and Kingdom, 2007 *Vision Research* **47** 834–844). The SFAE is the shape analog of the well-known size, or luminance spatial-frequency aftereffect (LFAE) discovered by Blakemore and Sutton (1969 *Science* **166** 245–247). It is widely believed that the LFAE is mediated by luminance spatial-frequency-selective channels, while it has been suggested that the SFAE is mediated by curvature-selective channels. However both aftereffects might be mediated by the same mechanism, even though the stimuli involved have little Fourier energy in common. We measured SFAEs using sine-wave-shaped contours and edges, and LFAEs using sine-wave, square-wave and line luminance gratings. We found that the aftereffects were much lower when adaptors were luminance-defined and tests shape-defined compared to when adaptors and tests were of the same type, suggesting that SFAEs are LFAEs are mediated by different mechanisms.
[Supported by a NSERC (Canada) grant given to FK.]

◆ **Local position representation for complex images**
H Galperin, P Bex¶, J Fiser§ (Department of Psychology [§ Volen Center for Complex Systems], Brandeis University, Waltham, USA; ¶ Schepens Eye Research Institute, Harvard Medical School, Boston, USA; e-mail: hgalp@brandeis.edu)
We examine how local position information of different complex scenes is represented in the visual system. A 2AFC paradigm was used to examine internal noise and sampling efficiency for three classes of stimuli: natural objects, fractal patterns and random circular patterns, all synthesized from the same set of Gabor wavelets. Each trial, a noiseless source image was presented first for 1 s, followed by a reference image that contained a fixed amount of external position noise (s) on each element, and a target image containing additional position noise ($s + Ds$) under the control of a staircase. Subjects identified the image with more noise. Equivalent noise functions fitting the results indicated approximately identical internal noise but sampling efficiency that increased with predictability across image classes. This suggests a flexible position representation that compares the observed structure with prior experience.

◆ **Perceived properties of $1/f^{\beta}$ noise surfaces**
P R Green, P Shah¶, S Padilla¶, M Chantler¶ (School of Life Sciences [¶ School of Mathematical and Computer Sciences], Heriot-Watt University, Edinburgh, UK; e-mail: P.R.Green@hw.ac.uk)
We report results from experiments investigating the relationships between physical properties of surface textures and their visually perceived roughness. The textures are of a novel kind; densely sampled two-dimensional $1/f^{\beta}$ noise processes are used to create surface height maps, which are rendered using combined point-source and ambient lighting to give images that strongly resemble surfaces of natural materials such as stone. At the same time as having a natural appearance, these images are fully parameterised and controllable. Surfaces are shown in motion to provide rich cues to their relief, and are generated in real time to enable observers to manipulate surface parameters dynamically. A method of adjustment is used to investigate the effects of the two surface parameters, magnitude roll-off factor and RMS height, on perceived roughness. The results are used to develop a model for perceived roughness of these surfaces, based on Gaussian bandpass filtering of the height spectrum. After using isotropic surfaces in these first experiments, we then extend the model to surfaces with directional height spectra.

◆ **A cognitive model for face perception**
A Ishai (Institute of Neuroradiology, University of Zurich, Switzerland; e-mail: ishai@hifo.uzh.ch)
Face perception elicits activation within a distributed cortical network in the human brain. The network includes visual (core) regions, which process invariant facial features, as well as limbic and prefrontal (extended) regions, which process changeable aspects of faces. Analysis of effective connectivity reveals that the major entry node in the face network is the fusiform gyrus and that the functional coupling between the core and the extended systems is content-dependent. Thus, viewing emotional faces increases the neural coupling between the fusiform gyrus and the amygdala, whereas viewing famous faces results in increased effective connectivity between the fusiform gyrus and the orbitofrontal cortex. A model for face perception is proposed, which postulates bidirectional connections between all face-responsive regions and further assumes that the flow of information through the network is stimulus- and task-dependent. New testable

predictions are suggested: viewing animated faces would increase the effective connectivity between the superior temporal sulcus and the inferior frontal gyrus, whereas viewing disgusted faces would increase the coupling between the fusiform gyrus and the insula.
[Supported by Swiss National Science Foundation grant 3200B0-105278.]

◆ **Global form integration in the ageing visual brain**
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Despite the ease with which we identify objects in complex environments, the computation of meaningful global forms from local image features is a challenging task for the visual system. Here, we investigate the behavioural and neural changes in our ability to perceive global forms with ageing. We use Glass patterns, parametrically varying the perceived global form (eg concentric, radial) whilst ensuring that the local statistics remain similar. Our findings show decreased sensitivity for the detection of global forms with age that is associated with enhanced fMRI activation in fronto-parietal areas while decreased activation in ventral occipitotemporal areas in older participants. Sensitive multivariate methods for fMRI data analysis show that mainly dorsal occipitotemporal areas contain information that allow us to discern global form patterns (eg concentric vs radial) in both young and old participants. Thus, our findings suggest that global form perception is mediated by selective neural populations in dorsal visual areas across the life span and supported by enhanced processing in a fronto-parietal network in older age.

POSTERS

ANALOGOUS CONCEPTS IN HAPTICS AND VISION

◆ **Attending to tactile, visual or bimodal targets: effects on the P3 and the relevance for brain machine interfaces**
A M Brouwer, J van Erp, F Aloise¶, F Cincotti¶ (TNO Human Factors, Soesterberg, The Netherlands; ¶ Laboratory of Neuroelectrical Imaging, Fondazione Santa Lucia IRCCS, Rome, Italy; e-mail: anne-marie.brouwer@tno.nl)
The P3 is a peak in EEG occurring after the presentation of a target. Research has focused on visual and auditory P3s. However, for controlling brain machine interfaces, tactile P3s are more suitable since tactile stimuli are not noticed by others and keep the user's eyes and ears free. We investigated P3s in response to tactile and visual stimuli unimodally, and bimodally. The tactile stimulus was a burst of vibration delivered by one of eight tactors around the waist. The analogous visual stimulus was a flashed circle in a schematic representation of the tactor layout. Participants attended to the vibrations and/or flashes of the target presented amongst non-targets. Tactile targets evoke stronger P3s than visual targets on frontal and central electrodes; the opposite happens on the occipital channel. Visuo-tactile stimuli only modestly strengthened the P3. We conclude that tactile stimuli applied to the waist are suitable to elicit P3s and have great potential for use in BMIs. In a follow-up study, we demonstrate this by building an example BMI.
[Supported by the Braingain Smartmix project.]

◆ **Driving with reduced visual acuity and a bioptic telescope in the Netherlands**
B J M Melis-Dankers, A C Kooijman¶, W H Brouwer§, R A Bredewoud#, J M D Witvliet (Royal Visio, National Foundation for the Visually Impaired and Blind, Huizen, The Netherlands; ¶ Department of Ophthalmology [§ Department of Psychology], University Medical Center Groningen, The Netherlands; # Netherlands Bureau of Driving Skills Certificates (CBR), Rijswijk, The Netherlands; e-mail: BartMelis@visio.org)
In Europe, driving a car is prohibited if binocular visual acuity is below 0.5 (20/40). Some US states allow the use of a bioptic telescope when driving. Our project aims to introduce bioptic driving in the Netherlands. After a pre-selection process based on available medical information, thirty-six subjects (visual acuity: 0.16 – 0.5) were invited for assessment (vision, mobility, neuropsychological, motivation and driving skills). Sixteen subjects did not meet the inclusion criteria and two decided not to participate. Eighteen subjects were trained to use a monocular bioptic telescope (3× magnification). They all completed the pre-driving training successfully and received driving lessons from specialised driving instructors. Nine subjects passed the official practical fitness to drive test. Seven were excluded after driving lessons, and two withdrew on their own initiative. This is the first study in Europe to prepare subjects with reduced visual acuity to drive with the use of a bioptic telescope. Half of the subjects who entered the bioptic training program passed the official fitness to drive test.

◆ **Visual and haptic perception of parallelity in adults**
I Hansen, H Jeurissen, H I van Mier (Faculty of Psychology, Cognitive Neuroscience, Maastricht University, The Netherlands; e-mail: i.hansen@student.unimaas.nl)
Research in adults has revealed that haptic perception of parallelity deviates from physical reality. This is most likely caused by the egocentric influence of the hands. In this study we examined the effect of informative vision, providing apparent allocentric cues. We expected that the latter would result in higher accuracy. Twenty blindfolded adults performed a haptic parallelity task (task HP) by rotating a test bar in such a way that it felt parallel to a reference bar. The influence of informative vision was investigated by allowing participants to look at the test bar, while the reference bar was blocked from their view (task VH). In both tasks, the distance between and orientation of the bars was manipulated. Participants performed significantly better in the visual haptic task. Significant effects of distance and orientation were found, although these effects were significantly larger in the haptic parallelity task. The results clearly showed that informative vision led to more accurate performance probably by reducing the egocentric bias due to using allocentric cues.

◆ **Observers vary movement parameters in active touch depending on stimulus stiffness**
L Kaim, K Drewing (Institute for Psychology, Giessen University, Germany; e-mail: lukas.kaim@psychol.uni-giessen.de)
This study investigates the influence of stimulus properties on movement control in active perception. We studied exploratory movement parameters in haptic perception of stimuli with different stiffness values. Virtual stimuli were generated using a PHANToM force-feedback device. Participants freely explored pair-wise presented stimuli and were asked to select the softer one. Afterwards we analyzed their exploratory movements considering the parameters velocity, pressure and the indentation depth. We found a systematic influence of stimulus' stiffness on pressure/indentation depth and velocity. We conclude that observers adapted the movement parameters depending on stiffness variations. We discuss whether such adaptation might serve to optimize perception, extending optimal observer models known from vision towards active touch.
[Supported by DFG, DR 730 1-1, FOR 560]

◆ **Perception of acceleration and deceleration in visual, tactile and visuo-tactile stimuli**
M Jacono, M Gori, A Sciutti, G Sandini, D Burr¶ (Istituto Italiano di Tecnologia, Genoa, Italy; ¶ Dipartimento di Psicologia, Università degli Studi di Firenze, Italy; e-mail: marco.jacono@iit.it)
Psychophysical literature suggests that the human visual system is more sensitive to speed than acceleration (the temporal derivative of velocity). However few studies consider tactile perception of acceleration and none of them analyzes the visual–tactile modality. Here we investigated visual, tactile and bimodal perception of acceleration/deceleration by measuring speed discrimination over a wide range of transient speeds (from 6.8 to 454 cm s^{-1}). The stimuli were physical wheels etched with sinewave profile. They could be seen, felt or concurrently seen and felt. Subjects were presented sequentially with the standard stimulus, characterized by a fixed final velocity and variable accelerations and with the comparison test, which reached different final velocities with maximal acceleration. Subjects had to evaluate in 2AFC protocol which interval contained the faster movement, using only visual, only tactile or bimodal information. We found similar PSEs among visual, tactile, and bimodal tasks considering all the different accelerations. Moreover we investigated the difference between deceleration and acceleration and the integration of bimodal signals characterized by opposite direction of motion.

◆ **Memory capacity for haptic common objects**
T Nabeta, T Kusumi (Department of Cognitive Psychology, Kyoto University, Japan; e-mail: nabeta@educ.kyoto-u.ac.jp)
Classical studies have shown that humans can correctly remember a large number of objects in the visual domain. However, very little is known of the haptic domain. This study examined the capacity and modality specificity of haptic memory. Fifty-nine subjects participated in an experiment consisting of haptic-learning and recognition-testing phases. In the learning phase, 100 or 500 common objects were presented via a haptic modality. In the recognition test, these objects and distractor objects were presented via haptic or visual modalities. Two main results were obtained. (i) In the haptic test, recognition sensitivity (d') after learning 100 or 500 objects was comparable, and (ii) d' in the haptic test was greater than that in the visual test. The results showed that the memory capacity for haptic objects is nearly 500. In addition, the capacity of haptic memory depends on a modality-specific system, suggesting that the memory of common haptic objects contains object features specific to that modality.

◆ **Strength of saccade deviation as an indicator of the amount of visual attention allocated in space**

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By using a modified exogenous and endogenous cueing task, we present evidence that the strength of saccade deviation can represent an important measure that can reveal the amount of attention allocated to any particular location in time. In the endogenous version of the cueing task, eye movements to a different location in space deviated away from a possible target location. However, this deviation was stronger for the cued than for the uncued location. In the exogenous version of the cueing task, an abrupt onset cue indicated the target location at chance level. When there was a delay between the cue and the target, the amount of saccade deviation away was stronger for the uncued than for the cued location, signifying the occurrence of inhibition of return at the cued location. Because attentional allocation evokes activity in the oculomotor system, this activity has to be inhibited in order to execute an eye movement to a different location. Stronger inhibition then leads to stronger deviations.

◆ **Revisiting the fingertip – fovea analogy**

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Foveated perception refers to the ability to cyclically attend to small samples of the world at high resolution. Yet, the conscious experience is that of a stable and uniform world. 'Foveated touch' could be similar to foveated vision. When scanning a textured surface with several fingers, one feels a single surface, not several; in vision, a textured surface looks uniform, not like a collection of patches. Vision can give rise to visual suppression of image displacement, or failure to detect absolute displacement of a feature. We investigated what could be called tactile suppression of stimulus displacement. We designed an experiment where subjects scanned a single Braille dot with two fingers, but the stimulus changed absolute location during the short instant when the contact left one finger and shifted to the other. There were instances when the perceptual system did not accurately remap the stimulus during the transition from one finger to the other and failed to detect the change, thereby making the world appear more stable than it really was.

ATTENTION AND RELATED ISSUES

◆ **Timescale-invariant neural response properties yield 'stack'-memory behaviour**

A J Noest, R van Ee¶, R van Wezel (Functional Neurobiology [¶ Physics of Man], Helmholtz Institute, Utrecht University, The Netherlands; e-mail: a.j.noest@bio.uu.nl)

The world contains dynamical structure over a vast range of timescales, and evolution is likely to favour exploiting as much structure as possible without incurring too much physiological cost. In neural signal processing, multi-timescale response properties are actually almost 'for free': For example, they arise already at the level of ion-channel state-dynamics. This invited our theoretical approach, which analysed the problem on three interrelated levels: (i) Starting from minimal functional and neural feasibility demands, we derived the appropriate filter-kernels, which proved to have power-law structure. In contrast to existing temporal scale-space constructions, ours avoids problems of timescale-selection. (ii) Considering realisations, we showed how various types of basic neural machinery generate members of our family of kernels, with their singularities suitably 'tamed'. (iii) Analysing simple models incorporating these kernels, we not only recovered many experimental results, but also found the striking property of 'stack'-memory: Behaviour in the near future depends on the recent past, while the more distant future depends on the more remote past [as found by Brascamp et al, 2008 *PLoS One* **3**(1) e1497].

◆ **Effects of form and category information in RSVP-task**

A Köpsel, F Fährmann, T Bachmann¶, A Huckauf (Faculty of Media, Bauhaus University Weimar, Germany; ¶ Department of Psychology and Estonian Center of Behavioral and Health Sciences, University of Tartu, Estonia; e-mail: anne.koepsel@medien.uni-weimar.de)

In rapid serial visual presentation (RSVP) tasks, streams of equal letters (eg 'I') are presented which are interrupted by one target. The usual task in such settings is temporal order judgement, that is, the specification whether target in stream or single target is presented earlier. However, this task is prone to response biases. We investigated which information of the targets in streams except their temporal sequence can be extracted from the display. Therefore, we added other tasks which were to be executed by the same participants for the same presentations: temporal

order judgement, a form judgement (round versus angular), or a category judgement (letter versus digit). Given an observer correctly judged the temporal order, the probability of having perceived the form and the category at more than 80% correct relatively large. Hence, response biases seem to be less problematic in temporal order judgement tasks than expected. The data support the notion that form and category information are automatically processed in alphanumerical symbols.

◆ **Multiple single pulse TMS to V1 has locally desensitizing effect for scotomas**
C Murd, I Luiga¶, K Kreegipuu, T Bachmann¶ (Institute of Psychology [¶ Institute of Public Law], University of Tartu, Estonia; e-mail: Carolina.Murd@ut.ee)

Scotomas in brief coloured gratings were induced by transcranial magnetic stimulation (TMS) to study carryover and adaptation effects. Biphasic single pulse TMS was applied over V1 with 35, 94, or 199 ms interstimulus intervals (ISI). Thus, V1 was stimulated 3×60 times: to one pre-established stimulation location in one hemisphere (selected randomly, I block) then turned to the other hemisphere for a symmetrical location (II) and returned to the firstly stimulated hemisphere location (III). Nine observers drew a scotoma and rated its contrast each trial. Scotomas were the largest with 94 ms ISI, especially when the left hemisphere was stimulated. The size of scotomas was larger in the I block compared to the III block. In the II block the scotomas were not smaller. The contrast of the scotoma region of the stimulus was the lowest in the I and higher in the III block. Therefore, V1 became less sensitive to TMS as we found less pronounced scotomas after 60 trials of stimulation to one location. The adaptation effect of vision impairment was location-specific.

◆ **Late retroactive influence of attention on processing in human early visual cortex**
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Although we are unable to report all the details of a briefly presented visual display, a cue presented after its disappearance can allow us to retrieve any subset of this display (Sperling, 1960 *Psychological Monographs* **74**). Although this intriguing phenomenon has been studied for several decades, its neural bases remain elusive: does the cue simply allow a 'readout' of a fading information buffer, or does it act directly on the ongoing visual processing? To explore these questions, we performed an fMRI experiment in which participants were asked to report what they saw in one of the four quadrants of a briefly presented visual display using an auditory cue played several hundred milliseconds after the display was removed. The results show that successful report of the visual information corresponds to an increased activity in early visual cortex following this auditory post-cue in the region coding for the cued quadrant. This suggests that spatial attention can bias ongoing visual processing several hundred milliseconds after the visual input has been removed.

◆ **Pip and pop: non-spatial auditory signals modulate spatial visual selection**
E Van der Burg, C N L Olivers, A W Bronkhorst¶, J Theeuwes (Cognitive Psychology, Vrije Universiteit Amsterdam, The Netherlands; ¶ TNO Human Factors, Soesterberg, The Netherlands; e-mail: e.van.der.burg@psy.vu.nl)

Visual attention is drawn to visual objects that stand out from the background, such as a red object among green objects. When such clear bottom – up signals are absent, top – down control may play a larger role, such that knowledge on the visual properties relevant to the task determine which object is selected. In the present study we show that a signal that is neither low-level visual, nor provides any top-down knowledge on the location or identity of the visual target object, still affects the selection of that object. We demonstrate that a non-spatial auditory event (a 'pip') can guide attention towards the location of a synchronized visual event that, without such an auditory signal, is very hard to find. Phenomenally, the pip makes the visual target pop out from its complex environment. This 'pip and pop' effect, as we have dubbed it, is not due to general alerting. Instead, we propose that the effect is due to audiovisual integration. The present study provides evidence that non-spatial sounds affect spatial visual selection.

◆ **Congruency of gaze capturing events modulates the attended field of view**
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Directing gaze to the most informative regions in an image is expected to optimize visual communication. Directing gaze can be done by attracting it by presenting brief gaze capturing events (GCE). Past research has indicated that GCE effectiveness is affected by GCE congruency as

well as the size of the attended field of view. Here, we wondered whether expected cue congruency influences the size of the attended field of view. Subjects performed a dynamic continuous search task while their gaze position was being tracked. During the search task, an abruptly appearing GCE was presented at a random time and location. GCE congruency was varied between 0, 10, 50 and 100%. A free viewing task served as a control condition. We found that GCE effectiveness in the fovea and parafovea was little influenced by congruency. In contrast, in the peripheral visual field, capture effectiveness at 100% congruency approached 100%, whereas it approached chance level at 0% congruency. We conclude that GCE congruency strongly modulates the attended field of view.
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◆ **The capture of attention by match to attentional set and by deviation from expectation**
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Involuntary capture of attention has been assumed to involve visual salience (VS), side effects of attentional set (AS), and expectancy deviation (ED). I report on experiments that test the AS and ED hypotheses, while excluding VS as a factor by presenting only two items in each trial. AS was manipulated defining the target and the non-target by colour (eg green and red), with the test stimulus being similar to the target or distractor set (eg turquoise or violet); ED was varied by contrasting these two colours with a quite different colour (blue). The participants were naive as to the first presentation of the test stimulus. Dependent variable was inattentional blindness (IB) for the new colour, indicating the failure of attentional capture. It was found that IB was not strongly dependent on AS, but on ED. These results imply that ED can outplay AS in determining IB and attentional capture. Moreover, they reveal that ED affects attention even in the absence of VS.
[Supported by DFG grant Ho 3248 1-3 to GH.]

◆ **Hemifield and hemisphere asymmetries in endogenous spatial attention: fNIRS study**
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Our previous study reported the visuospatial attention asymmetry about visual hemifield, where a higher attentional load increased hemodynamic responses in the posterior cortex and the increase was larger when attending left visual hemifield. In order to investigate the cause of the asymmetry, we examined the relationship between the behavioural performance of attentional tracking task and cortical activation. Stimuli consisted of four radial gratings positioned around the fixation point. Twenty normal adults tracked rotation of the one or two grating(s) indicated by cue stimuli. After 10 s rotation, tracking accuracy was tested by 2AFC questions. fNIRS probes were positioned on the posterior part of participants' head. We measured oxy-Hb from 24 measurement points simultaneously. Higher attentional load increased cortical activation in the participants with higher tracking performance, and decreased it in the participants with lower performance. This trend was conspicuous in the left posterior parietal cortex when attending right visual hemifield, which suggested the hemispheric asymmetry about attentional resource control for each visual hemifield.

◆ **Contralesional impairment in temporal feature integration following cortical and subcortical lesions**
I Arend, R Ward, R Rafal (School of Psychology, Bangor University, UK;
e-mail: i.arend@bangor.ac.uk)
When participants are asked to report a target defined by a combination of features presented by means of rapid serial visual presentation (RSVP) they often report the feature that is either preceding or following the target as being the target feature. These temporal binding errors are often accompanied by high levels of confidence so that participants are surprised with the mismatch between their perceptual experience and the presented stimulus. Despite of its behavioural significance the neural basis of these errors remain unexplored. Here we looked at the contribution of two brain areas previously implicated in feature integration: the parietal cortex and the pulvinar nucleus of the thalamus. Patients with parietal and pulvinar lesions were asked to report the shape of the only white letter embedded in a stream of black distractor letters presented either in the ipsi- or contralesional field. The high occurrence of contralesional temporal binding errors for both parietal and pulvinar patients strongly implicate these regions in the time-course of visual awareness.
[Supported by BBSRC, UK.]

◆ **Various unattended stimulus dimensions leave a distinctive footprint on short-term visual memory**

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Attention can filter out task-irrelevant stimulus attributes. Using the same stimuli and tasks, we compared selective filtering for different basic attributes: orientation and spatial location. Stimuli were sinusoidal gratings whose spatial frequencies varied. Subjects judged whether a probe stimulus' task-relevant frequency matched either of two just-seen study stimuli. In one experiment the task-irrelevant dimension was the orientation of one component in a compound grating. In a second experiment the task-irrelevant dimension was the spatial location at which gratings were presented. To quantify the success of filtering, we varied the similarity on irrelevant dimension between probe and study items. Both experiments demonstrated effective but incomplete filtering of the irrelevant dimension. The irrelevant dimension's influence on recognition performance varied from 12 to 39%; generally, irrelevant orientation was more influential than irrelevant location. A global-matching model of short-term memory suggests that recognition judgments varied systematically with summed similarity of the probe's frequency to that of each study item, the task-irrelevant dimensions operate by altering the effective summed probe-item similarity.

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◆ **Relative to what? Allocentric and egocentric priming in visual search**

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Priming refers to the influence that previous experience with a stimulus can have on future encounters with that same stimulus. Previously, we found location priming for targets defined in egocentric and allocentric frames of reference (Ball and Schenk, 2007 *Perception* **36** Supplement, 37). However, when both frames of reference predict target location, it is unclear whether the absolute (egocentric) or the relative (allocentric) location would be primed. In our visual search paradigm, target location was defined in either egocentric, allocentric, or egocentric – allocentric combined coordinates. We found (i) priming for both frames of reference, with greater egocentric priming than allocentric priming; and (ii) priming was greatest when both frames of reference provided information about target location. Moreover, the amount of priming when combining frames of reference did not differ from the amount of egocentric priming alone. This absence of an additive effect suggests that when both frames of reference are available, egocentric location information drives the priming effect.

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◆ **Investigations on the size of inhibitory region in selective tuning model of attention**

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According to the selective tuning model of attention the processed visual input is surrounded by an inhibitory region (IR). One of the open issues is the shape and size of IR, which we address in this report. I replicated Cutzu and Tsotsos experiment (2003 *Vision Research* **43** 205 – 219; Experiment 1) and introduced two new conditions: number of items (8, 12, 16) and item size (100%, 150%), to test whether the size of IR depends on the proximity of other stimuli and on the stimulus size. No firm conclusion could be drawn from a pilot study ($N = 6$) for the generally lower success rates when compared to the original study (44% vs 30%). These results are probably caused by improper fixations during the trial. In the original study subjects were instructed to maintain the fixation to the central point, but actual gaze positions were not recorded. In this study the eye movements are recorded so as to eliminate the effect of improper fixations.

◆ **Attentional guidance by object context cueing: a study of eye movements**

M van Asselen, J Sampaio, M Castelo-Branco (Faculty of Medicine, Coimbra University, Portugal; e-mail: masselen@ibili.uc.pt)

Implicit context cueing refers to the facilitation of a visual search by learned contextual features of our environment. In the current study the mechanism underlying this phenomenon is investigated. In contrast to previous studies in which spatial information was used as a contextual cue, we used object identity. The location of the target was not predictable. Eye movement data was recorded for sixteen healthy adults in order to define different oculomotor parameters. Results indicate that the faster response times in trials with a repeated context are due to a decrease in the number of saccades and not due to shorter fixations, saccades or motor responses. In a second study, the role of peripheral vision in implicit context cueing was studied.

The same experiment was repeated, but now subjects had to fixate a cross. Unexpectedly, repeated object information facilitated search when only peripheral vision was used. Together, this suggests that fewer saccades are necessary to locate the target, possibly because the target is recognized faster in peripheral vision.

◆ **Denoising forced-choice detection data**
M A García-Pérez (Facultad de Psicología, Universidad Complutense, Madrid, Spain; e-mail: miguel@psi.ucm.es)

Subjects in a 2AFC detection task must guess on trials in which neither presentation appeared to display a stimulus. Subjects could instead be instructed to use a 'guess' key, which would produce a random guess and record the resultant correct or wrong response as emanating from a computer-generated guess. A simulation study shows that 'denoising' 2AFC data with information regarding which responses result from guesses yields estimates of threshold and spread of the psychometric function that are more precise than those obtained in the absence of this information, and parallel the precision of estimates obtained with yes–no tasks running for the same number of trials. Simulations also show that partial compliance with the instructions to use the 'guess' key reduces slightly the quality of the estimates, which are still more precise than those obtained from conventional 2AFC data. An empirical study with thirteen subjects confirms the validity of the simulations, and proves the feasibility of using a 'guess' key in addition to the conventional response keys defined in 2AFC tasks.
[Supported by grant SEJ2005-00485.]

◆ **Effects of action on asymmetries of attentional allocation across the vertical visual field**
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We examined whether action affects the allocation of visual attention across the vertical visual field in visual search tasks. In two experiments, participants performed a conjunction search task. Stimuli were presented on a touch screen monitor. After detecting the target, they reported its locations either with a mouse cursor (Mouse task) or by touching the locations directly on the monitor (pointing task). In Experiment 1, the results showed that the advantage of the upper visual field (UVF) over the lower visual field (LVF) was smaller in the pointing task than in the mouse task. In Experiment 2, we examined how the start position in the pointing movements affects the allocation of attention. The results showed that regardless of the start position, the advantage of the UVF, though not significantly, tended to be smaller in the pointing task than in the mouse task. These results indicated that action would change the pattern of allocation of visual attention across the vertical visual field.
[Supported by Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (B) (No. 18330155).]

◆ **Neural correlates of visual enumeration under attentional load**
P Vetter, B Butterworth, B Bahrami (Institute of Cognitive Neuroscience, University College London, UK; e-mail: p.vetter@ucl.ac.uk)

Subitizing, the fast and accurate apprehension of numerosity for 1 to about 4 items, has traditionally been thought of as a preattentive process and functionally distinct from the enumeration of larger numerosities. Recently, we showed in a dual-task paradigm manipulating attentional load that subitizing performance is severely impaired under conditions of reduced availability of attentional resources. Here we investigated how the brain activations related to visual enumeration, both within and outside the subitizing range, are modulated by attentional load. We measured BOLD activity while subjects performed an enumeration task either on its own or together with a colour detection task of either low or high attentional load. Preliminary results from six subjects showed parietal activations for enumeration when performance was intact compared to when it was impaired due to the attentional demands of the additional task. These results confirm the behavioural finding that enumeration, in particular subitizing, requires visual attention and involves higher level brain areas.

◆ **Assessing the gradient of visual attention in depth: An Eriksen-flanker study**
G Rinkenauer, M Grosjean (Leibniz Research Centre for Working Environment and Human Factors (IfADo), Dortmund, Germany; e-mail: rinkenauer@ifado.de)

Two Eriksen-flanker task experiments were employed to assess the gradient of attention in depth. In both experiments, target and flankers were either presented at the same or at different depth planes, and the lateral target-flanker distance (eccentricity) was manipulated. Stimulus onset asynchrony (SOA) between flankers and target was 0 ms in Experiment 1 and 100 ms in Experiment 2. Vergence and accommodation of the two eyes were controlled by presenting a fixation

stimulus at the same depth plane as the subsequent target. The size of the flanker-interference effect as a function of depth and eccentricity was used to assess the attention gradient. The results show that the distribution of attention in depth was larger when the flankers appeared before (SOA = 100 ms) than simultaneously (SOA = 0 ms) to the target. These findings can be accounted for with a binocular gradient model that assumes that the distribution of attention in depth is determined by the superimposition of depth-dependent monocular attention gradients for each eye.

◆ **Meditation reduces age-dependent decline in the allocation of attentional resources**
S van Leeuwen, L Melloni, N G Müller (Brain Imaging Center, Johann-Wolfgang-Goethe Universität Frankfurt, Germany; e-mail: sara_vanleeuwen@yahoo.com)

Here we explore whether mental training, in the form of meditation, can affect attention and also help to overcome age related attentional decline. To this end, we compare performance on the attentional blink (AB) task between three populations: long-term meditation practitioners from an older population, age-matched control subjects, and young control subjects. Our results show that long-term meditation practice leads to a reduction of the AB. Furthermore, meditation practitioners taken from an older population, performed comparably to a control group taken from a younger population, whereas the control group, age-matched to the meditators' group, revealed a blink that was comparatively larger and broader. Our results support the hypothesis that internally driven mental training in the form of meditation practice can: (i) alter the efficiency with which attentional resources are distributed, and (ii) help to overcome age-related attentional deficits in the temporal domain. This study provides further evidence that cognitive functions can exhibit plasticity even in later stages of life.

◆ **Temporal binding, illusory conjunctions, and the ST2 model**
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How does the visual system bind temporally coeval stimulus features into distinct mental percepts? Here we investigate this problem of temporal binding, concerned with how features presented in rapid succession at the same location are combined into coherent representations. In comparison to its classical spatial counterpart, this relatively less explored phenomenon is distinctive because of the lack of a spatial anchor. Neural activations of the features of temporally proximal stimuli overlap in time, often resulting in conscious perception of nonexistent objects with incorrect feature combinations, called illusory conjunctions. We present evidence that informs our neurophysiologically plausible model of temporal attention and its role in binding. The ST2 model explains a broad range of behavioural and EEG data relating to attentional blink and RSVP, and is now extended to model temporal binding and the formation of illusory conjunctions. We comparatively evaluate our model against other approaches and use it to make qualitative predictions about EEG patterns, which could be used to inform further experimentation towards validating the model.

◆ **Visual search of moving natural images**
T Takeuchi, T Sugiyama¶, H Imai¶ (Sensory and Motor Research Group, NTT Communication Science Laboratories, Japan; ¶ Department of Psychology, Tokyo Woman's Christian University, Japan; e-mail: tatsuto@apollo3.brl.ntt.co.jp)

Visual search based on objects' motion direction or speed is known to be efficient if differences between the motion components of the target and distractors are large. Here we asked whether visual search of moving natural images is similarly efficient. The visual stimuli used comprised 20 movies including such moving objects as a car, animals, or landscape. When the target was a movie played forwards, the distractors were the same movie played backwards, and vice versa. When each stimulus was presented alone for a short duration (less than 100 ms), subjects could correctly indentify whether it was being played forwards or backwards. However, in the visual search condition, even though all objects in each stimulus moved in opposite directions in the target and the distractors, we found that visual search was inefficient. A significant set-size effect was observed for most of the movies. No search asymmetry was observed except when the stimulus contained expanding/contracting motions. These results suggest a limitation in the allocation of attentional resources in visual search.

◆ **Natural image statistics differ for fixated vs non-fixated regions**
V Yanulevskaya, J M Geusebroek, J B C Marsman¶, F W Cornelissen¶ (ISLA, Informatics Institute, University of Amsterdam, The Netherlands; ¶ Laboratory for Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, The Netherlands; e-mail: yanulevs@science.uva.nl)
Knowing why we direct our gaze to particular locations in images is important for understanding image interpretation. We hypothesized that under natural free viewing conditions our gaze is first drawn to image regions that statistically differ from the rest of the image. To test this, we computed local image statistics for the regions where subjects fixated during a free viewing task and compared these to the statistics of randomly selected (non-fixated) patches. In particular, we focus on the distribution of contrasts and edges in natural images, which is well described by the two-parameter Weibull distribution. Besides the contrast parameter, we also consider edge frequency as an additional attractor. In the experiment, we used *National Geographic* photos as stimuli. Our results demonstrate significantly different distributions of Weibull parameters for fixated and non-fixated image regions. The results identify both contrast and edge frequency to be cues for attention. Hence, natural image statistics as captured by the two-parameter Weibull distribution could play a role in determining where we direct our first few saccades.
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◆ **ERP correlates of processing visual spatiotemporal regularities**
P Pollux, K Guo (Department of Psychology, University of Lincoln, UK; e-mail: ppollux@lincoln.ac.uk)
In our dynamic visual environment, objects often move in statistically predictable ways. The expectation of this spatiotemporal regularity in stimulus structure influences our target detection/discrimination at early stages of visual processing, suggesting that early visual cortex is involved in the computation of spatiotemporal regularity. Here we investigated the time course of potential ERP effects associated with processing spatiotemporal regularities. Stimuli consisted of five horizontal bars (predictors) appearing successively towards the fovea followed by a target bar. Each target required a key-press on detection. Results showed that compared to conditions where five predictors were presented in a randomised spatial order, target detection times were faster, and contralateral P1/N1 peak latencies were shorter, when the predictor–target sequences were predictable. Both measures were most prolonged when only the target was presented. The early ERP latency effect persisted when the high-pass filter was increased to reduce potential influences of the expectancy wave (CNV). Time-course and scalp-distribution of the latency effect seems consistent with the idea that early visual cortex plays an active role in the coding of spatiotemporal regularities.

BINOCULAR VISION AND SPATIAL LOCALISATION

◆ **The influence of spatial attention and eye movements on distance estimation**
A Oleksiak, M Manko¶, A V van den Berg, A Postma, C J M van der Ham, R J A van Wezel (Helmholtz Research Institute, Utrecht University, The Netherlands; ¶ Faculty of Biology, Jagiellonian University, Cracow, Poland; e-mail: a.oleksiak@uu.nl)
Notwithstanding a plethora of research on spatial attention and eye movements it is not clear how these two contribute to distance estimation. By presenting two dots sequentially (first one dot for 100 ms followed by a simultaneous display of two dots for another 100 ms) we prompted shifts of focus of attention and eye movements. The subjects' task was to assess the distance between the two dots and after a short delay to reproduce it based on a new reference dot. As a control condition the two dots were presented simultaneously for only 20 ms, which precluded any shifts of attention or eye movements. The results indicate that information in the form of an eye movement vector influences distance estimates (the direction of bias) but does not improve them (absolute error values) compared to the condition when spread attention is used. These findings demonstrate that additional information about eye (attention) movement vector does not improve distance assessment.

◆ **Sensitivity and response criterion during binocular rivalry suppression: a TSD analysis of eye rivalry and image rivalry**
R Bhardwaj, R O'shea (Department of Psychology, University of Otago, New Zealand; e-mail: bhari434@student.otago.ac.nz)
During binocular rivalry, one stimulus is visible (dominant) while the other stimulus is invisible (suppressed); after a few seconds, perception reverses. Alternations in perception could be from competition between the eyes (eye rivalry) or from competition between the images (image rivalry). We measured sensitivity and response criterion during eye and image rivalry using the theory of signal detection. Rival stimuli were either continuous (eye rivalry) or swapped between the eyes

at 1.5 Hz and flickered at 18 Hz (image rivalry). The probe was a 106 ms contrast increment to one of the rival stimuli, presented to either eye, or swapped along with the stimulus in image rivalry. We found that sensitivities were less during suppression than during dominance. Response criteria were essentially similar during dominance and suppression and were generally conservative. Depths of suppression of sensitivity were similar during eye and image rivalry. We discuss how the similarity in suppression depths of the two types of rivalry places constraints on models of rivalry.

◆ **Processing of symbolic and non-symbolic numerosity in the absence of awareness**
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We investigated the explicit and implicit judgment of small numerosities in the absence of awareness. Numerosity stimuli (1, 2, or 3 gabor patches) were presented to one eye but suppressed from awareness by continuously flashing a mask in the other eye. In the first experiment, subjects were unable to explicitly judge discrete numerosities in a 3AFC task when they were unaware of the suppressed stimulus. In the second experiment, the number of suppressed and invisible stimuli (prime) affected the speed of numerosity judging for visible targets presented subsequent to the invisible primes. Reaction times to the target increased with numerical distance between prime and target. The third experiment, in which we presented a symbolic prime (Arabic digit), did not show the same effect on reaction times. These results suggest that extraction of information concerning non-symbolic numerosity occurs in the absence of awareness. Although this information is not available to explicit judgment it could be traced by its implicit effect.

◆ **Cueing in cyclopean space**
W H Ehrenstein, D Bauer, A Plinge (Leibniz Research Centre for Working Environment and Human Factors, University of Dortmund, Germany; e-mail: ehrenstein@ifado.de)

In Posner's spatial cueing paradigm, a target within the frontoparallel plane is typically faster detected if it occurs at the cued rather than uncued location (left or right). We asked whether similar cueing effects occur also in depth under cyclopean viewing conditions. Sparse random-dot patterns were generated using a dual DVI technique with direct driven image light amplifier projection producing different depth planes within Panum's range. A central square (6°) precued either the front or back plane for 200 ms; after inter-stimulus intervals (ISIs) of 50, 150, or 400 ms the target (3° square, concentric to the precue area) occurred for 250 ms in different (protruding or receding) depth. Mean response time for twelve participants was faster for valid cues (454 ms) than invalid (491 ms) at the shortest ISI ($p < 0.01$). At higher ISIs, however, this advantage dropped to insignificant values, yielding a highly significant cue × ISI interaction. Thus, cueing effects in cyclopean depth seem to be rather transient under conditions exclusively based on postchiasmatic visual processes.

◆ **Local binocular depth contrast effect with curved surfaces**
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Although many studies have shown binocular slant contrast effects may be related to global processing of disparities, there have been few studies demonstrating local depth contrast of surface analogous to the luminance domain (eg Chevreul illusion). In this study, we tried to demonstrate local lateral interaction of surfaces in depth domain by placing a depth gap adjacent to a curved depth surface (convex or concave). We conjecture that the difficulty of demonstrating local contrast effect might arise from the tendency for flat surfaces to stay flat and it might be easier to make curved surfaces flat. The results showed that a convex surface placed next to an inducer with uncrossed disparity (ie placed behind) had a flatter appearance. On the contrary, a concave surface had a flatter appearance with an inducer having crossed disparity (in front). These results suggest that there is a local depth contrast effect in depth domain and stereo system has classical centre–surround antagonistic mechanism closely analogous to luminance receptive field.
[Supported by Global COE Program, MEXT.]

◆ **Binocular spatial updating after passive whole body translation and rotation**
J Dits, J J M Pel, R Stam, J van der Steen (Department of Neuroscience, Erasmus MC, Rotterdam, The Netherlands; e-mail: j.dits@erasmusmc.nl)

Humans can keep track of remembered target locations in space, and even as they move, eye movements are adjusted accordingly. Several extra-retinal cues are involved, but sources and mechanisms remain under debate. To test the role of vestibular signal updating, we applied

passive Gaussian velocity whole sway body translations ($A = 10$ cm, $V_{max} = 0.3$ m s^{-1}) and yaw rotations ($A = 10^\circ$, $V_{max} = 33^\circ$ s^{-1}) with a 6DF motion platform. Subjects fused dichoptically presented platform-fixed targets at 94 cm and 31 cm straight ahead. A binocular earth-fixed target, left of the platform-fixed target sight line at 45cm viewing depth, was flashed (80 ms) before platform motion onset. The flash induced different retinal projections on left and right eye. We tested monocular and binocular conditions. Saccades made towards the memorized flashed target location after translation and rotation were respectively 50% and 70% correct. Simultaneously, corrective vergence eye movements were induced in the memory phase of binocular conditions with 30% undershoot (divergence) after translation and 10% overshoot convergence) after rotation. Our findings suggest systematic binocular spatial memory coding based on retinal and vestibular input.

◆ **Vergence errors during short and steady fixations measured with objective and subjective methods**

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Fixation disparity (vergence error) can be measured objectively with eye trackers and subjectively with dichoptic nonius lines. Varying the vergence stimulus at constant accommodative stimulus (forced vergence), previous studies found differences between objective and subjective fixation disparity, which were interpreted as a shift in retinal correspondence that increases with forced vergence. We tested whether objective and subjective fixation disparity might be similar without forced vergence. In conditions of non-forced vergence at a 60 cm viewing distance, we found that objective fixation disparity was considerably larger than subjective fixation disparity. Since the difference varied among our twenty-five subjects, subjective fixation disparity explained only about 35% of the inter-individual variability in objective fixation disparity. Our results were similar for short fixations (about 1.5 s) between saccadic gaze shifts and for steady fixations (120 s). Inter-individual correlations showed (i) that objective fixation disparity was related to heterophoria, the vergence state without fusion stimulus, and (ii) that the transient divergent state during saccades was related to the interocular difference in saccadic velocity.

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◆ **How the brain processes correlated and anticorrelated stereoscopic motion-in-depth**

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To understand the interactions among a variety of cues for stereoscopic motion-in-depth we used fMRI (3T, 2s TR, $3 \times 3 \times 3$ mm) to investigated the whole-brain network activated by (i) correlated and (ii) anticorrelated dynamic random-dot stereomotion of both high and low densities with and without monocular motion cues. Each condition had a control that cancelled any differential BOLD response to confounding factors. Correlated cyclopean stereomotion activated a distributed occipital-to-prefrontal network. Paradoxically, however, addition of monocular-motion cues reduced the signal in several areas, posing challenges for theoretical models of motion-in-depth incorporating monocular motion signals. As expected, high-density anticorrelograms did not create any depth or motion-in-depth perception and did not activate the network; conversely, low-density anticorrelograms supported both depth and motion-in-depth and activated a substantial subset of the network. The same network was engaged (to different degrees) by all conditions generating perceived motion-in-depth, implying its generic role in 3-D-motion processing. The full array of results across cortical areas has clear implications for the mechanisms of dynamic stereopsis.

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◆ **Experiential space is hardly metric**

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In real-life conditions, an observer is only rarely required to metrically estimate spatial relations within the environment. In the conditions of psychophysical experiment, however, the observer is typically confronted with metric tasks (eg, magnitude estimation, matching, blind walking). Such tasks place too high requirements on the observers causing judgments in the experiments on visual space perception to be rather imprecise. Moreover, observers become less confident about their answers and their answers are frequently contaminated by artefacts (knowledge and memories). Less demanding perceptual tasks in experiments are expected to avoid sophisticated heuristics and lead to obtaining ecologically valid data. To test this prediction, we introduced a novel ordinal task in which the observers compared length intervals so that they ranked the distance of a number of objects from the reference point. The data indicate a slightly higher accuracy and reliability in observers' judgments compared with previous findings in the literature.

◆ **Changing the contrast of stimuli in binocular rivalry: effects on onset and sustained rivalry**
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Few studies have investigated whether the psychophysical processes involved in all periods of binocular rivalry are the same, and there is no general agreement on this yet [Carter and Cavanagh, 2007 *PLoS ONE* **2** e343; vanBoxtel et al, 2007 *Journal of Vision* **7**(14.3) 1 – 11]. We investigated the effects of stimulus contrast on temporal course of interocular suppression, testing the validity of Levelt's second proposition (Levelt, 1966 *British Journal of Psychology* **57** 225 – 238) at different times during binocular rivalry. The mean dominance duration of small foveal stimuli was measured at the initial onset period and during a sustained period of 1 min, while the contrast of one eye's stimulus was varied and the contrast in the other one was fixed. Results were similar for both rivalry periods: the increase of ipsilateral contrast not only affected contralateral eye—as Levelt's proposition predicts—but also produced an increase in dominance time of that same eye. These results suggest that both forms of rivalry, onset and sustained, involve basically identical mechanisms.

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◆ **Perception from abrupt and continuous modulation of binocular disparities**
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In study of perception from binocular disparity, whereas spatial properties of its processing have been reasonably well proved, its temporal properties are less known. The present study aims at examining the effects of temporal disparity modulation on perception. In our experiments an observer viewed right and left images with each eye through mirrors. The image was a random-dot pattern divided into four horizontal bands. The bands were separated in depth with shearing disparities. While the observers viewed the image, the disparity was temporally decreased or reduced to zero, abruptly or continuously, in each condition. The observer reported whether he/she detected the disparity change, and, if not, the perceived depth by adjustment method. The observer often failed to detect the decrease, especially in continuous modulation. The perceived depth was generally equivalent to the average of disparities during the whole observation. These results suggest that, in binocular disparity processing, the sustained system has some temporal window within which the disparity signal is integrated to yield depth perception.

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◆ **Binding of visual hemifields is provided by reciprocal and non-reciprocal interhemispheric connections within primary cortical areas**
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In normal cats callosal fibres connect retinotopically corresponding but nonsymmetric loci in cortical areas 17 and 18, where the retinal naso-temporal overlap zone is represented in both hemispheres (Olavarria, 1996 *Journal of Comparative Neurology* **366** 643 – 655). Our aim was to evaluate the reciprocity of such connections. Using HRP as a tracer, we investigated the interhemispheric connections of single ocular dominance columns (ODCs) in areas 17 and 18, and in the transition zone between them. Reciprocal callosal connections were revealed in areas 17 and 18 for ODCs located in vicinity of projection of visual field vertical veridian (azimuth from 0 deg to 2 – 3 deg). However the more distant ODCs (azimuth from 2 – 3 deg to 7 deg) receive callosal inputs but do not send axons to the transition zone 17/18 of opposite hemisphere. The width of nonreciprocal interhemispheric connections zone increases to 20 deg in monocularly deprived and in strabismic cats. We speculate that revealed subdivisions within callosal zone may reflect the evolutional development of visual system.

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◆ **Interaction between yellow/blue chromatic and luminance mechanisms in disparity detection**
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Previous studies have suggested that the disparity tuning of both red/green chromatic and luminance mechanisms was similar, yet reported that for stereoscopic depth identification the chromatic contrast threshold was higher than the luminance threshold. Moreover, the red/green opponent signal suppressively interacted with the luminance signal in disparity coding. Most of these previous studies just used red/green stimuli, because the fovea plays a substantial role in depth

perception and mostly L- and M-cones cover the fovea. Here we tested whether the S-cone isolating mechanism contributes to depth perception. We found that the disparity tuning of both S-cone isolating and luminance mechanisms was similar, but more chromatic contrast was required to identify depth than luminance contrast. We also made clear that the S-cone isolating mechanism and the luminance signal suppressed each other in producing the disparity information. This indicates that the S-cone isolating mechanism negatively interacts with the luminance mechanism and has a capability to produce stereoscopic depth signal, even though there is a relatively small S-cone population in the fovea.
[Supported in part by Japanese MEXT grants 17530537 to TY and 17560236 to TK.]

◆ **Five-month-old infants are sensitive to pictorial cues for depth: a meta-analysis of preferential-reaching studies**
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This meta-analysis is motivated by an inconsistency within research on infants' sensitivity to pictorial cues for depth. On one hand, according to most preferential-reaching studies, there is little evidence of the ability to respond to individual pictorial depth cues at 5 months of age. In contrast, preferential-looking experiments show that infants as young as 3 – 4 months are able to extract pictorial depth. To test the hypothesis that significant sensitivity to pictorial depth is present even in younger infants, we combined the data for 5-month-olds who participated in the existing preferential-reaching studies. Results from 16 studies (466 infants 5 – 5.5 months of age) were integrated and the average he/she detected Z-value was computed. One-tailed p for this Z-value is highly significant (< 0.001). Overall, the findings confirm the hypothesis that sensitivity to pictorial depth cues is present in some 5-month-old infants. It is also the case that between 5 and 7 months there is a large increase in responsiveness to pictorial depth cues.

CLINICAL ASPECTS

◆ **Glare induced changes in pain threshold in myopic and emmetropic subjects**
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In a previous study we have found that discomfort glare is more pronounced in myopic as compared to emmetropic subjects. Since stimulation of pain receptors in extraocular muscles was suggested as a possible mechanism for discomfort glare we compared pressure pain thresholds in myopes versus emmetropes under low (moderately bright field) and high (sequence of high energy flashes) glare conditions. Pressure pain thresholds were measured by a modified force transducer (Grass FT10) coupled to an amplifier and recording system (DA100C, MP 100 system; Biopac, Inc.) Following glare inducing stimulus a gradually increasing pressure was applied at the lateral angle of the eye over the belly of the orbicularis oculi muscle. The subjects were required to press a key as soon as they experienced pain and the pressure was immediately released. The experimental procedure was controlled by a SuperLab 4.0 software. The results showed that glare affected the two groups we studied in a different and consistent way—raising the pain threshold in myopes and decreasing it in emmetropes.

◆ **The problems incident to an adequate assessment of the eye optical quality and visual acuity in school children**
G I Rozhkova (Institute for Information Transmission Problems, Russian Academy of Sciences, Moscow, Russia; e-mail: gir@iitp.ru)
The purpose of this report is to present a number of substantial conclusions drawn from the analysis of the data obtained in the framework of our longitudinal program aimed at an adequate assessment of the eye optical quality and visual acuity in school children. In total, more than 1000 subjects were examined by several teams over 2000 – 2008 years using various measuring procedures in varying conditions of examination. The measurements included auto-refractometry with and without cycloplegia to assess clinical refraction, keratometry, estimation of visual acuity at several viewing distances (3 – 5 distances in the range 0.5 – 5.0 m) and at various illumination levels (150 – 1000 lx). The results of the measurements revealed much individual variation of acuity distance dependence in subjects with similar refractive data. Cycloplegic refractive errors did not yield significant advantage over noncycloplegic parameters for correlation with acuity data. It is concluded that a reasonable estimate of the eye optics and visual resolution capabilities requires at least 3 viewing distances, 2 luminance levels and some additional procedure to estimate tonic accommodation.
[Supported by the RAS Biological Branch and RFBR grants 01-04-49484 and 04-04-48894.]

◆ **Visual field and visual acuity changes in damage of chiasma opticum**

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Pituitary adenoma (PA) mostly affects lateral sectors of visual field (VF), because the medial fibers of the retina intercross in the chiasma above the tumor. Enlargement of the tumour disturbes blood supply of the chiasma and demyelinisation of axons can occur. The purpose of the study is to estimate the changes of VF and visual acuity (VA) according to the diameter of PA. thirty-five persons (70 eyes) with various size of PA were tested. Perimetry and VA were estimated. Computerized program AKIENA (created in CKMU) was used for evaluation the deficit of VF. Patients were split into two groups by the diameter of PA: (i) < 3 cm, (ii) > 3 cm. Lateral sectors of VF were damaged for the most part in all groups ($p < 0.05$). VA and VF were statistically worse in the second tumor's size group ($p < 0.05$). There was low correlation between the size of PA and VF deficit. Also, there was low correlation between the size of PA and VA.

COLOUR AND BRIGHTNESS

◆ **Guilty or innocent? Distance and orientation in suspect identification under poor illumination conditions**

T A Agostini, G Righi¶, A C G Galmonte§ (Department of Psychology, University of Trieste, Italy; ¶ Faculty of Medicine, University of Udine, Italy; § Department of Psychology and Cultural Anthropology, University of Verona, Italy; e-mail: agostini@units.it)

Visual perception plays a crucial role in evidence provided by witnesses. It is not unusual for an accused to be found guilty solely on the basis of eyewitness testimony. We were asked to reproduce the visual conditions in which observers would witness a mafia murder, and then to test if they could confidently identify the killer. A group of seventy-two observers were tested. Two variables were manipulated: the distance killer – observer (6 m or 16 m) and the orientation (killer viewed frontally, 45° left or 45° right). The illumination was controlled (low intensity). The experiment was run on two separate days. On day 1, each observer (twelve for each condition) viewed the killer for 1.5 s. They immediately completed a questionnaire about what they had just seen. Four days later they were asked to identify the killer among five look-alike people in a simultaneous lineup. Our results further challenge the notion that eyewitnesses can provide reliable evidence in identification parades.

[This work was supported by MIUR Grant 2005115173.]

◆ **Turning yellow into green**

K Brecher (Departments of Astronomy and Physics, Boston University, USA; e-mail: brecher@bu.edu)

Pattern induced flicker colour (PIFC) has been studied for nearly two centuries. There is no completely satisfactory explanation for its origin. PIFC is most conveniently elicited using black and white patterns on slowly spinning (5 to 10 Hz) disks such as Benham's top. It can also be induced with rotating black and white patterns on computer screens (http://lite.bu.edu/vision/applets/Color/Benham/Benham.html). At higher rotation frequencies, observers report only the appearance of gray from spinning black and white disks. We will present new disk patterns consisting of concentric rings divided into black, white and yellow sectors that elicit the appearance of green in most observers. Including some red sectors makes the induced green appear more saturated. Unlike PIFC, the green colour is observed at all rotation rates, even above the flicker fusion frequency. We have developed a JAVA application, based on Jan Koenderink's colour scramble demonstration, which suggests that Bezold colour spreading may be the cause of the observed disk colour. However, PIFC effects may also play a role.

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◆ **Hue discrimination in cases of optic nerve drusen**

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The purpose of the work is to determine hue discrimination in cases of optic nerve drusen (OND). Computerised Farnsworth Munsell 100 Hue test program has been used for colour discrimination. The type of colour deficit has been computed by measuring the zones of colour confusion. We examined thirty-seven (62 eyes) patients with OND, and thirty-three age-matched controls. The mean age was 33 years in patients with OND and 32 years for the control group. Visual acuity and perimetry was normal in both groups. Patients with OND performed less well than the control group. The number of mistakes was 120 for OND patients against 92 for the control group ($p = 0.003$). Perception was worst in the red colour range. Red colour diapazone was 80.94 ($\pm$23.3), green colour 26.57 ($\pm$11.22), blue 16.69 ($\pm$4.71) ($p < 0.001$). Our results lead to the conclusion that OND affects most of all the perception of red colour.

◆ **Brightness perception: one simple model explains most if not all effects**
J M H du Buf, J Rodrigues (Institute for Systems and Robotics, Vision Laboratory, University of the Algarve, Campus de Gambelas FCT-DEEI, Faro, Portugal; e-mail: dubuf@ualg.pt)
Few models can explain Mach bands (Pessoa, 1996 *Vision Research* **36** 3205 – 3227). Our model employs a multiscale line- and edge-coding by simple and complex cells. Lines are interpreted by Gaussian functions, edges by bipolar Gaussian-truncated error functions. Widths of these functions are coupled to the scales of the underlying cells and the amplitudes are determined by their responses. A low-pass filter is used for constructing background brightness. This model explains Mach bands by the fact that simple cells cannot discriminate between ramp edges and lines, such that positive and negative lines are produced at ramp edges. Apart from Mach bands and attenuations by adjacent stimuli (Pessoa, 1996 *Perception* **24** 425 – 442), the model can explain grating induction, Chevreul steps, Craik – O'Brien – Cornsweet discs, and opposite induction effects (simultaneous brightness contrast and assimilation), including variations by Blakeslee et al (2005 *Vision Research* **45** 607 – 615) and variations of Adelson's tile and snake illusions (Logvinenko and Ross, 2005 *Spatial Vision* **18** 25 – 72). We conclude that brightness is, by and large, a straightforward data-driven process.
[Supported by FCT funding of ISR-IST with POS-Conhecimento and FEDER; FCT project PTDC-EIA-73633-2006 SmartVision.]

◆ **The phantom gradient: a variation in lightness induction without a perceived variation in the background colour**
S Gori, A C G Galmonte¶, G Dazzan, T Agostini (Department of Psychology, University of Trieste, Italy; ¶ Department of Psychology and Cultural Anthropology, University of Verona, Italy; e-mail: gori@psico.univ.trieste.it)
The so-called phantom gradient (PG) can be observed when a surface is filled by a linear luminance gradient whose variation is under threshold; under these conditions the surface appears homogeneous. It is known that a perceived luminance gradient affects the lightness of a target superimposed on its centre, in the direction of contrast (Agostini and Galmonte, 2002 *Psychonomic Bulletin & Review* **9** 264 – 269). Under PG conditions the gradient is not noticeable but still it affects the lightness of a superimposed patch. In a series of experiments we show that the direction of the PG lightness induction varies according to the gradient width: for wide and medium widths invisible gradients produce an effect in agreement with simultaneous contrast, while narrow ones result in an effect in the direction of assimilation. Target lightness is always significantly different from its physical value. The gradients were never detected by the observers. Therefore, it seems that the visual system assigns lightness values according to the global spatial distribution of luminance gradients.

◆ **Edginess about blindsight**
I H M Alexander, A Cowey (Department of Experimental Psychology, University of Oxford, UK; e-mail: iona.alexander@psy.ox.ac.uk)
Blindsight occurs when part or all of the visual cortex (V1) is destroyed or denervated by white matter damage. It is the remarkable ability of some such patients to detect, localise, and discriminate a variety of visual stimuli confined to their blind defect, which do not provide artefacts like scattered light, and of which the patient denies having any conscious visual percept. We investigated why some stimuli in blindsight are easier to discriminate than others, and how the brain manages to process unacknowledged information about luminance, wavelength, and motion. Using Gabor and Gaussian patches to eliminate sharp borders and edge detection mechanisms, we found an impairment in luminance detection with Gabor patches. In addition we examined the colour detection mechanisms of blindsight using blue/yellow and blue/black stimuli with revealing results. It is established that blindsight subjects can discriminate between some colours, but here we show that blindsight also allows detection of a pure change of colour. Finally, we found that TMS over V5 but not V3 impairs motion discrimination.

◆ **The number of discernible colours perceived by protanomalous and deuteranomalous in natural scenes**
J Linhares, P Pinto, S Nascimento (Department of Physics, University of Minho, Portugal; e-mail: jlinhares@fisica.uminho.pt)
To address the issue of how impaired the colour vision of anomalous trichromats relatively to normal trichromats is, the number of discernible colours seen by anomalous trichromats was estimated from hyperspectral data of 50 natural scenes. In the computations it was assumed that the anomalous cone sensitivities were derived from normal's by introducing variable spectral shifts. Thus, for protanomalous the L-cone was obtained by shifting the M-cone towards long

wavelengths; for deuteranomalous the M-cone was obtained by shifting the L-cone towards short wavelengths. For each scene the CIELAB colour volume was estimated from each one of the anomalous sensitivities and then segmented into unitary cubes. The number of discernible colours was obtained by counting the number of non-empty unitary cubes. It was estimated that typical protanomalous (shifted by 10 nm) and typical deuteranomalous (shifted by 6 nm) distinguish about 70% and 60%, respectively, compared with normal observers. This suggests that a large section of the male population has considerably impaired colour vision.
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◆ **Second order chromatic Mach bands**
A Tsofe, H Spitzer, S Einav (Department of Biomedical Engineering, Tel-Aviv University, Israel; e-mail: marco@post.tau.ac.il)
Mach bands are an optical illusion consisting of two wide bands, one light and one dark, separated by a narrow light-to-dark ramp. Achromatic contrast Mach bands can be perceived near the contrast ramp. Until recently there was no consensus on the perception of chromatic Mach bands under controlled luminance conditions. Using a novel paradigm, we showed the existence of the chromatic mach bands. Here we show that a repertoire of second order chromatic Mach bands can be clearly perceived under iso-brightness conditions. Our chromatic contrast Mach bands consist of two regions with different chromatic saturation contrasts and have a ramp contrast modulation between them. This effect has been tested on three observers for 15 different chromatic contrast Mach bands stimuli. The results show that the perceived contrast Mach bands in chromatic and achromatic contrast stimuli yielded significant and approximately the same relative magnitude responses. The suggested mechanism of chromatic and achromatic Mach bands will be discussed in reference to the mechanism and computational model of the induction effects.
[Supported by Fred Chaoul generous donation and the AMN Foundation.]

◆ **Saccadic distractor effect and S-cone processing in normal observers and two cases of hemianopia**
N Ridgway, M-J Macleod¶, M Milders, A Sahraie (School of Psychology [¶ Department of Medicine and Therapeutics], University of Aberdeen, UK; e-mail: n.ridgway@abdn.ac.uk)
When observers have to make saccades to a target with a distractor presented at a non-target location, saccadic latencies are significantly slower than to targets presented in isolation. This is termed the saccadic distractor effect (SDE) and is thought to be explained by the competitive interactions between target and distractor and activity at the superior colliculus. We have measured the SDE in a group of normal participants and two hemianopic patients for luminance-defined and chromatic signals in the presence and absence of dynamic visual noise. Similar to previous reports, we found some evidence of a SDE for luminance-defined stimuli embedded in random noise. In the absence of luminance noise, a significant SDE was found for both luminance defined stimuli and S-cone contrast targets. Both hemianopic patients showed evidence of SDE for luminance-defined targets. Surprisingly, one patient showed a significant SDE for S-cone stimuli. These findings are significant as S-cone afferent signals reportedly, do not project to midbrain structures such as superior colliculus, a structure implicated in both SDE and blindsight.
[Supported by James Mearns Charitable Trust.]

◆ **The influence of temporal S-cone modulation on rod thresholds**
R C Baraas, H Sun, L A Hagen (Department of Optometry & Visual Science, Buskerud University College, Norway; e-mail: rigmor.baraas@hibu.no)
Previous studies have reported complete summation between rod and S-cone signals at threshold [Buck, 2004, in *Visual Neurosciences* volume 1, Eds M Chalupa, J S Werner (MIT Press, Cambridge) pp 863 – 878], suggesting that the two signals interact within the same pathway. It is therefore likely that adaptation of S-cones will influence rod thresholds. Here, thresholds were measured for a rod pulse superimposed on a S-cone sinusoidally modulated background at different phases. Stimuli were generated with a 2-channel 4-primary Maxwellian view system. Detection thresholds for a 100-ms 1-deg rod-isolating pulse were measured at 6 deg extrafovea (nasal) against an adapting background that was either (i) a 12-deg steady full field, (ii) a 1-deg cone-modulating local field, (iii) a 12-deg cone-modulating annulus, or (iv) a 12-deg cone-modulating full field. The cone modulation was a temporal sinusoid along the S axis, and did not modulate rods. Results show that rod thresholds varied systematically with the phase of the S-cone modulation, and the phase that gave maximum rod threshold was not the same for the different conditions.
[Supported by the Norwegian Research Council, Grant 176541 V10.]

◆ **Artistic imaging by edge enhancing smoothing**
G Papari, N Petkov (Department of Mathematics and Computing Science, University of Groningen, The Netherland; e-mail: smirnov79@yahoo.it)
Two important visual properties of paintings and painting-like images are the absence of texture details and the increased sharpness of edges as compared to photographic images. Painting-like artistic effects can be achieved from photographic images by filters that smooth out texture details, while preserving or enhancing edges and corners. However, not all edge-preserving smoothers are suitable for this purpose. We present a simple local-edge-preserving smoother. A large variety of experimental results shows that the output of the proposed operator is visually similar to a painting. Comparisons with existing techniques on a large set of natural images highlight conditions on which traditional edge-preserving smoothers fail, whereas our approach produces good results.

◆ **The effects of noise masking on spatial frequency discrimination**
T Putzeys, R Goris, J Wagemans (Laboratory of Experimental Psychology, University of Leuven, Belgium; e-mail: tom.putzeys@student.kuleuven.be)
To infer characteristics of the mechanisms underlying early visual processing, many psychophysical studies explored perception of and discrimination among spatial frequencies of single-component sinusoidal gratings. One striking finding of these studies is the shift in perceived spatial frequency following various experimental manipulations, such as adaptation. More specifically, adaptation causes a shift away from the adaptation grating's spatial frequency, suggesting that perceived spatial frequency depends on the relative output of various frequency-tuned channels. Assuming that adaptation reduces the activity of these channels, we predict that increasing channel activity will cause a shift in the opposite direction. We tested this prediction using a noise masking paradigm. Spatial frequency discrimination performance was measured using sinusoidal gratings embedded in low-pass, high-pass, and white noise. While perceived spatial frequency was not perturbed in the white noise condition, spatial frequency was overestimated in the high-pass condition and underestimated in the low-pass condition, thus confirming predictions. A computational multiple channels model, consisting of a linear filter stage followed by a channel population read-out mechanism, will be discussed.

◆ **Envelope selectiviy of second-order visual channels revealed by masking**
V Sierra-Vázquez, I Serrano-Pedraza¶ (Facultad de Psicología, Universidad Complutense de Madrid, Spain; ¶ Department of Psychology, University of Kent, Canterbury, UK; e-mail: vicente@psi.ucm.es)
Contrast-modulation detection thresholds were obtained by means of Bayesian staircases using a 2ifc masking paradigm. We used contrast modulated stimuli where the test envelopes were Gabor patches of frequencies of 1 and 3 cycles deg^{-1} and the mask envelopes were narrow band-pass 1-D noises. Both test and mask had the same static carrier (2-D broadband binary noise). Squared thresholds were obtained as a function of the mask centre frequency. Results show masking effect within a narrow band around the test frequency. Theoretical thresholds from the critical-band-masking model (transferred to contrast-modulation domain) were fitted to the data using Gaussian or log-Gaussian shapes as power gain functions with fixed- and best-channel detection models. Results of fitting were similar for both shapes of gain functions with both detection models. Octave bandwidth of assumed second-order channels decreases with the peak frequency of channel as an exponential function. Our results support the existence of second-order channels acting as a modulation filter bank of overlapping band-pass filters selectively sensitive to the spatial-frequency of the image envelope.

EYE, HAND AND BODY MOVEMENTS

◆ **Memory of complex scenes according to expertise and eye movements**
A Blavier, P Souveryns¶, A S Nyssen§ (FNRS, University of Liege, Belgium; ¶ Department of Art History [§ Laboratory of Cognitive Ergonomics], University of Liège, Belgium; e-mail: adelaide.blavier@ulg.ac.be)
Our purpose was to analyse the memory of complex scenes (paintings) according to the eye movements and expertise. Six paintings were separately and randomly presented for 10 s. Fifteen novice subjects and fifteen art historians (experts) were asked to look freely at each painting. After each presentation, questions were asked about their knowledge of the painting (eg author's name, painting's name) and about pictorial details. Despite significant differences in knowledge about the paintings between experts and novices there was no difference in the accuracy of the answers. Moreover, the answers of novices were more accurate if they looked longer at the specified detail and when that detail was watched early on in the presentation. In contrast, accuracy of answers in the expert group was not influenced by duration or time of watching the

specified detail. These findings suggest experts may hold inaccurate representations not influenced by eye movements, whereas accuracy in novices is influenced by eye movements.
[This research was funded by a Grant from the National Fund of Scientific Research of Belgium.]

◆ **Pointing at targets under spatial and temporal uncertainties: dissociations of space and time**
B Rodríguez-Herreros, J López-Moliner (Facultat de Psicologia, Universitat de Barcelona, Spain; e-mail: borja.rodriguez@ub.edu)
Temporal and spatial information are necessary when pointing to moving objects at a specific location. Spatial uncertainty is usually reduced by constraining the hitting zone or by freely choosing where to hit. Here we introduce an interception paradigm that allows us to modulate the spatial and temporal uncertainty of where and when subjects have to point. We show initial parts of trajectories of two objects that move (laterally or sagittaly) at similar or different speeds along a collision path. Subjects had to point to the contact point at the correct time. We looked at the pointing temporal and spatial errors for the two axis and speed similarity. We found that temporal error was largely reduced in the sagittal condition (100 ms) relative to the lateral one (250 ms). However the spatial error increased when the two speeds were similar in the sagittal condition but the opposite was observed in the lateral condition. Speed difference seems to affect subjects' update of changing positions while leaving unaffected the temporal error.
[ESF and Grant SEJ2006-27544-E.]

◆ **Fitts's law and the planning of sequences of saccades**
C C Wu, B S Schnitzer, M Singh, Z Pizlo¶, E Kowler (Department of Psychology, Rutgers University, Newark, USA; ¶ Department of Psychology, Purdue University, Lafayette, USA; e-mail: chiachie@eden.rutgers.edu)
According to Fitts's Law, widely applicable to motor behaviour, the time to carry out a movement depends on the index of difficulty, where ID = log (2 * target separation/target diameter). We investigated whether Fitts's Law applies to sequences of saccades. Saccades were made in sequence to 4 circles at the corners of an imaginary square. The time to complete the sequences increased with ID. As ID increased, the time of the primary saccade (latency+duration) decreased, and corrective saccades became more frequent. This suggests that when required precision exceeds capacity (eg, small targets; large eccentricities), the preferred strategy favoured rapid primary saccades, followed by corrections. Large targets and small eccentricities encouraged single, slower primary movements and fewer corrections (see Meyer et al, 1988). We conclude that (i) Fitts's Law applies to saccadic sequences; (ii) properties of saccades often attributed to structural aspects of the stimulus can instead result from strategies designed to achieve required accuracy in the minimal amount of time.

◆ **The influence of perceived surface slant of ambiguous stimuli on saccade size**
D A Wismeijer, C J Erkelens (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: d.a.wismeijer@phys.uu.nl)
We investigated the influence of perceived surface slant on saccade size using ambiguous slant rivalry stimuli. In a slant rivalry stimulus, the perspective cue specifies a surface slant oppositely oriented to the surface slant defined by the disparity cue. Observers of such a stimulus perceive one of two mutually exclusive surface slants with opposite sign; one based on perspective foreshortening and the other one based on disparity. Thus slant perception alternates whereas the slant cues remain constant. It is thus possible to distinguish between the influence of perception on saccade size and the influence of slant defining cues on saccade size. We used both a computer generated stimulus and a real 3-D stimulus, also known as a reverspective scene. Observers were instructed to make a saccade from the center of the stimulus to the end of the perceived slanted surface and report their percept. Saccade size closely approximated the veridical size of the stimulus in both perceptual conditions. We conclude that saccade size is not influenced by perceived surface slant.

◆ **Comparison of behavioural and fMRI studies of the reverse perspective illusion**
T Hayashi, N D Cook, A Shiraiwa (Faculty of Informatics, Kansai University, Japan; e-mail: hayashi@res.kutc.kansai-u.ac.jp)
The reverse perspective (RP) illusion produces a false sense of motion in a static picture as a consequence of a conflict between motion parallax and pictorial depth cues. We have measured brain activation in an fMRI experiment by changing the pictorial cues as well as the strength of the illusion in a behavioural experiment using stereo graphics images. The activations were not found in the frontal cortex but mainly in the visual fields of the occipital and parietal lobes, and were not affected by the type of stimulus. Only when subjects voluntarily see the illusion without pictorial cues can activations in the frontal field be observed. Illusion threshold was

affected by the pictorial cues, but once the illusion was observed it was sustainable even if the binocular disparity of stereo projection was changed to the reverse direction. Results indicate that the top–down processing for inversing the depth perception on the basis of pictorial cues may not work continuously once the RP illusion is observed.
[Supported by JSPS.KAKENHI, Grant No.16300085.]

◆ **Spatiotemporal encoding of saccade kinematics in the midbrain superior colliculus of macaque monkey**
J Goossens, A J van Opstal (Department of Biophysics, Donders Centre for Neuroscience, Radboud University Nijmegen Medical Centre, The Netherlands;
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Saccades have stereotyped characteristics. Their trajectories are virtually straight, and the amplitude-duration relation follows a straight line while peak velocity depends in a nonlinear, saturating way on saccade amplitude. Most models attribute this nonlinear 'main sequence' behaviour to saturation of firing rates in brainstem burst cells. However, there is little evidence to support this assumption. Here we present evidence for an alternative scheme, which proposes that the nonlinearity of saccade kinematics resides in the spatiotemporal dynamics of superior colliculus (SC) activity. We demonstrate that there is a gradient along the motor map of the burst properties of saccade-related cells: peak firing rates decrease, while burst durations and skewness increase from rostral to caudal locations. Simulations with our spike-vector summation model (2006 *Journal of Neurophysiology* **95** 2326–2341) show that this gradient can fully account for the kinematic nonlinearity of saccades. Without it, the model behaves as a linear system. We conclude that the SC acts as a nonlinear, vectorial pulse generator that specifies an optimal straight trajectory. This conclusion places the SC outside the feedback loop.
[Supported by NWO, ALW grants 864.06.005 (VIDI to JG) and 805.05.003 (VICI to AJvO).]

◆ **Attentional effects on power spectra for drift eye movements**
T Kohama, N Toda¶ (School of Biology-Oriented Science and Technology, Kinki University, Japan; ¶ Faculty of Information Science and Technology, Aichi Prefectural University, Japan; e-mail: kohama@info.waka.kindai.ac.jp)

Fixation eye movements are classified into three types of motion: microsaccades, drift, and tremor. These minute eye movements are necessary to maintain visibility of the static visual world. Recent studies have demonstrated a close relationship between the frequency of microsaccades and covert attention shift. However, the attentional effect on drift movements in attentive or inattentive fixation is not explored. In this study, we examine whether visual attention has any influence on drift eye movement based on statistical analysis of time series of fixation eye movements. Fixation data were collected under the following experimental conditions: (i) visual attention is focused on the foveal region, (ii) visual attention is dispersed over the parafoveal visual field, and the power spectrum of drift eye movements has been estimated. The results of our analysis show that the power in the 3–4 Hz frequency range declines when visual attention is focused on the foveal object. This suggests that concentration of attention onto the gazing object may enhance the stability of the fixation.

◆ **Saccadic compression depends on colour and luminance distribution of stimulus pattern**
A Miyamoto, K Ukai (Graduate School of Advanced Science & Engineering, Waseda University, Japan; e-mail: macjoy@suou.waseda.jp)

During saccades, perceptual image is compressed along the direction of eye movements. The present study aims to clarify how compression varies depending on the stimulus pattern. The target, composed of 7 bars, was presented during saccades. The basic arrangement of 7 bars was red/black/red/black/red/black/red. The size of each bar was 2.4 deg wide $\times$ 25 deg high, so that the entire width of the target was 17 deg. The luminance of the red bars was 5.5 cd m^{-2}. Black and surround were almost totally dark. Subjects were requested to evaluate the perceived width (as a percentage of the static image) for red, black, and the whole target. Colour and luminance variations of the target were pairs of red/green, red/2green, blue/black, green/black, and white/black. Results indicated that saccadic compression was observed for the whole target width, with less effect in the bright bars, and an enhanced effect in the dark bars. The effect was almost independent of the target colour. Saccadic compression of complex pattern may be affected by the luminance distribution of the stimulus.

◆ **Ageing affects the sensitivity to biological motion**
K S Pilz, A B Sekuler, PJ Bennett (Department of Psychology, McMaster University, Hamilton, Canada; e-mail: pilzk@mcmaster.ca)
Previous work in our lab has shown that older observers are less sensitive to low-level motion and have difficulties to discriminate the direction of motion. Here, we investigated whether this decreased sensitivity also applies to biologically relevant stimuli. Therefore, we asked older (> 60 years) and young observers (18 – 27 years) to detect the walking direction of point-light walkers. For both age groups, sensitivity to the walking direction improved significantly with stimulus duration in both upright and inverted walkers, but older observers needed significantly longer stimulus durations than younger observers to achieve the same level of performance. Both age groups also showed a decrease in performance when the walkers were inverted. This effect was more pronounced in older subjects. Finally, young observers showed the same level of performance for walkers presented with and without noise. Performance of older observers, however, decreased significantly when the walkers were presented in noise. These results suggest that older observers are less sensitive to biological motion.

◆ **Effect of ramp response velocity on accommodative suppression**
S Mucke, V Manahilov, N C Strang, D Seidel, L S Gray (Vision Sciences, Glasgow Caledonian University, UK; e-mail: Sven.Mucke@gcal.ac.uk)
We have recently shown a new suppression of contrast sensitivity to stimuli of higher spatial frequencies during the fast phase of accommodation ramp responses, which occurs in addition to optical blur related visual degradation. Accommodation models would predict that the strength of this accommodative suppression is dependent on the velocity of changes in ramp responses. To test this we assessed the strength of visual suppression at various time lags after the accommodation onset as a function of ramp velocity. Significant suppression (0.33 ± 0.12 log units, $p < 0.05$) of contrast sensitivity to 9 cycles deg^{-1} gratings was found during the fastest ramp responses (10 D s^{-1}) but not at velocities below 2 D s^{-1}. There was no significant suppression for gratings of 1 and 4 cycles deg^{-1} at any accommodation velocity. The data were accounted (adjusted $R^2 = 0.9$) for by a model of accommodative suppression, assuming a subtractive suppression mechanism whose output is proportional to the velocity of the accommodation response. These findings suggest that the suppression mechanism could reflect a central 'corollary discharge' generated by fast accommodation velocities.

◆ **A memory- and visually-guided saccade paradigm with increased memory load using fMRI**
V Fischer, M Raabe, D Bernhardt, M W Greenlee (Department of Experimental Psychology, University of Regensburg, Germany; e-mail: Volker.Fischer@psychologie.uni-regensburg.de)
Memory- and visually-guided saccades were examined in several previous fMRI studies and have shown different activation patterns using mostly one dimension (position of target) for memory encoding (eg, Srimal and Curtis, 2008 *NeuroImage* **39** 455 – 468). To increase memory load and therefore make the paradigm more sensitive for spatial working memory, participants had to memorise three stimulus dimensions in our experiment: position, colour and form. Each dimension had four possible occurrences. To ensure comparability of the memory- and visually-guided saccade trials, the same type of stimuli were shown inside the two tasks in temporally reversed order. As found in previous fMRI studies (eg Brown et al, 2004 *Journal of Neurophysiology* **91** 873 – 889), the GLM results of nine subjects show an increased hemodynamic response in the dorsolateral prefrontal cortex, the supplementary eye fields, and the posterior parietal cortex for the memory-guided task. The increased response in these areas suggests their role in the visual working memory task.

MOTION PERCEPTION AND TEMPORAL ISSUES

◆ **The grouping of global motion components is influenced by both form and motion cues**
A I Meso, J M Zanker (Department of Psychology, Royal Holloway University of London, UK; e-mail: a.i.meso@rhul.ac.uk)
The simultaneous perception of two objects or layers within the same spatial region—transparency—can be based on form or motion cues that identify the individual components. In this study, we explicitly incorporate both cue types into transparently moving 'random disc kinematogram' stimuli. The discs are randomly distributed as in random dot kinematograms but are larger, providing (circular, figural) form information. With a 2AFC comparison task, we investigate quantitatively the perceptual mechanisms of separating and grouping of global motion components, estimating the strength of perceived transparency of two transparently moving disc populations with different velocities. The disc parameters of size, speed, density, and luminance are all shown to affect perceived transparency. The trends in the data suggest that both the motion and form cues contribute to the grouping and separation of components. We also test

the separation of discs under linear and nonlinear superposition which seems to indicate that linear superposition is more compatible with moving stimuli while nonlinear superposition is more compatible with stationary transparent stimuli.
[Supported by EPSRC CASE studentship EP-D504538-1.]

◆ **Motion spatial facilitation assessed by reaction time**
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In a previous study we demonstrated that two concurrent moving stimuli increase the flash-lag effect, presumably due to a shorter latency in movement perception. A mechanism of preactivation of neighbouring areas of the cortex by a moving object has been postulated. A a consequence the time needed to detect a target should decrease when its presentation is preceded, in a certain spatiotemporal window, by a moving object converging towards the same spot. We tested this hypothesis by measuring the time required to detect a Gaussian patch preceded by moving Gabor patches. We found a reduction of perceptual latency for specific combinations of distance, time, and orientation of the Gabor patches. This is probably due to a facilitation wave consistent with neurophysiological data on long-range horizontal connections, supporting the influence of these connections on motion perception. Interestingly, we also found an increment of perceptual latency that follows the facilitation wave consistent with the activation of local inhibitory circuits.

◆ **Distinct position assignment mechanisms revealed by cross-order motion**
A Pavan, G Mather¶ (Department of General Psychology, University of Padua, Italy; ¶ Department of Psychology, University of Sussex, Brighton, UK;
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Motion shifts the perceived position of a moving object. It has been shown that both first-order (luminance defined) and second-order (eg contrast defined) motion shift perceived position, but with different spatiotemporal tuning (Bressler and Whitney, 2006 *Vision Research* **46** 1120 – 1128). These differences reveal distinct position assignment mechanisms for these two types of motion. To investigate whether first- and second-order systems independently assign the position, we measured position shifts using first-order, second-order, and cross-order stimuli. Horizontally offset first- and second-order drifting Gabors were placed above and below a central fixation point. Subjects judged the position of the top Gabor relative to the bottom one. Results showed a strong position shift when both Gabors were first-order and a weak position shift when both were second-order. However, no appreciable position shift was found when one Gabor was first-order and the other was second-order (cross-order motion). This lack of effect using cross-order motion supports the hypothesis that the two motion systems independently assign the position of a moving object.

◆ **Using speed and size in motion-in-depth is time and task dependent**
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Rate of expansion, changing size, and changing disparity all contribute to perception of motion-in-depth. Here we focus on the first two cues and address whether their use depends on integration time and task. Stimuli consisted of circles whose size was sinusoidally modulated with different temporal frequencies. Within a trial, periods of visibility (either 0.2 or 0.5 s) alternated with blank displays (0.55 s) until the subject responded. In separate sessions participants detected motion or matched the speed of a test with a reference. Log-log plots of detection thresholds (or amplitudes set to match the speed) versus temporal frequency allowed us to distinguish the use of total change in size (zero slope) or speed (slope of -1) (Nakayama and Tyler, 1981 *Vision Research* **21** 427 – 433). In the speed-matching task, subjects switched from using size for short integration times to speed for longer presentation times. The opposite pattern is found when participants had to detect motion.

◆ **Binocular rivalry between fast 'streaky' motions deeply suppresses static orientation probes: evidence for motion streaks and selective rivalry suppression**
D Alais, D M Apthorp, P Wenderoth¶ (School of Psychology, University of Sydney, Australia; ¶ Department of Psychology, Macquarie University, Sydney, Australia;
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Does fast motion leave neural 'streaks'? Is rivalry suppression feature-specific or 'whole eye'? We test both by rivaling fast motions and measuring sensitivity to oriented probes at various orientations and spatial frequencies (SFs). Orthogonally translating Gaussian-blob fields engaged

in rivalry. Probes were brief monocular stimuli smoothly presented to dominant or suppressed eye with contrast varied to find threshold. 2×2 design: motion speed was fast ('streaky') or slow; probe orientation was aligned or orthogonal to streaks. Subsequent experiments varied probe SF and orientation to determine any rivalry suppression tuning. Consistent with 'streaks', probes aligned with motion trajectory were much more deeply suppressed than orthogonal probes, but only for fast motion. Tuning data showed the strong suppression in 'fast aligned' conditions weakened if probe orientation and SF differed from the 'streaks'. The high-speed orientation dependency suggests fast motions do leave neural steaks. High-speed rivalry therefore involves motion and orientation conflict, with suppression components from each dimension combining. The extra component in 'fast aligned' conditions was tuned, indicating feature-specific suppression.

◆ **Effect of field-of-view on the Coriolis illusion**

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Tilting the head during rotation about an Earth-vertical axis produces cross-coupled stimulation of the semicircular canals. Without visual feedback on the actual self-motion, this leads to the so-called Coriolis illusion. We investigated the effect of the field-of-view (FOV) on the magnitude and duration of the Coriolis illusion. Fourteen subjects were rotated leftward on a Barany chair at a constant velocity of 60 deg s^{-1}. After 30 s they tilted their head 45 deg to the right, resulting in a sensation of forward tumbling. In two conditions, subjects wore goggles with a FOV of 40 deg and 80 deg, respectively. Compared to a reference condition, in which subjects were blindfolded, both FOV conditions significantly reduced the magnitude and duration of the Coriolis illusion by 60 – 80%. However, the difference between both 40 deg and 80 deg FOV was not significant. In contrast, the FOV significantly affected settings of the 'subjective visual horizon' against a constantly rotating visual background, measured in an additional test. These results suggest that the Coriolis illusion does not simply depend on visually-induced self-motion, or 'vection'.

◆ **Perception of duration in the parvocellular system**

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It as been suggested that perception of time might be mediated preferably by the fast and transient magnocellular system as opposed to the slow and sustained parvocellular system. We compared the perceived duration for stimuli that excite optimally the parvocellular pathway (1 cycle deg^{-1} equiluminant and 14 cycles deg^{-1} luminance modulated Gabor patches) with those optimal for the magnocellular pathway (1 cycle deg^{-1} luminance modulated Gabor) over a wide range of contrasts (from twice to 15 times visibility threshold) and durations (from 500 to 1100 ms). For all conditions, equiluminant stimuli are perceived as shorter than luminance modulated Gabors both of low and of high spatial frequencies. The effect is about 150 ms and constant at all the durations tested. The results at various contrast levels indicate that equiluminant stimuli have higher thresholds to trigger the clock mechanisms. Overall the results imply that both the magnocellular and the parvocellular systems access reliably the timing mechanisms and that the difference in performance can be ascribed to the different temporal properties of the two systems.

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◆ **Does the visual system need higher energy for perceiving structural changes?**

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Bouncing perceptions of two disks moving along same path have been studied as a causality [Kanizsa, 1979, in *Organization in Vision* (New York: Praeger) pp 51 – 52; Sumi, 1988 *Perception* **17** 405 (abstract); Scholl and Nakayama, 2004 *Perception* **33** 455 – 469]. We observed two disks moving along same path in opposite direction and found that passing-through perception is dominant in peripheral, while bouncing perception is dominant (almost 100%) in central with attention. Surprisingly, when bouncing perception is dominant, two disks were perceived as if they rest at sufficiently before physically overlapping position and turn back, in both condition at higher speed and at rather slower speed; fully overlapped situation of two disks could not be perceived. In addition, we found that passing-through perception is dominant with the depth difference perception between two disks, while bouncing perception is dominant without the depth difference perception. These results imply that the visual system need higher energy for perceiving structural change and difficult to perceive as one disk even when two disks were fully overlapped.

◆ **What determines the strength of motion illusions in Op Art paintings?**
J M Zanker, F Hermens, R Walker (Department of Psychology, Royal Holloway University of London, England; e-mail: j.zanker@rhul.ac.uk)
Op artists used simple black and white patterns to elicit vivid sensations of movement in static images. The origin of such motion illusions have been in the centre of a scientific debate relating motion processing mechanisms to involuntary eye movements that generate characteristic motion interference patterns (Zanker and Walker, 2004 *Naturwissenschaften* **91** 149 – 156). To overcome the limitations of subjective ratings for illusory effects, we optimised a new method to quantify the strength of the illusion for synthetic 'riloids' that were inspired by Bridget Riley's 'Fall'. In a 2AFC paradigm the motion sensation arising from a test stimulus is compared with that from reference stimuli, which were combinations of a riloid and a checkerboard pattern at different contrast ratios. Using this method we found that pattern parameters related to the phase modulation of the riloid gratings affect illusion strength. The largest effect, however, is observed for variation of grating contrast. These quantitative data can be compared to computer simulations of motion detector networks in combination with the statistics of involuntary eye movements.
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◆ **Perceptual transitions in bistable perception occur correlatively between vision and hearing**
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Our perception fluctuates spontaneously among some percepts, typically when we face to ambiguous perceptual situation such as seeing reversible figures. Research has demonstrated that temporal patterns of perceptual transitions observed for different types of stimuli are correlated with each other within visual modality. However, Pressnitzer and Hupé (2006 *Current Biology* **16** 1351 – 1357) reported that such correlations were not observed across sensory modalities using bistable phenomena (visual plaid motion and auditory streaming). The present study further examined crossmodal correlations by comparing temporal dynamics of perceptual transitions occurred during 7.5 min observations of three types of phenomena: visual plaid motion, auditory streaming, and auditory verbal transformation. Significant correlations for individual biases in the bistable percepts were reported within vision and hearing, but not reported across sensory modalities. The critical finding was that the frequencies of perceptual transitions were correlated significantly between vision and hearing, although the crossmodal correlations were relatively weaker than those observed within each sensory modality. The results suggest that perceptual transitions in vision and hearing share some mental processes.

◆ **Bistability of point-light biological motion and Necker cubes under stereoscopic and perspective depth cues**
M H E de Lussanet, M Lappe (Department of Psychology, Westfälische Wilhelms-Universität Münster, Germany; e-mail: lussanet@psy.uni-muenster.de)
The depth of a point-light walker in half-profile is ambiguous. In the present study we asked whether this depth percept is bistable. We measured the influence of monocular (linear perspective) and of binocular (stereo) depth cues on the accuracy and the stability of the percept. We compared the sensitivity for walking and for rocking Necker cubes. Perspective was useless for Necker cubes but could be used for the walking, and stereo completely disambiguated the Necker cubes but was of less help for walking. In the bistability task, depth made the correct percept more stable and the wrong percept less stable than the flat displays. Flat biological motion was less stable than a rocking Necker cube but more stable than a stationary Necker cube. We conclude that the depth percept of biological motion percept is truly bistable, similar to the Necker cube. The influence of depth, and the correspondence between sensitivity and bistability indicates that the cortical representation of biological motion includes depth information.

◆ **World stability during visual translations: analyzing the speed perception compensation mechanism**
M Vidal, P Pretto¶ (LPPA, Collège de France, Paris; ¶ Max Plank Institute for Biological Cybernetics, Tübingen, Germany; e-mail: manuel.vidal@college-de-france.fr)
While walking, the visual scene analysis provides both structural information about the environment, and self-motion characteristics. These two categories are in fact strongly interrelated. During constant speed translations on a plane, the angular retinal speed varies according to where we look at, and still self-linear speed is perceived as constant which allows the world to appear stable. We studied factors involved in the retinal-to-linear compensation mechanism underlying this perceptual stability. In all experiments we used a speed discrimination task between two

gaze directions (12°, 20°, or 28° below horizon). When keeping the eyes static, the compensation was almost perfect if viewed with a full field 86%, whereas it was poorer, but far from null, if viewed with a 6° vertical aperture 74%. When tracking a target on the plane, this compensation improved for both full and limited field. Finally, reducing the visual scene to the tracked target also allowed for good compensation, though worst than with the plane. These findings are discussed with regard to inverted structure-from-motion mechanisms.

◆ **Different form – motion interaction in detection of radial, concentric, and spiral patterns**
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Dynamic Glass patterns (Ross et al, 2000 *Current Biology* **10** 679 – 682) cause strong impression of dynamic movement, although they have no directional information. This suggests that there is a strong form – motion interaction in visual processing. We examined whether the interaction changes depending on difference of global structure of a dynamic Glass pattern. We measured coherence thresholds for detecting global structures (radial, concentric, and two spiral patterns) in moving, dynamic Glass, and static Glass patterns, respectively, in order to compare the thresholds among the three pattern conditions. In detection of radial and concentric pattern, thresholds for the dynamic Glass patterns were quite similar to those for the moving patterns, while they were significantly lower than those for the static Glass patterns. On the other hand, thresholds for dynamic Glass patterns were significantly higher than those for moving patterns in detection of the other two spiral patterns. This implies that form – motion interaction is much more relevant for the detection of global structures in radial and concentric patterns than for other motion patterns.

◆ **Perception of trajectory of an approaching object in flight**
P A Duke, S K Rushton¶ (School of Psychology, University of Leicester, UK; ¶ School of Psychology, Cardiff University, UK; e-mail: pad11@le.ac.uk)

It has been suggested (Harris and Drga, 2005 *Nature Neuroscience* **8** 229 – 233) that perceived approach trajectory is a function of the change in an object's visual direction (delta-direction). We recently concluded that perceived trajectory is based on a speed-ratio: the ratio of lateral angular speed to speed of motion-in-depth (Rushton and Duke, 2007 *Vision Research* **47** 899 – 912). To discriminate between these two proposals we compared the perceived trajectory of objects of differing size: delta-direction predicts the perceived trajectory will be independent of object size; the speed-ratio predicts perceived trajectory will become less eccentric with increasing ball size. Observers compared the trajectory direction of two approaching objects, of the same or different size, seen in separate intervals. Observers judged whether the object in the second interval was travelling on a trajectory tending to the left or right of parallel with respect to the first interval trajectory. From the responses we estimated perceptually parallel trajectories. Object size was found to influence perceived trajectory in-line with the use of the speed-ratio.

◆ **Accuracy of stereomotion speed perception in RDS and DRDS stimuli**
K Brooks, L Stone¶ (Department of Psychology, Macquarie University, Sydney, Australia; ¶ Human Systems Integration Division, NASA Ames Research Centre, Moffett Field, USA; e-mail: kevin.brooks@psy.mq.edu.au)

Stereomotion (binocularly specified motion-in-depth) studies have established the existence of several cues to speed. For binocular features, cues involve (a) changes in disparity over time ('changing disparity', CD), or (b) differences in the velocities of features between the eyes ('interocular velocity difference', IOVD). Although the precision of these has been studied, their accuracy has not. We performed a 2AFC stereomotion speed discrimination experiment ($N = 4$) to ascertain the relative perceived speed of RDS (CD and IOVD cues) and DRDS (CD only) stimuli undergoing directly approaching or receding motion in depth. Despite lacking IOVD information, DRDS stimuli appeared to move more rapidly, on average by $\sim$20%. Our observations are consistent with a scheme in which the contributions of cues relying on monocular motion signals (looming and IOVD) are reduced in dynamic stimuli due to their lack of reliability. While DRDS stimuli are relatively unaffected by the contributions of such cues signalling no stereomotion, RDS stimuli retain a significant and conflicting contribution from the looming cue, resulting in lower perceived speed.

◆ **Enhancing the smoothness of apparent motion by synchronous global changes**
T R Scherzer, V Ekroll (Institut für Psychologie, Universität Kiel, Germany; e-mail: scherzer@psychologie.uni-kiel.de)

Apparent motion stimuli often appear jerky, in particular if stimulus displacements and interstimulus intervals are large. We observed that flickering and jerkiness of a target was considerably

reduced when its disappearance during the interstimulus interval was accompanied by a simultaneous change of the background. Our data show that this 'smoothness effect' is stable over a wide range of various spatiotemporal parameters. We speculate that this phenomenon occurs because the visual system attributes the irregularities in the local stimulation to global events rather than to the moving object itself.
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◆ **Motion adaptation in population responses: models and measurements**
S P Heinrich, R Lipp, M Bach (Sektion Funktionelle Sehforschung, Universitäts-Augenklinik Freiburg, Germany; e-mail: sven.heinrich@uniklinik-freiburg.de)
Adaptation-induced reduction of a population response (eg, VEP, fMRI) to motion depends on the relative directions of adaptation and test stimuli. We modeled the shape of the population adaptation tuning function starting from individual neuronal detectors, taking into account their direction-dependent adaptation and their contribution to the population response. Different effects of adaptation have been proposed on a single-neuron level. We assessed an amplitude model (response reduction through adaptation), a width model (narrowing of tuning), a direction model (shift of the preferred direction), and a mixed model. The width model showed a sharper population adaptation tuning than the direction model for directions close to the adaptation direction, but not for other directions. In the direction model, the population response was reduced for directions away from the adaptation direction, but increased around the adaptation direction. The mixed model was similar to the amplitude model. Visual evoked potential measurements comparing the N2 amplitude obtained with moderate and strong adaptation were best explained by the amplitude and mixed models.

◆ **Dynamic auditory cues modulate visual motion processing**
W Teramoto, S Hidaka¶, J Gyoba¶, Y Suzuki (Research Institute of Electrical Communication [¶ Department of Psychology, Graduate School of Arts & Letters], Tohoku University, Japan; e-mail: teraw@ais.riec.tohoku.ac.jp)
This study investigated the effect of dynamic auditory cues on visual representational momentum (RM). A visual target smoothly moved towards a center of the display from the left or right side with/without auditory stimuli, and disappeared at unpredictable positions. Participants judged whether a probe presented after the target's offset was to the left or right of the target's final position. There were three sound conditions: silent, constant noise, and 'approaching noise' where, as the visual target approached the centre of the display, interaural time- and level-differences dynamically changed and overall intensity increased. The results showed that the remembered final position of the visual target with approaching noise was more mislocalized in the direction of visual motion, as compared with the other conditions. In a following experiment, we confirmed that the magnitude of mislocalization was larger in the condition where both of interaural differences and overall intensity dynamically changed than in conditions where only one of the cues changed. These findings suggest that dynamic auditory information mediate visual motion processing.
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◆ **Interactions between a stationary stimulus and a stimulus moving in depth**
S Tanahashi, I P Howard¶, K Ukai§, H Ujike# (York University, Toronto, Canada; also Waseda University, Tokyo, Japan; and AIST, Japan; ¶ Centre for Vision Research, York University, Toronto, Canada; § School of Science and Engineering, Waseda University, Japan; # Institute for Human Science and Biomedical Engineering, AIST, Japan; e-mail: zyuma1218@gmail.com)
A sensation of motion in depth occurs when a surface undergoing sinusoidal modulation of horizontal disparity is superimposed on a stationary stimulus. However, perceived motion in depth is not necessarily assigned to the display that changes in disparity. We investigated the stimulus factors that determine which of two superimposed frontal displays appears to move in depth. One display was stationary; the other underwent sinusoidal modulation of horizontal disparity. The stimulus factors were: relative size, relative luminance, which display was stationary, and the relative depth of the two displays. Nine observers tracked the perceived to-and-fro motion in depth of each display by moving an unseen knob along a track in the median plane. Motion in depth was generally assigned to the smaller stimulus whichever was moving. This is analogous to induced motion in which frontal motion of a large stimulus is assigned to a small stimulus. Also, motion in depth was generally assigned to the dimmer stimulus whichever was moving. There were some interactions but no significant effects of relative depth.
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OBJECTS, FACES AND SHAPES

◆ **Effects of static cast shadows on size judgments**

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A cast shadow is a pictorial depth cue strongly influences human judgments of spatial position of objects. We investigated how judgments of object size were affected by cast shadows. Adult participants classified computer-graphic balls of various sizes into large or small. In Experiment 1, the ball appeared with a cast shadow on a textured ground surface. Positions of ball and shadow were varied. When the shadow was located below the ball, the participants' judgments shifted to 'small' if there was a gap between the ball and the shadow, but did not if there was no gap. When the shadow was located above the ball, their judgments were not influenced. In Experiment 2, we compared texture alone, shadow alone, and the no-cue conditions. The participants perceived the size constancy illusion in the texture-alone condition but not in the other conditions. These results suggest that the human visual system rapidly extracts valid shadow information and calculate the spatial position of objects on the ground surface in object-size judgments.

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◆ **Timing of internal and external facial features**

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Timing of processing internal and external facial features was studied by measuring proportion correct functions of exposure duration with a same/different paradigm. The results indicate that processing of the two feature categories involves different mechanisms. First, relatively independent of task difficulty, external features can be matched at a 75% level of correctness already within the first 100 ms of exposure duration; in contrast, matching internal features at the same accuracy level required much longer exposure durations (100 – 250 ms), depending on the difficulty of the task. Second, with external features a higher saturation level of accuracy is reached than with internal features. Third, the facial inversion effect (FIE) is found with internal features consistently at all exposure durations and at all levels of task difficulty. For external features we find no FIE, with the exception of brief timings. Our results indicate a strong configural influence in the processing of internal features, and feature matching requires resolving this influence at the costs of additional processing time.

◆ **Do we process emotional and non-emotional facial expressions in the same way? Behavioural evidence of a possible dissociation**

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Neuropsychological and neuroimaging studies have shown that facial identity and emotional expressions are dissociable. However, it is unknown if the processing of emotional and non-emotional facial expressions involves a single system. We carried out a behavioural study in which we compared performance in a recognition task (2AFC paradigm) and in a same/different judgment task, using upright and inverted faces. In Experiments 1, 2, and 3 we manipulated, respectively, internal features, emotional facial expressions, and non-emotional facial expressions, and we measured accuracy and RT. Subjects were shown a different pattern of results for each of the three manipulations, particularly in the presence and amount of the inversion effect (IE). In a further experiment we tested subjects with a pathological score at standard face recognition tasks. They did not show an IE. In the same/different task, non-emotional facial expressions facilitated the judgment in the upright orientation, whereas emotions and features manipulation did not. The data suggest that non-emotional facial expressions could be processed in a specific way, and may be dissociable from other facial features.

◆ **Reactions to fear and anger: the detection of briefly presented facial expressions**

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We reasoned that responses to briefly presented facial expressions may reflect the operation of mechanisms evolved to make rapid expression-dependent judgments. We showed subjects four blocked series of faces, each block contained two facial expressions (neutral plus fear or anger) presented at one viewpoint (full face or 3/4 leftward). Blocks contained an equal mix of male and female faces, expressive and neutral faces. Faces were displayed for 100 ms and subjects were instructed to make rapid responses classifying the expressions as either neutral or angry/fearful. We calculated sensitivities (d'), response biases (c), and median reaction times. We found that

subjects were more sensitive to fearful than to angry expressions, and more sensitive to male than female expressions. Subjects were more willing to report an expression when viewing direct rather than averted faces, and were more liberal in their judgments of male anger than other expression/gender combinations. Our results are concomitant with a view in which rapid human expression analysis is preferentially tuned to detect briefly presented expressions of fear.

◆ **The development of phonemic – iconic congruency: children's performance in naming task**
D Jankovic (Department of Psychology, Faculty of Philosophy, University of Belgrade, Serbia; e-mail: djankovi@f.bg.ac.yu)

In previous experiments we used choice and visualization tasks to study the development of phonemic-iconic congruency and confirmed the phenomenon at all age-groups, starting from 5 year olds. The strength of the effect increases with age and is dependent of the type of the task performed (Jankovic, 2006 *Perception* **35** Supplement, 90). In this study we analyze the development of the phonemic – iconic congruency in the naming task. Three groups of respondents (9, 14, and 19 years) were asked to produce pseudowords corresponding to presented monochromatic abstract visual patterns. Visual patterns were varied according to the following dimensions: sharp/oval, dark/light, simple/complex, and compact/disperse. The corpus of 1875 pseudowords per visual pattern was obtained. The results confirmed the phonemic – iconic congruency phenomenon at all ages in this type of task, ie the distribution of phonemes and consonant-vowel patterns in pseudowords produced for abstract visual patterns strongly depends on physical characteristics of visual patterns. The results also showed increase in the strength of the effect with age.

◆ **Decoding scene categories using distributed patterns of fMRI activity**
E Caddigan, D B Walther¶, L Fei-Fei§, D Beck (Department of Psychology [¶ Beckman Institute], University of Illinois at Urbana-Champaign, USA; § Department of Computer Science, Princeton University, USA; e-mail: ecaddiga@uiuc.edu)

Human observers are able to quickly extract information from images of natural scenes (Potter and Levy, 1969 *Journal of Experimental Psychology* **81** 10 – 15). As a means of identifying regions potentially involved in scene category identification, we used fMRI and statistical pattern recognition algorithms (Cox and Savoy, 2003 *Neuroimage* **19** 261 – 270) to identify distributed patterns of activity associated with scene categories (eg, forests, buildings). In a leave-one-run-out cross-validation procedure, significantly above-chance classification rates were obtained using voxels from PPA (Epstein and Kanwisher, 1998 *Nature* **392** 598 – 601). A significant decrease in classification accuracy was observed when using fMRI data obtained while observers viewed inverted images. This 'inversion effect' for scenes was also seen as a decrease in accuracy for participants performing a rapid categorization task for inverted versus upright images. Moreover, a significant correlation was found between the categorization errors made by the statistical pattern recognition algorithms and those made by participants performing rapid categorization. These results suggest that the category information extracted from fMRI data by statistical pattern recognition algorithms may correspond to that used by human observers.

◆ **Perceiving facial expressions of emotions: a dimensional and feature-based account**
C Fiorentini, P Viviani (Faculty of Psychology and Educational Sciences, University of Geneva, Switzerland; e-mail: fiorentinichiara@gmail.com)

To understand how we recognize emotions from faces we still need to clarify (i) if expressions are mapped onto a categorical or a dimensional space; and (ii) if the recognition process is holistic or feature-based. We addressed these issues with a novel morphing manipulation. In Experiment 1 (identification task) and Experiment 2 (ABX task) equally spaced morphs are used to reveal the presence of categorical perception effects. We conclude that expressions of anger, fear, happiness, and disgust do not correspond to primary perceptual categories. Instead, they are coded in a continuous space structured by valence axes. In Experiment 3 we generated chimerical morphs between two expressions, by morphing the upper and lower face at different rates. Subjects identified the emotion globally expressed by the face as one or the other endpoint. The position of perceived subjective equality (PSE) along the morphing sequence was sensitive to the rate of change, implying that different facial features are salient for recognizing different emotions. This suggests that feature-based processing is sufficient for identifying expressions.

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◆ **Learning the gist? Priming of an object by a visual scene: effect of low spatial frequency content and familiarity**
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We studied the scene-facilitating effect on object categorization using a priming procedure: a 200 or 800 ms scene prime was presented prior to a target (a man-made or a natural object appearing in the scene) in two experiments. Low level information of the scene was varied using three primes: the complete normal scene, the low-SF scene, and a control random phase scene. Semantic information was also varied by (i) using low or high object/scene compatibility, and (ii) increasing scene familiarity with three learning blocks requiring semantic categorization of the scene (indoor/outdoor). Results showed a priming effect on RT for normal novel primes whatever its duration when the object/scene consistency is high, but the priming effect is restricted to the long duration for low-SF scene primes. For learned scenes, priming extended to low compatible pairs for normal scene primes and to short duration for low-SF primes. These interactions between low-level and high-level information give additional support to the role of the gist of a scene in object processing.

◆ **Are curved visual objects always preferred?**
I Bohrn, G Nabecker, C C Carbon (Faculty of Psychology, University of Vienna, Austria; e-mail: isabel.bohrn@univie.ac.at)

Do people always prefer curved visual objects over angular ones? Bar and Neta (2006 *Psychological Science* **17** 645 – 648) propose that angular shapes trigger feelings of threat which elicit disliking. However, analysing patterns of design and fashion development we do not observe stable preferences for curved design (Carbon and Leder, 2005 *Applied Cognitive Psychology* **19** 587 – 601). Forty-two participants rated the degree of curvature of representative popular car models of six brands of cars (Audi, BMW, Ford, Mercedes, Opel, VW) from ten pentades between 1950 and 2000. Here we show a periodic pattern of curvature in car design over all brands. A high degree of curvature was popular during the 50s, giving place to more angular shapes in the 70s and 80s, and moving back towards higher levels of curvature after 1985. Such regular shifts in popular design preferences conflict with a unidimensional theory of evolutionary-based preferences and emphasise the role of sociocultural modulation triggered by fashion trends and the changing zeitgeist.

◆ **Feature sensitivity as a result of visual categorization**
J B T Wegman, M van der Linden (F. C. Donders Centre for Cognitive Neuroimaging, Radboud University, Nijmegen, The Netherlands; e-mail: joost.wegman@fcdonders.ru.nl)

In this study we tested the hypothesis that category learning involves increased sensitivity to those features that are relevant for category membership. We trained twenty-four adults for three days with computer-generated fish stimuli. These stimuli were parametrically modified along four feature dimensions. Subjects learned to categorize the stimuli using a one-back same/different category task. For each participant two features were informative for category membership and two features were uninformative. The category boundary was a linear combination of the informative dimensions. During training, performance became faster and more accurate. Subjects were also more accurate and faster for fish further away from the category boundary, ie when features made categorization easier to recognize. Furthermore, after training, subjects showed a higher perceptual sensitivity to informative dimensions compared to non-informative dimensions in a similarity rating task. These data underline the relevance of task-specific informativeness on the representation of perceptual features in category learning. Currently we are investigating these representations using fMRI.

◆ **Contrast sensitivity changes in persons with prosopagnosia**
R Lukauskiene, R Liutkeviciene, D Zaliuniene, V Jasinskas, D Stanislovaitiene (Kaunas University of Medicine, Lithuania; e-mail: luka_rita@yahoo.com)

The aim of study is to investigate contrast perception disorders in prosopagnosia. Two persons (4 eyes) with prosopagnosia and forty healthy persons were tested. Contrast sensitivity was measured employing Ginsburg Box, VSCR-CST-6500 with a functional acuity contrast test chart at photoptic (85 cd m^2) and mesopic (3 cd m^2) luminance with and without glare at 5 standart spatial frequencies, from 1.5 to 18 cycles per deg^{-1}. The log of the values obtained was used to calculate the contrast sensitivity values. A difference level of 0.15 log unit between test at given spatial frequency was selected to determine clinical significance. There was no statistically significant difference at the mesopic luminance without glare for low frequencies, but for high

frequencies in persons with prosopagnosia, values were two times worse than those in the control group ($p < 0.005$). At photopic luminance in persons with prosopagnosia contrast sensitivity in all frequencies was worse than in the control group ($p < 0.005$).

◆ **Contrast detection thresholds for natural and $1/f$ random noise images**
D Ellemberg, A P Johnson¶, B C Hansen§ (Department of Kinesiology, Université de Montréal, Canada; ¶ Department of Psychology, Concordia University, Montreal, Canada; § Department of Psychology, Colgate University, New York, USA; e-mail: dave.ellemberg@umontreal.ca)
We compared detection thresholds in children and adults with natural images and $1/f$ noise images for which a specific octave of spatial frequency was removed. Our data show that for children and adults, detection thresholds for natural images were increased by the removal of spatial content. Thresholds were most elevated when the frequencies removed were those for which the visual system is most sensitive to. Unlike grating contrast sensitivity which becomes adult-like at each frequency by 7 years of age, contrast sensitivity for natural images only becomes adult-like by about 10 years of age. Further, sensitivity matures less rapidly for middle frequency filtered natural images than for the lower and higher frequency filtered natural images. Because of the important developmental differences between traditional contrast sensitivity compared to natural image contrast sensitivity, the latter might be a more ecologically relevant tool to assess the limits of visual perception in children and individuals with a visual pathology.
[Supported by an NSERC grant to DE.]

◆ **Impressions of smiling faces with cleft lip and palate**
K Masame, T Adachi¶, S Kochi§ (School of Nursing, Miyagi University, Japan; ¶ Department of Developmental and Clinical Studies, Miyagi Gakuin Women's College, Japan; § Clinics of Maxillo-Oral Disorders, Tohoku University Hospital, Japan; e-mail: masame@myu.ac.jp)
Most patients with cleft lip and palate (CLP) have reduced social and interpersonal communication skills. They often look relatively expressionless. A rating experiment was conducted to see if smiling faces of CLP patients improve their facial impression. According to the results of the discrimination between CLP faces and normal ones, three face types were used in the experiment: saliently deformed CLP faces, less saliently deformed CLP faces, and normal faces. A smiling face and a neutral face was prepared for each face. All faces were of adult females. Twenty female undergraduates rated each face for 9 impression items in 6 steps. A 3-way ANOVA showed that expression was significant, but that face types and interaction between expression and face types were not. Results indicate that, in spite of scarred upper lip and/or deformed nose, there was no difference of facial impressions between CLP faces and normal ones, and that the smiling faces of CLP patients do improve their facial impressions significantly.

◆ **Hemispheric differences in the perception of positive and negative facial expressions**
N T Alves, L M Silva, S S Fukusima, J A Aznar-Casanova¶ (FFCLRP, University of São Paulo, Brazil; ¶ Universitat de Barcelona, Spain; e-mail: nelsontorro@yahoo.com.br)
The divided visual field technique was used to analyze the patterns of brain asymmetry in the perception of positive and negative facial expressions. Eighty participants were distributed in five experimental groups in order to investigate separately the perception of expressions of happiness, surprise, fear, sadness, and neutral. In each trial, a target and a distractor expression were presented in a computer screen during 150 ms and participants had to determine the side (left or right) on which the target expression was presented. Expressions of happiness and fear were identified faster when presented on the left visual field, suggesting an advantage of the right hemisphere in the perception of these expressions. Fewer judgment errors and faster reaction times were observed for the matching condition in which emotional faces were presented on the left visual field and neutral faces on the right visual field. Although an advantage of the right hemisphere did not occur for the perception of all expressions, results tend to support the right hemisphere hypothesis for emotional processing.
[Supported by CNPq.]

◆ **Why are unrelated associations learned more rapidly in a consistent temporal order?**
O Hamid, A Wendemuth¶, J Braun (Institute of Biology, Department of Cognitive Biology, Otto von Guericke University, Germany; ¶ Institute of Electronics, Signal Processing and Communications, Magdeburg, Germany; e-mail: Oussama.Hamid@ovgu.de)
Observers viewed highly distinguishable, fractal objects and learned by trial and error to respond to each object with one of four possible motor responses. In five experiments, associations between visual objects and motor responses were learned more rapidly for objects presented in a

consistent temporal order (objects with consistent predecessor objects). Incremental learning of action weights for current and past objects does not account for the observed effects of temporal order ('direct actor'). However, a modified model with differential learning rates for current and past objects agrees qualitatively with observations. In the modified reinforcement model, a Kalman filter quantifies the certainty with which past observations predict future rewards and adjusts learning rates accordingly (Sutton, 1992 *Proceedings of the 7th Yale Workshop on Adaptive and Learning Systems* pp 161 – 166). But does reinforcement learning of additional action weights truly capture the essence of the temporal order effects? We also consider an alternative view, according to which consistent temporal order eases the recognition problem posed by unfamiliar fractal objects.

◆ **Familiarity aids detection of family resemblance**
P J B Hancock, A L Bulloch (Department of Psychology, University of Stirling, UK; e-mail: pjbh1@stir.ac.uk)

Previous research has shown that we can detect family resemblances above chance, but by no means infallibly. A typical task might be to present a picture of a child and two possible parents. We asked whether personal familiarity with, for example, the parents, but not the child, would assist with determining which pair are related. Since nearly everything about familiar face processing is better, we expected to find an improvement, but there are also theoretical grounds for thinking it could be worse. Familiar faces produce categorical judgments: decision boundaries around them are sharper. It is therefore possible that those unfamiliar with the faces might see the resemblance more easily. Our experiment used photographs of siblings, children, or parents of staff and fourth-year students, and tested first-year students, who knew few of the people depicted, and fourth-year students, who knew many. Both matching performance and ratings of resemblance were higher for fourth-year students. The results will be discussed in terms of theoretical models of how we learn and represent faces.

◆ **Effects of self-motion on gloss perception**
Y Sakano, H Ando (Universal Media Research Center, NICT/ATR Cognitive Information Science Laboratories, Kyoto, Japan; e-mail: sakano@atr.jp)

We investigated whether temporal changes of the scene caused by lateral motion of the observer—including motion parallax and temporal changes in luminance of the specular highlights of the surfaces—affect the perception of surface gloss. The stimulus was a computer-generated display which simulated a glossy and bumpy surface. Subjects moved their heads back-and-forth laterally observing the stimulus monocularly. The test stimulus changed temporally in luminance of specular highlights and in position on a 2 – D computer monitor depending on the subjects' head positions so that the surface appeared to be stationary in the 3-D space while the reference stimulus did not change on the monitor. The subjects compared the glossiness of the test stimulus with that of the reference stimulus. The rated glossiness of the test stimulus was higher than that of the reference stimulus. The results suggest that temporal changes of the scene caused by lateral motion of the observer enhance the strength of perceived gloss.

◆ **Binocular rivalry between patterns and visual noises: way to 'see' your spontaneous activity in the early visual system by yourself**
S Wakisaka, Y Gunji¶, H Ohta§, K Kitajo, Y Yamaguchi (DEI Lab, Brain Science Institute, RIKEN Brain Science Institute, Japan; ¶ Department of Earth and Planetary Sciences, Faculty of Science, Kobe University, Japan; § Department of Physiology, National Defence Medical College, Japan; e-mail: sohei@wakisaka.net)

We found recently a novel visual illusion during binocular rivalry between patterns and visual noises, which we called diagonal mesh pattern (DMP). This illusion can be considered as the result of recurrent mutual interaction between spontaneous and sensory-driven activity in the early visual system. Interestingly, in the illusion, spontaneous activity in the visual system seems to dominate sensory-driven activity, rather than the latter merely affecting the former. In other words, spontaneous activity can be 'stronger' than sensory-driven activity, contrary to previous findings. This notion is seemingly contradictory. What is 'spontaneous' activity with sensory input? We will discuss the validity of our theoretical model (recurrent orientation interaction model—ROIM) based on accepted ideas, as well as the result of preliminary brain activity measurements. DMP and ROIM provide new ideas for investigating the visual system. Finally, we present a physical phenomenon (ie the output of recurrently wired waveform processors) that can be explained by ROIM in a more generalized context, implying a wide coverage for our notion.

[We would like to thank Prof. K Kitaoka for his great help.]

◆ **How big is visual long-term memory? Evidence for massive and high fidelity storage**
T F Brady, T Konkle, G A Alvarez, A Oliva (Department of Brain and Cognitive Sciences, MIT, USA; e-mail: tfbrady@mit.edu)

Although people can remember a massive number of pictures (Standing, 1973 *Quarterly Journal of Experimental Psychology* **25** 207 – 222), the fidelity with which human memory can represent such a large number of items has not been tested. We conducted three large-scale memory experiments (2500+ objects or scenes) and systematically varied the amount of detail required to succeed in subsequent memory tests. Contrary to the commonly accepted view that natural image representations contain only the gist of what was seen, our results show that the human memory is able to store an incredibly large amount of visual images as well as a large amount of visual detail per item: for instance, observers remembered 87% of images with enough detail to distinguish an object they had viewed from the same object in a different state or pose (for example, a coffee cup that was half empty versus the same cup being full). These results present a challenge for neural and computational models of object and natural image recognition to account for such large and detailed storage capacity.

[Supported by an NSF CAREER award (0546262) to AO.]

◆ **Adapting to emotional faces in rivalry**
W J Adams, K H Gray, M J Garner (School of Psychology, University of Southampton, UK; e-mail: w.adams@soton.ac.uk)

Viewing faces with a particular identity or emotional expression induces aftereffects such that the perceived identity or expression of a face viewed subsequently is biased. Recently, Moradi et al (2005 *Neuron* **45** 169 – 175) found that adaptation to identity does not occur when the face is suppressed in binocular rivalry. We tested whether adaptation to emotional expressions can occur in the absence of conscious awareness. During adaptation, an emotional face (happy, angry, or fearful) was presented to one eye with a dynamic noise pattern to the other eye. Observers reported (i) when the adaptation face was dominant, and (ii) the perceived expression of a subsequent test face. Test faces were morphed combinations of a neutral face with one of the adapting expressions. Adapting to an emotional expression biased the perceived emotion of the test faces. These effects were seen even when the emotional expression was suppressed in rivalry. Our results are broadly consistent with fMRI studies showing activity related to emotion expressions under suppression in rivalry and backward masking.

[Supported by EPSRC Grant EP-D039916-1 to WJA.]

◆ **Face gender discrimination performance can be altered using male and female face masks**
Z Basseda, A Zadbood¶ (Interdisciplinary Neuroscience Research Program, Medical Sciences, University of Tehran, Iran; ¶ School of Medicine, Shahid Beheshti University M.C., Tehran, Iran; e-mail: zbasseda@gmail.com)

Previous studies have shown that exposure to a face affects the subsequent perception of other faces, and this aftereffect has been studied in face identity, gender, expression, and race. Studies have also shown that both low-level and high-level mechanisms are responsible for this effect. In this study, we examined the effect of backward masking of faces with male, female, and androgynous face masks at different SOAs (50, 80, and 110 ms) to assess the processing of information of face gender and its time course. Masks differed from targets in size and position to minimize low-level interactions. The performance of subjects in a gender discrimination task was measured under different masking conditions. The trend of data showed that masks of each gender reduce the gender discrimination performance for targets of the same gender more than for targets of the opposite gender at all SOAs. This suggests that processing of gender begins from early SOAs. These results imply that masking with faces might help in the study of processing gender-related information of faces.

[The authors wish to thank Dr M Vaziri for her kind help.]

SEGMENTATION AND GROUPING

◆ **Specificity of the visual second-order mechanisms**
V Babenko, D Yavna (Department of Psychology, Southern Federal University, Russia; e-mail: bvv@psyf.rsu.ru)

Second-order mechanisms (SOM) are unselective of texture modulation type (TMT) in filtering-rectification-filtering models. Recently this thesis has been called in question (Kingdom et al, 2003 *Visual Neuroscience* **20** 65 – 76) and the position is ambiguous (Pearson, 2007 *Perception* **36** 45). We aimed to determine SOM specificity to TMT. We used patch textures in which contrast, orientation, or spatial frequency were sinusoidal modulated. Each texture was tested in turn. All textures, including unmodulated ones, were used as masks. Spatial frequency and axes of modulation were coincident in all images. For all TMT it was found that masking runs up to

maximum when TMT coincides for both test and mask. The masking effect for each test was almost the same in other combinations. However the masking effect at the coincidence of the test and the mask was greater when the modulated parameter was orientation. The results show SOM specificity to TMT and more independence of the mechanism which is selective to the orientation modulation.

◆ **Unmasking the standing wave illusion: the role of apparent motion**
E Hein, C M Moore (Department of Psychology, University of Iowa, USA; e-mail: elisabeth-hein@uiowa.edu)

We investigated the mechanism behind the standing wave illusion: a central bar becomes invisible when two adjacent flanking bars are presented in counterphase with the central bar. Participants judged the visibility of the central bar, while we manipulated the spatial separation between flankers and the central bar. In two experiments we showed that the central bar becomes invisible even if central bar and flankers are clearly separated. These findings contradict traditional explanations of the standing wave illusion in terms of local inhibitory processes. We suggest that the visibility of the central bar depends on the perception of apparent motion between the central and flanking bars. When the central bar and the flankers are interpreted as one object moving in apparent motion, the central bar becomes invisible because its representation is overwritten by the representation of the flankers. This interpretation was supported in a third experiment, in which we manipulated the interstimulus interval between central bar and flankers. Implications of these findings for apparent motion and metacontrast masking are discussed.
[Supported by NIH grant MH067793 to CM.]

◆ **Visual texture properties**
G Lado, S Pescio¶, M L F de Mattiello§ (Fundación de Investigaciones Visuales Franco Mattiello, Buenos Aires, Argentina; ¶ Facultad de Arquitectura, Diseño y Urbanismo, Universidad de Buenos Aires, Argentina; § CONICET, Laboratorio de Investigaciones Visuales, Argentina; e-mail: info@fundvis.org)

Textural representation plays a significant role within the framework for the measurement of visual appearance, which looks at variations in intensity, colour, texture, and depth. Different techniques have been used to offer an objective analysis of this problem, ranging from the Fourier transform, passing through waviness to different computer models. In two previous papers we studied the influence of symmetry and colour in the recognition of 12 modules by means of psychophysical techniques and neural networks at different presentation times of between 5 and 20 s, observing different but consistent responses between the two methodologies used. These results provided the impetus for this paper in which equal but repeated modules within a 3×3 matrix designed to generate a textured frontoparallel plane could be classified by density and regularity on an ART type network which we have already applied for other purposes. They also indicated whether the symmetrical differences observed in previous papers continued to be different. The results obtained prove to be consistent with the psychophysical results.

◆ **The perception of subjective contours and neon colour spreading patterns in 4-month-old infants**
M Kavsek (Institute for Psychology, University of Bonn, Germany; e-mail: kavsek@uni-bonn.de)

In the present habituation/dishabituation study, infant sensitivity to subjective contours and to neon colour spreading patterns was explored. In Experiment 1, 4-month-old infants were habituated to a subjective Kanizsa square and tested afterwards for their ability to differentiate between the subjective square and a non-subjective pattern constructed by rotating the inducing elements. Data analysis indicated a significant preference for the non-subjective pattern. A control condition proved that this result was not generated by local differences between test displays. In Experiment 2, infant perception of a neon colour spreading display was analysed. Again, 4-month-old infants could discriminate between the illusory figure and a non-illusory pattern. Furthermore, infants in a control group did not respond to the local differences between two non-illusory targets. Overall, the findings show that young infants respond to illusory figures which are generated by either implicit T-junctions (Experiment 1) or implicit X-junctions (Experiment 2).

◆ **Use of 'pop-out' paradigm to test graph comprehension in a three-dimensional scatter plot**
M Shovman, K Scott-Brown, A Szymkowiak, J Bown¶ (School of Social and Health Sciences [¶ SIMBIOS], University of Abertay, Dundee, UK; e-mail: m513959@abertay.ac.uk)

The emerging field of visual analytics applies abstract data visualisations to analyse complex, multivariate data. Data visualisations comprise a full spectrum of pictorial and symbolic elements; thus, juxtaposing theories of visual perception and reading comprehension, graph comprehension

can be linked to high-level perceptual organisation of the visual scene. The latter can be quantitatively assessed, eg, by the 'pop-out' paradigm: constant response times with increasing stimulus array size. We assessed detection of an outlier (defined by kinetic depth) in slowly rotating 3-D scatter plots, exploring comprehension of simple information—'an odd one out'. Results indicate that in larger stimulus arrays response times were longer while accuracy decreased, consistent with processes of visual search and not 'pop-out'. In line with previous research, these results suggest that 3-D charts, while visually impressive, are not efficient enough for data analysis and decision-making. Using 'pop-out' paradigm allows probing of high-level processes of graph comprehension with psychophysical methods, making it a viable approach to assessing data visualisation efficiency.

◆ **Contour integration by cue combination with colour and spatial frequency**
M Persike, G Meinhardt (Johannes Gutenberg University, Methods Section, Mainz, Germany; e-mail: persike@uni-mainz.de)

The contribution of cue combination to the saliency of visual contours was studied within the pathfinder paradigm. Single cue target contours were defined by orientation collinearity of contour elements, feature contrast in spatial frequency, or in colour. Double cue contours were combinations of the collinearity cue with each of the feature contrast cues. Cue summation, conceived as the performance benefit due to the combination of multiple cues, was measured in a 2AFC task with human subjects and tested against the predictions derived from independent feature processing (probability summation) and linear summation. Cue summation with spatial frequency contrast far exceeded the independence prediction and also surpassed linear summation in many cases. The saliency gain was particularly large when the spatial frequency deviation was defined by lowering the carrier frequency of contour elements relative to the background. Cue summation with colour contrast, however, only exceeded probability summation in few cases. Results suggest distinct grouping mechanisms in contour integration, the cooperation of which yields strong location binding and highly salient global contours.

◆ **Masking study of instant stimuli texture segmentation**
S Fomins (Department of Optometry and Vision Science, University of Latvia, Riga, Latvia; e-mail: sergejs.fomins@gmail.com)

Temporal stimuli were used to obtain the reaction times with the texture stimuli of different design (Fomins et al, 2007 *Perception* **36** 44). Stimuli consisted of the four textures imposed on the monotonous horizontally oriented texture background. The centre of the stimuli was filled with similar-orientation, empty, vertical, orientation textures. Stimulus exposure times ranged from 0.01 s to 0.15 s. In the masking study longer reaction times were indicated compared to our previous study. Similarities found previously in the responses to different design stimuli were not observed. However, the suppression of responses in the presence of collinear stimuli was still observed (Polat et al, 1998 *Nature* 580 – 584). Segmentation times obtained from psychometric functions are of values 40 – 60 ms and are in good correlation with the data by (Rousselet et al, 2002 *Nature Neuroscience* **5** 629 – 630).
[Supported by the European Social Fund.]

◆ **Idiosyncratic hot spots in crowding**
Y Petrov, O Meleshkevich, A Popple¶ (Department of Psychology, Northeastern University, Boston, USA; ¶ School of Optometry, University of California at Berkeley, USA; e-mail: yury@neu.edu)

Crowding has a peculiar property: a mask presented outward of the target (with respect to fixation) obscures the target identity most strongly. This hallmark asymmetry of crowding is very strong along the horizontal meridian. It is not yet known whether this property persists over the whole visual field. Here we studied 16 target positions in the visual field (8 directions $\times$ 2 eccentricities). The slant of the target Gabor ($\pm 45^{\circ}$) had to be identified in a 2AFC paradigm. The plaid mask made of two transparently overlaid Gabors was placed inward, outward, counterclockwise, and clockwise around the target. As expected, for targets positioned along the horizontal meridian, all six observers showed a markedly larger crowding for outward masks. Yet, there was a surprisingly large individual variation in both the strength and the asymmetry of crowding over the rest of the visual field. Thus, for three of the subjects the asymmetry was reversed at or near the vertical meridian. To summarize, we observed idiosyncratic hot-spot distribution of crowding effect across the visual field.

ORAL PRESENTATIONS

SEGMENTATION, GROUPING AND CROWDING

◆ **Grouping explains contextual modulation in low level vision**

B Sayim, M H Herzog, G Westheimer¶ (Laboratory of Psychophysics, EPFL, Lausanne, Switzerland; ¶ Department of Molecular and Cell Biology, University of California at Berkeley, USA; e-mail: bilge.sayim@epfl.ch)

Performance on a target can be modified by contextual elements. For example, when a Vernier is flanked by two lines, offset discrimination deteriorates compared to an unflanked presentation. This contextual modulation is usually explained by local spatial interactions between the Vernier and the flanks. We have shown that this explanation is inadequate. Instead, we propose that flanks interfere most strongly when they are grouped with the Vernier. In a number of experiments, we have shown that interference between flanks and Vernier can be reduced when the flanks form an independent group and the Vernier stands out. Our experiments show that this ungrouping can be established by differences in features like contrast polarity, colour, and stereoscopic depth, as well as flank grouping by figural properties. For example, Vernier discrimination thresholds are significantly lower when the Vernier is flanked by two cuboids compared to being flanked by two lines which are contained in the cuboids. Our results show that global Gestalt aspects are crucial in contextual modulation.

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◆ **Crowding depends on perceived (not physical) position**

S C Dakin, J A Greenwood, P J Bex¶, T A Carlson§ (UCL Institute of Ophthalmology, University College London, UK; ¶ Schepens Eye Research Institute, Harvard Medical School, Boston, USA; § Vision Sciences Laboratory, Harvard University, Boston, USA; also Department of Experimental Psychology, Helmholtz Institute, Universiteit Utrecht, The Netherlands; e-mail: s.dakin@ucl.ac.uk)

Object recognition in the peripheral visual field can be disrupted when distractors fall close enough to a target. To investigate whether physical or perceived location determines such 'crowding' we presented a Gabor target (static vertical carrier) 8 deg in the periphery, flanked above and below by distractors (drifting carriers, variable left or right offset). We first confirmed experimentally that the perceived location of flanks was offset in the direction of their carrier-motion (De Valois and De Valois, 1991 *Vision Research* **31** 1619 – 1626). We next used target-orientation discrimination (with similar stimuli) to examine crowding. We report that the magnitude of crowding depends on subjective (not physical) target-flank co-alignment. We also observe greater crowding for flank-carrier motion away from fixation, which we suggest arises from the De Valois effect combining with motion capture to effectively displace the stimulus further into the periphery, where crowding is more pronounced. Our findings are therefore consistent with both absolute and relative perceived position determining the extent of crowding.

[Funded by the Wellcome Trust.]

◆ **Grouping and strong limitations on visual representation of spatial relations**

R Watt (Department of Psychology, University of Stirling, UK; e-mail: r.j.watt@stirling.ac.uk)

A horizontal sequence of regularly spaced vertical lines can be easily discriminated from an irregular sequence. However, when additional distractor lines are randomly interleaved between the target lines the regular pattern cannot be detected at all event though the information required to detect the regularity is still all available. The observation suggests that there are strict limits on spatial measurements in vision: distances only between adjacent elements are available and cannot be summed further. Adjacency is defined in a 1-D stimulus but has limited meaning in a 2-D pattern. A regular square 2-D grid of dots can be discriminated from an irregular pattern made by shifting each dot randomly in any direction or in the direction of one of the grid dimensions or by shifting some dots in one grid dimension and some in the other dimension. Interleaved dots can be made in the same way. The results of the various combinations suggest how 2-D spatial relations between elements of the display are represented using neighbourhood grouping rules.

◆ **Short-term memory in neural border ownership signals**

R von der Heydt, P J O'Herron (Mind/Brain Institute, Johns Hopkins University, Baltimore, USA; e-mail: von.der.heydt@jhu.edu)

The rapidly fluctuating neural activity in the visual cortex is difficult to reconcile with the apparent stability of our visual world. In ambiguous displays, such as Rubin's vase-face figure, the fact that perception is stable for seconds between the figure-ground reversals indicates persistence of an internal representation, but its neural basis has not been discovered. We recorded

single-cell activity from cortical area V2 in awake fixating monkeys. Neurons were tested with display sequences consisting of a briefly presented square followed by a bipartite field in which border ownership was ambiguous. We found that border ownership signals persisted in the ambiguous phase. The signals decayed slowly (exponentially, time constant 400 ms), but were reset rapidly when new figure–ground information was presented (time constant 60 ms), a behaviour characteristic of memory devices. A blank period that silenced the V2 edge signals completely did not abolish the memory trace, indicating that the memory is not due to persisting activity in V2. Remaining hypotheses include residual synaptic currents and persisting activity outside V2.
[Supported by NIH grants EY02966, EY07143.]

◆ **Sensitivity to contour-curvature continuity**
A Hayes, J Cham¶, S K Khuu¶, N Brady (School of Psychology, University College Dublin, Ireland; ¶ Department of Psychology, University of Hong Kong, China;
e-mail: tony.hayes@ucd.ie)

We analysed contour curvature in natural images using a measure of curvature redundancy. For relatively shallow curvatures, contours tend to extend with an orientation that is shallower, though proportional, to contour curvature. This natural-image property becomes less pronounced for steeper curvatures. Is the visual system sensitive to this proportionate-curvature property of natural image contours? We used a contour-detection task to measure human sensitivity to contour-curvature continuity. Observers detected a Gabor-element-defined contour that was embedded in a field of randomly oriented Gabor elements. The contour consisted of four constant-curvature-aligned elements with independently aligned end-elements. Our results show that human vision is most sensitive to contours with 'ends' oriented proportionally to the angle of contour curvature. This relationship between curvature angle and the orientation of the 'ends' is evident for shallow angles of curvature, and the human-sensitivity results are quantitatively comparable to the pattern observed in natural images, supporting a conclusion of a close relationship between natural image curvature statistics and the coding of visual information.
[Supported by the Science Foundation Ireland and Research Grants Council of Hong Kong.]

◆ **Source confusion is a major cause of crowding**
H Strasburger, M Malania¶ (Department of Psychology, University of Frankfurt, Germany; ¶ Department of Ophthalmology & Vision Science, University of California at Davis, USA;
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In his Gestalt analysis of reading, Korte (1923) has proposed five reasons of what Stuart and Burian later called the crowding effect. One reason—word compression with loss of perception of character—has been widely recognized (Levi, 2008). However, one of Korte's reasons—the loss of positional information—has been largely neglected. We present new data which show that the confusion of entire characters accounts for more than 30% of the crowding effect. In a paradigm that separates featural from positional errors and further manipulates transient attention by a positional cue, we measured at 2°, 4°, and 6° horizontal eccentricity and a range of flankers' distances and cue sizes. The effect of flanker distance confirms earlier findings that distance acts similarly on both featural and positional errors. Source confusion is highest with flankers close by. Cue has an effect on featural information only, but cue size has no effect. Our results are a psychophysical counterpart to a separate neural coding of what and where in pattern recognition.
[Supported by DAAD travel grant to MM.]

MOTION AND TEMPORAL ISSUES

◆ **Temporal whitening is driven by transient noise**
J R Cass, D Alais (School of Psychology, University of Sydney, Australia;
e-mail: johncassvision@gmail.com)

Naturally occurring luminance distributions are approximately $1/f$ in their spatial and temporal spectra. By systematically varying the spectral profile of spatially and temporally broadband noise stimuli, we demonstrate that humans invariably overestimate the proportion of high spatial and temporal frequency input energy, effectively equalising (whitening) its response to stimuli with naturally occurring low frequency-biased spectra. Additional masking and adaptation experiments support an asymmetric noise account of temporal whitening, whereby sustained mechanisms receive unilateral noise from transient mechanisms. This noisy interaction, either simultaneously (via masking) or across time (via adaptation), generates a transient bias that serves to equalise the perceptual response to naturalistic low temporal frequency-biased stimuli. We also compare the effects of adaptation to low frequency biased (correlated) pink temporal noise and uncorrelated white temporal noise on the modulation transfer function. These results imply that: (i) the visual system overrepresents its transient input, decorrelating the long-range

temporal structure of natural scenes; and (ii) this transient bias is rigid and occurs even in the context of uncorrelated white noise input.
[Supported by a grant awarded to JC by the Australian Research Council (DP0774697).]

◆ **Temporal ventriloquism is a consequence of a competitive process that can facilitate sensory integration and segregation**
W Roseboom, D Arnold (School of Psychology, University of Queensland, Australia; e-mail: roseboom@psy.uq.edu.au)

Crossmodal conflicts, such as the ventriloquist effect, are often employed to examine how sensory events can become perceptually integrated. However, the vast majority of sensory events are unrelated. We therefore examined the possibility that processes might exist that both integrate and segregate sensory events over time. We determined points of subjective synchrony (PSS) between repetitive colour (V) and auditory (A) tonal frequency changes. By introducing additional visual events (aV), spatially offset colour changes, we were able to determine that apparent AV timing was contingent on aV. Specifically, A tended to be attracted toward the timing of the first visual change within a temporal window and therefore away from the second. This prompts two surprising observations. First, visual events can attract apparent auditory timing, the reverse pattern of results to that typically reported in the temporal domain. Second, apparent timing is driven by competitive interactions that can either make different events seem to occur closer together or further apart in time, thereby facilitating both sensory integration and segregation.

◆ **The continuous wagon wheel illusion and the 'WHEN' pathway of the right parietal lobe: a repetitive transcranial magnetic stimulation study**
R Vanrullen, A Pascual-Leone¶, L Battelli¶ (CerCo, CNRS – Université Toulouse 3, France; ¶ Berenson-Allen Center for Noninvasive Brain Stimulation, Department of Neurology, Beth, Israel; also Deaconess Medical Center, Harvard Medical School, Boston, USA; e-mail: rufin.vanrullen@cerco.ups-tlse.fr)

A continuous periodic motion stimulus can sometimes be perceived moving in the wrong direction. These illusory reversals have been taken as evidence that part of the motion perception system samples its inputs as a series of discrete snapshots. We have hypothesized that parts of the right parietal lobe ("WHEN" pathway) play a critical role in timing perceptual events relative to one another, and thus examined the role of the right parietal lobe in the generation of this 'continuous Wagon Wheel Illusion' (c-WWI). Consistent with our hypothesis, we found that the illusion was effectively weakened following disruption of right, but not left, parietal regions by repetitive transcranial magnetic stimulation (1 Hz, 10 min). These results were independent of whether the motion stimulus was shown in the left or the right visual field. Thus, the c-WWI appears to depend on higher-order attentional mechanisms that are supported by the 'WHEN' pathway of the right parietal lobe.

◆ **Motion-induced position shifts occur after motion integration**
G Mather, A Pavan¶ (Department of Psychology, Sussex University, Brighton, UK; ¶ Department of General Psychology, University of Padua, Italy; e-mail: g.mather@sussex.ac.uk)

Previous studies have shown that visual movement influences perceived position (motion-induced position shift, MIPS). Motion processing is widely believed to involve at least two stages: local detection of motion in striate cortex (V1), and global integration of local signals in extrastriate cortical area MT. What role do these two stages play in MIPS? To address this question we compared position shifts induced by Gabor patches containing single grating components to position shifts induced by Gabor patches containing two-component plaids. If motion and position signals interact only in V1, MIPS from plaids should reflect the average position shift induced by each component when presented separately. If the interaction occurs in MT, then MIPS from plaids should be consistent with an intersection-of-constraints or vector-sum computation on the components. Results showed that MIPS from plaids is much higher than that predicted from individual components, indicating that MIPS arises after, not before, motion integration.

◆ **Activity in area V3A predicts positions of moving objects**
G W Maus, S Weigelt¶, R Nijhawan, L Muckli§ (Department of Psychology, University of Sussex, Brighton, UK; ¶ Department of Neurophysiology, Max Planck Institute for Brain Research & Brain Imaging Centre Frankfurt, Germany; § Departmen of Psychology & Centre of Cognitive Neuroimaging, University of Glasgow, UK; e-mail: G.W.Maus@sussex.ac.uk)

A gradually fading moving object is perceived to disappear at positions beyond its luminance detection threshold (Maus and Nijhawan, 2006 *Vision Research* **46** 4375 – 4381), whereas abrupt offsets are usually localised accurately. What cortical areas are involved in this motion extrapolation

of fading objects? Using fMRI, we localised regions of interest (ROIs) in retinotopic maps abutting the trajectory endpoint of a bar moving either towards or away from this position while gradually decreasing or increasing in luminance. Area V3A showed predictive activity, with stronger BOLD responses for motion towards versus away from the ROI. This effect was independent of the change in luminance. In area V1 we found higher activity for high-contrast onsets and offsets near the ROI, but no significant differences between motion directions. More sensitive procedures are required to detect fading-specific motion extrapolation effects. We suggest that perceived final positions are based on an interplay of motion-sensitive and primary retinotopic representations. In the absence of high-contrast offset transients indicating final positions, predictive overshoots are perceived.

◆ **What is the reference in reference repulsion?**
P Wenderoth, M Wiese (Department of Psychology, Macquarie University, Sydney, Australia; e-mail: peterw@vision.psy.mq.edu.au)

Reference repulsion is a mechanism posited to explain systematic biases of direction judgment of single drifting dot displays (Rauber and Treue, 1998 *Perception* **27** 393 – 402). Rauber and Treue obtained systematic but, surprisingly, very different effects depending upon whether standard and comparison stimuli were presented simultaneously or successively. Successive effects were described as exhibiting repulsion from both vertical and horizontal cardinal axes whereas simultaneous effects showed repulsion from horizontal only. We contend that the proposed mechanism makes no testable predictions because the so-called reference can be specified only in a post hoc manner, a fact acknowledged by Rauber and Treue. We attempted to replicate Rauber and Treue's experiments but we obtained no systematic biases of direction judgment. Comparisons across several studies suggest that errors in direction judgments of single drifting dot patterns vary widely in magnitude and direction, as might be expected with what are essentially baseline or pretest measures. In our view, reference repulsion describes neither a real perceptual mechanism nor a predictable pattern of direction misjudgments.

COLOUR

◆ **'Mixing-in' afterimage colours**
R van Lier, M Vergeer, S Anstis¶ (NICI, Radboud University Nijmegen, The Netherlands; ¶ Department of Psychology, University of California at San Diego, USA; e-mail: R.vanlier@nici.ru.nl)

Coloured stimuli may reveal different afterimage colours at the same retinal location, depending on surface contours presented after the image (Van Lier and Vergeer, 2007 *Perception* **36** 200 – 201). Here we demonstrate that the filling-in of the afterimage colour depends on the colours that are presented inside and outside these contours. In the experiment, a composite star-like pattern alternated with the outline of one of its two component star-like shapes. The composite pattern was coloured, except the central area—which was grey. The component shapes were completely grey. The colours were drawn from the set of 'Teufel colours'. The participants matched the afterimage colour in the central area of the component shape (which coincided with the central grey area of the previously presented composite pattern) with Teufel-colour patches. The results show that the perceived afterimage colour is a mixture of filled-in afterimage colours, based on the—previously presented—colour outside the component shape and the complementary colour of the colour inside that shape.

◆ **The distribution of discernible colours in natural scenes**
S M C Nascimento, J M M Linhares, P D Pinto, D H Foster¶, K Amano¶ (Department of Physics, Minho University, Portugal; ¶ School of Electrical and Electronic Engineering, University of Manchester, UK; e-mail: smcn@fisica.uminho.pt)

Although the total number of discernible colours in natural scenes has been estimated from physical data, the distribution of colours has received little attention. To address this issue, an analysis was made of hyperspectral images taken from a database of 50 urban and rural scenes. The colour volume of the database was computed by expressing each pixel of each image in CIELAB space. To derive the distribution of colours, the volume was segmented into just distinguishable subvolumes, approximated by unit cubes, with each non-empty subvolume assumed to represent one discernible colour and its pixel population the total number of times it occurs over the 50 scenes. It was found that the fraction of discernible colours expressed as a function of occurrence could be described by a negative power-law and that most discernible colours appeared only rarely. Thus, 70% of the total number of discernible colours constituted only about 3% of the pixels sampled, implying that most of the natural chromatic distribution fell within a small colour gamut.

◆ **How efficiently does post-receptoral coding capture information about the natural world?**
D H Foster, I Marin-Franch, S M C Nascimento¶, K Amano (School of Electrical and Electronic Engineering, University of Manchester, UK; ¶ Department of Physics, Gualtar Campus, University of Minho, Braga, Portugal; e-mail: d.h.foster@manchester.ac.uk)
The light reflected from a scene into the eye varies with the scene being viewed and the lighting upon it. Despite these variations, there are strong statistical dependencies between the patterns of receptor responses to a particular scene under different illuminations. These dependencies represent the information available about the scene, quantifiable by measures defined by Shannon. The fact that information is available, however, does not imply it is retrievable in any particular experimental task. Responses of four well-known physiological and psychophysical models of opponent and non-opponent coding were simulated computationally with hyperspectral data from 50 natural scenes and three daylight illuminants. It was found that the information retrieved in a generic colour-matching task was well below the maximum possible, and that all four models transmitted information inefficiently. Nevertheless, for all but one of the models, opponent variables together carried more information than non-opponent variables, supporting the intuition that chromatic properties are more useful than achromatic ones for discrimination and identification in the natural world.
[Supported by the EPSRC.]

◆ **A pure sensation for colour?**
S J Cropper (Department of Psychology, University of Melbourne, Australia; e-mail: scropper@unimelb.edu.au)
This work focusses on developing and justifying a new paradigm providing a measure of colour processing at a level higher than simple detection or discrimination, but prior to the use of a colour name. The paradigm requires observers to both discriminate and freely-categorise 256 scaled cardinal colour stimuli; both tasks are performed on exactly the same stimulus set. Observers' categorical space has significantly different borders than the discrimination space for the same stimuli, yet is idiosyncratic and exhibits no boundary effect. Manipulation of stimulus contrast, duration and size, and the complete collected data from 15 colour normal observers and 3 dichromats leads to the tentative conclusion that this paradigm is valid and potentially very informative. William James described a 'pure sensation' as an internal perceptual experience free from meaning, memory or the constraints of language; this is what we have tried to measure for the percept of colour. We believe that to further our understanding colour vision we have to have some psychophysical measure of pure colour sensation.

◆ **Munsell chip classification reveals stable colour categories under illuminant changes**
M Olkkonen, T Hansen, K R Gegenfurtner (Department of Psychology, University of Giessen, Germany; e-mail: kmolkkonen@gmail.com)
Characterising colour constancy with colour naming overcomes many limitations inherent in asymmetric matching or achromatic adjustments: it is a direct measure of colour appearance that allows the quick sampling of a large portion of colour space. Our observers classified simulated Munsell chips varying in chromaticity and luminance into 1 of 9 colour categories under 5 different illuminants. Category boundaries were fitted to the naming data to determine the effect of illuminant change on colour categories and on the location of the boundary convergence points. Observers were fairly consistent in their classification performance: 73% of the chips were classified in the same colour category under 4 of the 5 illuminants and 50% of the chips under all illuminants. Classification consistency approached general response variability measured over time, and was highest for stimuli darker than the background or close to the focal hues. High stability was also evident from boundary fits and convergence points. In conclusion, Munsell chip classification was based on stimulus reflectance rather than on the overall colour signal.
[Supported by DFG grant Ge 879 5-2.]

AFTEREFFECTS AND ADAPTATION

◆ **Multistable perception despite unambiguous motion stimuli in vision, proprioception, and touch**
T Seizova-Cajic, A O Holcombe¶ (Faculty of Health Sciences [¶ School of Psychology], University of Sydney, Australia; e-mail: t.seizovacajic@usyd.edu.au)
Bistable or multistable perceptual states usually occur with ambiguous stimuli such as the Necker's cube or rivalrous dichoptic stimuli. We investigated bistable responses to unambiguous stimuli in three different modalities to explore their properties and potential similarity with other forms of bistability. In vision, a rotating circular array of bars during prolonged viewing (3 – 4 min) appears to move in reverse a number of times (sometimes called a wagon-wheel illusion). In proprioception, prolonged biceps vibration induces illusory forearm extension but also reversals.

In touch, we show for the first time that perceived direction of textured surface motion across fingertips also reverses after prolonged stimulation. The initial percept usually lasts longest in all three modalities suggesting that initial adaptation to the stimulus is required to initiate the alternative percept. Subsequent dynamics resembles that of rivalry, including small correlations among the duration of successive percepts (in vision) and gamma like distribution of dominance durations. We propose that rivalry between signals indicating the opposing directions may explain motion reversals in all three modalities.

◆ **A proprioceptive aftereffect following exposure to a crossmodal Ames' window**
M Bertamini, N Bruno¶ (School of Psychology, University of Liverpool, UK; ¶ Dipartimento di Psicologia & BRAIN Center for Neuroscience, Università di Trieste, Italy; e-mail: m.bertamini@liv.ac.uk)

In the visual – haptic Ames's window (Bruno et al, 2006 *Perception* **35** 25 – 30) participants monocularly view and bimanually hold a trapezoidal window. As a consequence, they experience their hands at different distances (far and near) even though they are in fact equidistant from the body. In Experiment 1, after exposure to the illusion for 3.5 min, participants tried to position their hands at equal distances with their eyes closed. Their settings documented a proprioceptive aftereffect. In Experiment 2 exposure was reduced (2 min) and in a new control condition participants held the hands next to the window but without holding it. The aftereffect was replicated but no aftereffect was present in the control condition. These results indicate that partial visual capture of proprioception can occur from mere exposure to conflicting bimodal stimulation, without purposive action and error signals. The study also has implications for theories of sensory merging.

◆ **Being in the dark about seeing your hand: multisensory conflict resolved by proprioception erasing visual information**
H Hogendoorn, M P M Kammers, T A Carlson¶, F A J Verstraten (Helmholtz Institute, Department of Experimental Psychology, Universiteit Utrecht, The Netherlands; ¶ Harvard Vision Sciences Laboratory, Harvard University, Cambridge, USA; e-mail: j.h.a.hogendoorn@uu.nl)

In multisensory conflict, vision usually dominates proprioception. We demonstrate a new conflict in which proprioceptive information erases visual information. In a dark-adaptation paradigm, observers viewed their hands during a brief flash, creating an afterimage. The effect of new proprioceptive information on this visual afterimage was investigated by observers moving one of their hands in either its visually matching or mismatching location (creating a vision – proprioception discrepancy). Moving a hand in its visual location consistently resulted in disappearance of that hand's afterimage, showing erasure of visual information by proprioception. Strikingly, when the hand was moved in a mismatching location, no disruption of the afterimage occurred. This suggests that when new proprioceptive information about the hand mismatches the static visual position of the hand, multisensory conflict is resolved by disowning the visual hand. In other words, there is no need to update outdated visual information. Thus, while feeling your hand move in the visual location prevents you from seeing it, moving it at a different location will keep it in sight.

◆ **Haptic and visual subitizing**
M A Plaisier, W M Bergmann, A M L Kappers (Helmholtz Instituut, Universiteit Utrecht, The Netherlands; e-mail: M.A.Plaisier@phys.uu.nl)

Subitizing is the effect that subjects can judge the number of items presented very efficiently and error-free up to three or four items while for larger numbers of items response times and error rates increase strongly. Most research on numerosity perception has been done in vision. Here we show, for the first time, that this effect also exists in active touch by asking subjects to judge the number of spheres in their hand. We address the question of why two regimes exist by investigating the role of discriminability differences between numerosities in both haptics and vision. When numerosities were chosen at constant relative intervals, performance improved for large numerosities (>4) in both modalities, but for smaller numerosities response times were still faster. This suggests that varying relative differences between numerosities alone cannot explain the existence of a subitizing regime. While the available cues in haptics and vision are quite different (weight cues, pattern recognition), the similarities between the results in both modalities suggest involvement of comparable underlying mechanisms.

[Supported by a grant from the Netherlands Organisation for Scienctific Research.]

◆ **Independent local adaptation of tactile frequency and duration**
J Watanabe, T Amemiya¶, S Nishida¶, A Johnston§ (PRESTO Japan Science & Technology Agency, Japan/NTT Communication Science Laboratories, Japan; ¶ NTT Communication Science Laboratories, NTT Corporation, Japan; § Department of Psychology, University College London, UK; e-mail: watanabe@avg.brl.ntt.co.jp)
A variety of temporal illusions have been reported in visual perception studies within several hundreds milliseconds, which is an essential range in sensorimotor processing. Although previous physiological studies indicate similarities between information encoding in visual and tactile sensations, we know little about tactile temporal perception. In this presentation, we show a similar illusory change of perceived frequency and duration in the tactile sensation to that shown in vision (Johnston et al, 2006 *Current Biology* **16** 472 – 479). After a 35 Hz vibration was presented to one finger for 20 s, a test 25 Hz vibration was presented for 1 s to the adapted finger. The perceived frequency or duration of the test vibration was compared with one of a probe vibration presented to the unadapted finger, whose duration was 1 s, when frequency was varied or whose frequency was 25 Hz, when duration was varied. The 25 Hz vibration were perceived as reduced to 20 Hz in frequency and to 900 ms in duration. These results suggest that tactile frequency and timing events are independently encoded in the local somatosensory areas.

THE RANK LECTURE

◆ **'Controlled hallucination' and 'inverse optics'**
J J Koenderink (Department Physics of Man, Helmholtz Institute, Utrecht University, The Netherlands; e-mail: j.j.koenderink@phys.uu.nl)
Vision as 'inverse optics' has been a mainstream notion in both human and machine vision since (at least) Marr's *Vision* of 1982. It is often considered the uniquely 'truly scientific' approach. Although there have been successes (mainly in machine vision), the cracks in the foundation begin to be increasingly noticeable. Problems are of a technical nature, namely the intrinsic ambiguities, the ignorance of required boundary conditions, or the lack of means to check prior assumptions, but also of a fundamental nature, namely the impossibility to account for the intentionality of vision. An alternative notion of vision as 'controlled hallucination' (sometimes attributed to Max Clowes's *On Seeing Things* (1971) is often ridiculed, or dismissed as 'unscientific', but deserves serious consideration. In this paradigm one gets intentionality 'for free', whereas the ontological status of such apparently common sense concepts as 'features' or 'cues' have to be reconsidered. Instead of being parts of the optical structure (in the inverse optics context considered 'information' or 'data') they are tentatively assigned by the agent thus inverting the causal flow of visual processing. I will compare these (not mutually exclusive) approaches from the perspectives of human and of machine vision. 'Inverse optics' is a viable concept in the context of 'controlled hallucination'.

Wednesday

ORAL PRESENTATIONS

OBJECTS AND SHAPES

◆ **Information, symmetry, and vision**
J S Lappin (Vanderbilt Vision Research Center, Vanderbilt University, Nashville, USA; e-mail: joe.lappin@vanderbilt.edu)

The fundamental problem of vision concerns how perception of environmental objects derives from retinal images. Information in general, and information for vision in particular, is based on approximate isomorphism between objects and their representations. These corresponding structures must satisfy two properties: (i) discrimination, where structural variations in a representation must distinguish structural variations in objects, and vice versa, and (ii) symmetry, where correspondence between the objects and their representations remains invariant under changing irrelevant properties. Thus, one can propose an appropriate symmetry as a necessary requirement, and then identify the structural invariant that satisfies this requirement. This research strategy, involving symmetry, has illuminated problems of shape perception. First, correspondence between environmental objects and retinal images involves local surface shape, an invariant under 3-D motions (Koenderink & van Doorn). Second, psychophysical experiments find that observers (a) accurately discriminate local surface shape, (b) do not reliably discriminate lower-order properties (eg, depth and slant), and (c) satisfying symmetry, reliably discriminate shape under varying lower-order properties.

◆ **The role of shape properties in perceived similarity between novel 3-D objects**
K Torfs, J Wagemans, H Op de Beeck (Laboratory of Experimental Psychology, Katholieke Universiteit Leuven, Belgium; e-mail: katrien.torfs@student.kuleuven.be)

We investigated the role of shape properties when people perceive similarity between novel objects. In particular, we compared the role of the global aspect ratio and retinotopic envelope of objects (here referred to as 'global shape') with the role of shape curvature aspects like whether objects contain straight or curved edges (here referred to as 'local shape'). We used a stimulus set with nine novel objects that varied in shape properties. In two experiments, subjects rated the perceived similarity among these objects. In Experiment 1 ($N = 8$), subjects had to rate the perceived similarity between pairs of objects. In Experiment 2, subjects ($N = 18$) were asked to rate how well 12 shape properties applied to each object. The results showed that objects with the same local shape properties are being perceived as most similar. Objects with different local and global shape properties were rated as least similar. These results indicate that local and global shape properties contribute to perceived shape similarity, with the strongest contribution coming from local shape properties.

◆ **Perceiving 3-D objects: perspective versus convexity/concavity; stereo versus motion parallax**
T V Papathomas, A Jain¶, A Sherman§ (Laboratory of Vision Research and Department of Biomedical Engineering [¶ Department of Biomedical Engineering; § Laboratory of Vision Research], Rutgers University, Newark, USA; e-mail: papathom@rci.rutgers.edu)

First we studied the roles of linear perspective and angle polarity (concavity versus convexity) as depth cues; second, we compared the roles of stereo and motion parallax in recovering depth. There were two classes (full-surface and stick figures) of real symmetric 3-D objects composed of two congruent trapezoids sharing a common edge. We used a 2×2 stimulus design: proper or reverse perspective (4 values) $\times$ concave or convex angle. We also used 2×2 viewing conditions: monocular or binocular $\times$ stationary or moving observer. Motion amplitude was equal to interpupilary distance to allow comparison of motion and stereo parallax. The data displayed a consistent pattern across the two stimulus types. Even small values of perspective dominated over angle polarity. Binocular viewing improved performance over monocular viewing. Moving observers had an advantage over stationary observers only for monocular viewing. We concluded that (i) perspective was much stronger than angle polarity, (ii) stereo parallax played a bigger role than motion parallax in recovering depth, and (iii) motion parallax was effective only when stereo parallax was absent.

[Supported by the Aresty Research Center for Undergraduates at Rutgers University.]

◆ **A novel simplicity principle that allows the recovery of solid shapes**
Z Pizlo, Y Li, T Sawada, R M Steinman (Department of Psychological Sciences, Purdue University, Lafayette, USA; e-mail: pizlo@psych.purdue.edu)

A single 2-D image of a solid (3-D) shape leads to a 3-D shape percept that is usually veridical. This achievement is remarkable because of the geometrical fact that this 2-D image cannot provide a unique description of the 3-D object producing the 2-D image. The depth of each point

'out there' is ambiguous in its 2-D image. But, when a 3-D shape is viewed, this ambiguity disappears. The image points are 'organized' into a 2-D 'retinal shape' and the 3-D shape 'out there' is recovered as a 'whole' by built-in simplicity constraints. We have identified four effective constraints: 3-D symmetry, planarity, maximum 3-D compactness, and minimum surface. These constraints explain how 3-D shape constancy is achieved and how a 3-D shape's symmetry can be detected in a 2-D image. Psychophysical tests showed that: (i) our simplicity constraints are more important than depth cues, including binocular disparity and motion parallax, and (ii) maximum 3-D compactness is the essential constraint. Ecological justification for our new simplicity principle will be discussed.
[Supported by the National Science Foundation and the US Department of Energy.]

◆ **Multidimensional contour vectors for category representations**
C Rasche (Institute of Psychology, Justus-Liebig University Giessen, Germany; e-mail: rasche15@gmail.com)

Motivated by an alternative interpretation of how visual pop-out is computed, a contour decomposition is suggested, which extracts its geometrical and contextual aspects. The decomposition transforms the contour geometry into a local-global spectrum, which expresses in its lower (local) range the contour's smoothness and in its upper (global) range the form, such as its degree of curvature. The contextual aspects include the degree of isolation (region), contrast and fuzziness. Combining all these aspects into a multidimensional vector, it is shown on 60 000 images (COREL collection), that (i) a single contour can be very characteristic to a category, such as a horizontal, wiggly contour to a landscape scene; (ii) images can be sorted according to their texture properties; (iii) a histogram representation of such contours can be specific to superordinate, basic, or subordinate categories. Concluding, this study demonstrates the representative power of multidimensional contour description, which could explain a number of recognition phenomena, such as its rapid pop-out detection, its vast memory capacity and its processing speed.
[Supported by GazeCom IST-C-033816, Prof. K Gegenfurtner.]

◆ **Predicting successes and failures of 3-D shape estimation**
R W Fleming (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: roland.fleming@tuebingen.mpg.de)

Humans are generally pretty good at visually estimating the 3-D shape of objects. However, under some circumstances we are subject to illusions. For example, in 'shape from shading', certain illumination conditions can systematically alter perceived 3-D shape. Similarly, in 'shape from texture', certain textures can induce systematic misperceptions of shape. Most computational theories of 'shape-from-x' focus on achieving accurate shape reconstruction. However, a good model of human vision, should account for the pattern or errors as well as successes. Here, in a series of gauge-figure and similarity rating tasks, we measure how perceived shape changes across variations in illumination, surface reflectance, texture, and certain shape transformations. We then show how a number of simple image statistics derived from filters tuned to different orientations and scales qualitatively predict the pattern of both successes and errors. Importantly, this shows how both similarities and differences between cues (such as shading, highlights, and texture) might be explained by a common front-end.

SHIFTS AND DISTRIBUTION OF SPATIAL ATTENTION

◆ **Changes in visual masking during presaccadic remapping of space**
A R Hunt, P Cavanagh¶ (Vision Sciences Laboratory, Department of Psychology, Harvard University, Cambridge, USA; ¶ Laboratoire Psychologie de la Perception, Université Paris Descartes, France; e-mail: ahunt@wjh.harvard.edu)

In many visual areas, receptive fields remap in anticipation of the retinal shift that will occur when the eyes move. We measured the accuracy to discriminate a target in the presence of high-contrast masks presented in both a control condition (no eye movement) and during the 100 ms remapping interval before a saccade. In the control condition, masks interfered with target identification only when they spatially overlapped. During remapping, two changes emerged: (i) the effect of masks presented at the same location as targets was reduced, and (ii) masks presented in the location corresponding to the anticipated retinotopic position of the target after the impending eye movement interfered with target discrimination. The results suggest that remapping receptive fields in anticipation of the eye movement shifts the location from which information about the target is being accrued. The shift away from the actual target location reduces masking for masks appearing on the target, but increases masking when the mask appears in the anticipated retinotopic location of the target after the saccade.

◆ **How does the frontal eye field affect early visual processing? Contrast discrimination in patients with frontal-eye-field lesions**
U Budnik, R Rafal¶, P Sumner (School of Psychology, University of Cardiff, UK; ¶ Wolfson Centre for Clinical and Cognitive Neuroscience, University of Wales, Bangor, UK; e-mail: budniku@cardiff.ac.uk)
Transcranial magnetic stimulation (TMS) of the frontal eye field (FEF) has been found to modulate visual perception, enhancing contrast sensitivity in periphery relative to fovea. Similarly, the BOLD response for early visual cortex (V1 – V4) was relatively increased in periphery (Ruff et al, 2006 *Current Biology* **16** 1479 – 1488). If TMS acted as a 'virtual lesion', patients with FEF lesions should show a similar pattern: relatively enhanced peripheral contrast perception. If the TMS effect was due to nonspecific subthreshold activation of FEF (as suggested by Ruff et al), patients should show the opposite effect: relatively impaired peripheral contrast detection. We measured discrimination thresholds for oriented Gabor patches presented at fovea or 13 eccentricity in three patients with right FEF lesions, who showed relative impairment for contrast discrimination in the periphery when compared to neurological and healthy controls. Thus, damage to FEF appears to impair relatively low-level perception, consistent with the idea that activation of FEF (naturally or using TMS) leads to a relative enhancement of visual processing in the periphery.
[Supported by the Wales Institute of Cognitive Neuroscience (ICN).]

◆ **Probing the link between sources and targets of attentional control: a concurrent TMS – fMRI study of visuospatial selection**
K Heinen, C Ruff, O Bjoertomt, B Schenkluhn, S Bestmann, F Blankenburg¶, V Walsh, J Driver, C Chambers§ (Institute of Cognitive Neuroscience, University College London, UK; ¶ Department of Neurology, Charité, Humboldt University, Berlin, Germany; § School of Psychology, Cardiff University, UK; e-mail: k.heinen@ucl.ac.uk)
Converging evidence suggests that selective spatial attention is controlled by a frontoparietal cortical network. In addition, neuroimaging studies show that activity in human (extra)striate visual cortex is modulated by the spatial distribution of attention. Crucially, however, there is little direct evidence connecting sources of attentional control with sensory representation in visual cortex. Here we probed this missing link by establishing simultaneously the effects of AG stimulation on spatial orienting behaviour (TMS) and the corresponding BOLD response in visual cortex (fMRI). Subjects undertook a covert-orienting task with non-informative reflexive cues in a concurrent TMS – fMRI environment. To disrupt spatial reorienting of attention between the cue and target (on invalid trials), a rapid train of TMS was delivered to the right AG synchronously with target onset. Simultaneously, the target-related BOLD response was measured in areas V1 – V5, and in frontoparietal areas. Our results provide evidence for interhemispheric interaction following TMS stimulation of the right AG during a spatial attention task and parietal gating of sensory representations in the visual cortex.
[Supported by a BBSRC David Phillips Fellowship (to CC).]

◆ **Neural correlates of motion-induced blindness in the human brain**
M L Scholvinck, G Rees (Institute of Cognitive Neuroscience and Wellcome Trust Centre for Neuroimaging, University College London, UK; e-mail: m.scholvinck@ucl.ac.uk)
The role of early visual cortex in awareness remains a topic of much investigation. This can be studied using bistable perception paradigms, such as motion-induced blindness, in which a salient target amidst a moving field of distractors repeatedly disappears and reappears. We investigated the neural correlates of this phenomenon by measuring fMRI responses in visual cortex while participants reported disappearances and reappearances of the target. Surprisingly, perceptual invisibility of the target was coupled to increased neural activity in early visual cortex and V5/MT compared to when the target was visible. This increase was significantly greater in cortical retinotopic regions corresponding to the spatial location of the target, than in control regions elsewhere in early visual cortex. We suggest that these findings result from a weak arousal effect general to the whole of visual cortex, superimposed on which is a spatially specific process possibly related to completion of the field of distractors. These results add to the existing literature on bistable phenomena and will help to understand bistable perception more generally.

◆ **Capture of attention by scene-relative object movement during self-movement**
S K Rushton, C J H Ludwig¶ (School of Psychology, Cardiff University, UK; ¶ Department of Experimental Psychology, University of Bristol, UK; e-mail: rushtonsk@cardiff.ac.uk)
If the observer is not moving object movement is uniquely signalled by retinal image motion. Under such circumstances a moving object captures attention. During self-movement the global image

motion that results from movement of the eyes may mask the image motion that signals object movement. We investigated whether a moving object captures attention in this case. Through stereo glasses, observers viewed 24 objects arranged in a 3-D volume. Four of the objects were potential target objects that could change shape. During viewing the camera viewpoint was translated and rotated to simulate self-movement. Observers were required to identify a shape change as rapidly as possible. On every 35th trial an object within the scene would unexpectedly move at approximately the same time as the shape change. When the object that changed shape was also the object that moved, response time was shorter that when a different object moved; this is the hallmark of attentional capture. Therefore we conclude that during self-movement, unexpected object movement captures attention.

◆ **Neural processing of task-relevant stimuli outside the focus of attention**
R Houtkamp, J Braun (Department of Cognitive Biology, Otto-von-Guericke University, Magdeburg, Germany; e-mail: Rozemarijn.Houtkamp@Nat.Uni-Magdeburg.de)

We know that focussing attention on a task-relevant stimulus enhances the associated neural activity in visual cortex. But does activity also increase when a task-relevant stimulus remains outside the focus of attention? We dissociated task-relevance and attention-focus with a dual-task paradigm that combined a central task 'inside' and a peripheral task 'outside' the focus of attention, while measuring BOLD-activity related to central and peripheral stimuli. When an attention-demanding peripheral pattern was task-relevant while the attention-focus remained on central patterns, peripheral BOLD-activity was moderately higher than when the peripheral pattern was not relevant to any task. When the peripheral pattern was not only task-relevant but also at the focus of attention, a further increase in BOLD-activity was observed. With an alternative, less attention-demanding peripheral task, task-relevance alone failed to modulate BOLD-activity. The observed modulation by task-relevance was thus doubly dissociated from behavioural performance, such that either could be seen to increase without the other. Our results show that task-relevance and attention-focus differentially influence behavioural performance and BOLD-activity in visual cortex.

POSTERS

ANALOGOUS CONCEPTS IN HAPTICS AND VISION

◆ **Haptic perception of space in infancy: influence of visual cues**
A Streri, E Gentaz¶ (Laboratory for psychology of Perception, University Paris Descartes, France; ¶ University Mendès-France, Grenoble, France; e-mail: arlette.streri@univ-paris5.fr)

The present research examined the influence of visual contextual cues on the manual discrimination of spatial orientations in 5-month-old infants. Different visual contextual cues were proposed during the haptic discrimination task: congruent-informative, noncongruent-informative or non-informative. A familiarization/reaction to novelty procedure was used in three experiments. In Experiment 1, a congruent-informative visual context (alternate black and white stripes tilted to 20°-left) was present and a haptic discrimination between a 20°-left rod and a 30°-left rod was observed. In Experiment 2, the visual context cues (black dots) were noninformative, and infants could not discriminate these two oblique rods. In Experiment 3, the presence of a non-congruent visual context as in Experiment 1 disturbed the gravitational vertical perception usually observed: infants could not discriminate the vertical rod from the 10°-left rod. This showed that only the informative (congruent and noncongruent) visual contextual cues influenced the haptic discrimination of orientations infants. The results are discussed in relation with the models of multisensorial integration.

◆ **Crossmodal visuo-haptic integration in an illusion of length**
F Mancini, E Bricolo, M Sacerdoti, M Tadini, G Vallar (Department of Psychology, University of Milano Bicocca, Milan, Italy; e-mail: f.mancini2@campus.unimib.it)

Arrows placed at the ends of a line may affect its estimated length. These illusions (Müller-Lyer and its variants) have been extensively investigated in the visual modality. These 'optical' illusions also occur in touch, opening a debate on whether modality-specific or shared processes underlie visual and haptic illusory effects. In order to investigate hypotheses of specific versus common underlying mechanisms, we assessed the performance of twenty-four undergraduates in the manual bisection of the Judd illusion in three separate conditions, presented in a counterbalanced order. Under visual and haptic presentations, the same stimulus material (plastic shapes on a board) was used, while in the crossmodal condition participants looked at the arrows and touched the line placed on the back of the board. Results indicate that illusory effects do not differ in touch and vision, and are present—albeit reduced—in the crossmodal condition. This is compatible with the view that crossmodal integration involves additional processing resources.

Correlations across the three conditions are discussed and related to current models of illusion processing.
[Supported by PRIN 05 and IRCCS Istituto Auxologico Italiano.]

◆ **Aesthetics by numbers: computationally derived features of visual textures explain their aesthetics judgment**
K V Haak, R H A H Jacobs, S Thumfart¶, B Henson§, F W Cornelissen (Laboratory for Experimental Ophthalmology & BCN NeuroImaging Center, University Medical Center Groningen, University of Groningen, The Netherlands; ¶ Profactor GmbH, Steyr-Gleink, Austria; § School of Mechanical Engineering, University of Leeds, UK; e-mail: k.v.haak@med.umcg.nl)
Artists and designers often use visual textures to convey or strengthen the emotional impact of their work. Nevertheless, visual textures have been largely neglected in aesthetics research. In this exploratory study, we studied to what extent relatively low-level image features can explain aesthetics judgments of visual textures. Subjects rated visual textures on a continuous scale on eight perceptual dimensions (eg, roughness, naturalness, colourfulness) and an aesthetics dimension (beauty). In addition, a large set of image features was computed using computer vision algorithms. Subsequently, the image features and perceptual judgments were subjected to a principal component analysis. Two principal components explained most of the variance in the perceptual dimensions, and five explained most of the image feature-space. Next, we examined the relationship between the principal components of the image features, principal components of perceptual dimensions, and aesthetics judgments. This analysis revealed that visual texture aesthetics can be explained based on computationally derived image features when an intermediate perceptual assessment step is allowed for.
Supported by [R Renken, R Sijbom, M Schotkamp, E.A de Breij, R Sonnega.]

◆ **The effects of adaptation on haptic roughness perception**
M Kahrimanovic, W M Bergmann Tiest, A M L Kappers (Helmholtz Institute, Universiteit Utrecht, The Netherlands; e-mail: m.kahrimanovic@phys.uu.nl)
Adaptation effects have been studied extensively in vision. In the present experiments, haptic roughness adaptation effects were investigated. Subjects examined embossed dot patterns of varying dot spacing. In Experiment 1, they had to discriminate between two stimuli that were presented simultaneously to adjacent fingers, after adaptation of one of these fingers. The results showed that adaptation to a rough surface decreased the perceived roughness of a subsequently examined surface with the adapted finger, whereas adaptation to a smooth surface increased the perceived roughness. In Experiment 2, discrimination was between subsequent test stimuli, while the adjacent finger was stimulated simultaneously. Perceived roughness of the test stimulus was shifted towards the roughness of the adjacent stimulus. Taken together, adaptation caused roughness perception to shift away from the roughness of the adaptation stimulus, while simultaneous stimulation of the fingers caused the perception to shift towards the adjacent stimulus. These results are reminiscent of visual simultaneous contrast versus assimilation effects and open up the possibility of investigating whether comparable mechanisms are involved in haptics and vision.

◆ **Developing a reference frame for testing cross-modality effects of vision and touch**
M Jakesch, M Zachhuber, H Leder, C C Carbon (Faculty of Psychology, University of Vienna, Austria; e-mail: martina.jakesch@univie.ac.at)
As shown recently, the psychophysics of many tactile qualities follow complex, multidimensional, higher-order relations (eg Bergmann-Tiest and Kappers, 2007 *Acta Psychologica* **124** 177 – 189). The complexity increases further on determining crossmodal psychophysical functions. Our tactile test material consisted of tactile plates of the Sensotact V2 reference frame targeting three dimensions that varied the physical parameters of temperature, roughness, and hardness on five levels each. Twenty-six participants had to direct the positioning of the whole material on three subsequent 301-level scales of the target dimensions. For each scale, two plates representing minimum and maximum were used as anchors at the scale points of 100 and 200, respectively. Ratings for blindfolded vs sight condition differed most strongly on the temperature and hardness scale, indicating crossmodality effects. To develop a reference frame for testing tactile material crossmodal effects need taking into account. Furthermore, to be of applied value, calibration of such a system has to include psychological variables and not rely solely on physical variables.

◆ **Differential amygdalar activity for beauty versus roughness judgments**
R H A H Jacobs, R Renken¶, F W Cornelissen (Laboratory for Experimental Ophthalmology, University Medical Center Groningen [¶ BCN NeuroImaging Center], University of Groningen, The Netherlands; e-mail: r.h.a.h.jacobs@med.umcg.nl)
Previous neuroaesthetics research has suggested that certain emotional brain centres, such as the amygdala, are responsive to the aesthetic status (beautiful, neutral, ugly) of stimuli. Aesthetic and emotional stimuli share the dimensions of arousal and valence. Controlling for the arousal of emotional stimuli still yielded effects of valence on the amygdalar response. In neuroaesthetics, the effect of arousal has not been controlled for yet. Here, we sought to focus on valence in aesthetics by using relatively non-arousing stimuli, namely textures. We hypothesized that the amygdalar response would differ for beautiful, neutral, and ugly textures, and that these effects would be amplified in an evaluative (beauty) compared to a descriptive judgment (roughness). Unexpectedly, we found that amygdalar activity was strongly affected by the type of judgment, yet in the complete absence of an effect of beauty status. We conclude that making evaluative judgments on low-arousal stimuli results in a top–down boosting of amygdalar evaluative function. Previous influences of aesthetic status on amygdalar activity may have been caused by arousal effects.

◆ **Generalized adaptive procedure for psychometric measurement**
T Tanner (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: tanner@tuebingen.mpg.de)
A new Bayesian adaptive psychometric method based on the theory of optimal experiments is introduced and evaluated in simulations over a set of possible observers. The method is flexible enough to be adapted to a wide range of psychophysical experiments (blocks of constant stimuli, n-AFC, yes/no, and discrimination paradigms) and allows specification of many types of assumptions. The four parameters of standard psychometric functions can be estimated in real-time (scales easily to more parameters). An important novelty is the possibility to adjust the desired accuracy of the parameters of interest by weights. Dynamic termination criteria can significantly improve efficiency compared to a fixed number of trials. Yes/no designs turned out to be more efficient than n-AFC in most circumstances. When using blocks of constant stimuli the performance was comparable to single stimuli placement while being more robust to certain experimental phenomena. Simulations showed that the method is at least as efficient and much more flexible than established methods.

◆ **Mirror symmetry topographical mapping is a fundamental principle of cortex organization in vision and touch: a whole brain fMRI study of body representation**
Z Tal, R Geva, U Hertz, A Amedi (Department of Physiology, Faculty of Medicine, The Hebrew University of Jerusalem, Israel; e-mail: zoharit@gmail.com)
Vision and touch are characterized by a topographical mapping of the sensory world onto primary and secondary cortices. In such topographical maps, adjacent neurons represent adjacent sensory building blocks (eg visual field and body parts). But how common are such topographical maps outside primary sensory areas? And can we characterize similar principles of organization across modalities? Using fMRI, we applied continuous and periodic sensory stimulation to detect further topographically sensitive areas in the somatosensory modality. We used phase locking Fourier techniques combined with a spherical cortex-based alignment approach to detect such topographic maps. Using these methods, we report here the preliminary finding of several novel somatotopic maps of the human brain, beyond the well-known homunculus in the post-central gyrus. We also find additional topographic body sensitivity in the parietal and occipital cortex. Our results suggest that mirror symmetry topographical mapping may be a fundamental principle of mapping in vision and touch and a more common characteristic of associative and multisensory cortex than previously suspected.
[Supported by the International HFSP CDA award (to AA).]

ATTENTION AND RELATED ISSUES

◆ **Episodic retrieval accounts of priming in visual search explain only a limited subset of findings on priming**
A G Asgeirsson, A Kristjansson (Department of Psychology, University of Iceland, Reykjavik, Iceland; e-mail: aga2@hi.is)
Recent results on priming in visual search have suggested that priming reflects not facilitated processing of particular features as proposed by Maljkovic and Nakayama (1994 *Memory & Cognition* **22** 657–672) but rather facilitation of episodic memory representations of preceding trials. For example, Huang et al (2004 *Memory & Cognition* **32** 12–20) found that when target size was repeated, repetition of target colour speeded response times but when target size was

different from that in the previous trial, repetition of target colour slowed response times indicating that the effects were not independent of one another. Here we show that these results apply only to limited scenarios. Very slight tweaking of experimental parameters, particularly the unconfounding of effects of repetition of target vs distractor stimuli, in a search task similar to the one used by Huang et al, abolishes the interaction critical for the episodic memory explanation. The results argue against episodic retrieval accounts of priming, which can only account for a limited subset of visual search results.

◆ **Can feature binding be explained by certainty in space and time?**
A N Rich, E Vul¶ (Macquarie Centre for Cognitive Science, Macquarie University, Sydney, Australia; ¶ Brain & Cognitive Sciences, MIT, Cambridge, USA;
e-mail: arich@maccs.mq.edu.au)

Visual attention allows us to determine which features belong together to form a single object. Here, we test the hypothesis that attention increases certainty about the spatiotemporal locations of features, and feature binding is the consequence of this certainty. Participants viewed brief displays of coloured letters either presented simultaneously in a circle around fixation, or sequentially in an RSVP stream. They reported the identity and colour of a cued item. Errors in these tasks tend to contain features of objects that appear adjacent to the target. If attention selects objects or Boolean maps representing a conjunction of features, errors should reflect the identity and colour of the same item more often then the identity of one item and the colour of another. The results show, however, a striking lack of correlation between identity and colour errors, suggesting instead that given a particular spatiotemporal uncertainty, features are sampled independently. Our results suggest that feature binding arises from spatiotemporal certainty, rather than from explicit object files.
[Supported by NHMRC and Menzies Foundation of Australia.]

◆ **Does the self-face grab and/or retain attention? An eye movement study**
C Devue, S Van der Stigchel¶, S Brédart, J Theeuwes¶ (Department of Cognitive Science, University of Liège, Belgium; ¶ Department of Cognitive Psychology, Vrije Universiteit Amsterdam, The Netherlands; e-mail: cdevue@ulg.ac.be)

Previous studies that investigated the ability of high priority stimuli to grab attention reported contradictory results. In the present study, eye tracking was used to examine the effect of the presence of the self-face among unfamiliar faces in a visual search task in which face identity was task-irrelevant. We evaluated whether the self-face (i) received prioritized selection, (ii) retained attention, and (iii) whether its status as target or distractor had a differential effect. Another highly familiar face was included to control whether possible effects were specific to the self-face or could be explained by high familiarity. We found that the presence of the self-face affected performance on the search task. This was not due to a prioritized processing but rather to a difficulty to disengage attention. Crucially, this effect seemed due to self-face familiarity. Indeed, similar results were obtained with the other familiar face. Moreover, the effect of the self-face was stronger when it was presented as the target than when it was a distractor.
[Supported by the Belgian NFSR and the Dutch NWO.]

◆ **Low-level effects of reward can be disentangled from both spatial and feature attention**
C Simoncini, S Baldassi (Department of Psychology, University of Florence, Italy;
e-mail: claudio.simoncini@gmail.com)

We have previously shown that reward modulates orientation sensitivity when spatial attention is away from the target. Here we investigate whether reward could be distinguished also from feature-based attention. We used a dual task loading spatial-attention to the centre of the display while observers discriminate the tilt offset from vertical of a peripheral Gabor stimulus with or without reward. The Gabor stimuli were modulated along two colour axes, red/green and blue/yellow, and only one of them yielded reward based on a pre-cue indicating the colour axis of the stimulus that produced reward in the case of a correct orientation response. We measured thresholds and response distributions of the rewarded and non-rewarded conditions and found an effect of about 50% of threshold improvement with reward that coincided with a sharpening of the response distribution. Therefore, reward improves threshold even when the input features (colour) are distinguished from the output features measured (orientation). These data support our idea that reward modulates early stages of perception without the mediation of attention.

◆ **The contribution of scene context to change detection performance**
E Zimmermann, F Schnier, M Lappe (Psychology Department II, Westfälische Wilhelms-Universität Münster, Germany; e-mail: eckartzi@uni-muenster.de)
The gist of a visual scene is perceived in a fraction of a second but in change detection tasks subjects typically need several seconds to find the changing object in a visual scene. Does the search take into account that the objects in the scene are contextually related? If scene context helps structuring the search, change detection performance should be worse when context is disrupted. We investigated the influences of scene context on change detection performance in the flicker paradigm. We measured reaction times and gaze behaviour. Scene context manipulations consisted in scene inversion, scene jumbling, where the images were cut into 24 pieces and randomly recombined, and scene configuration scrambling, where the arrangement of the objects in the scene was randomized. Reaction times where significantly lower and gaze was more often directed to the changing region in images with normal scene context compared to the jumbled and configuration scrambled conditions. We conclude that the search for the changing object is guided by scene context.

◆ **Influence of prior knowledge on perceptual grouping**
S Essid (Laboratoire de Psychologie Cognitive, Université de Provence, France; e-mail: essidsassi@yahoo.fr)
According to the classical theory, grouping occurs before any other operations of the attention process, thus the grouping seems not to be affected by the top–down and endogenous process. However, recent research demonstrates that the viewer's knowledge can influence grouping. In order to examine whether grouping is influenced by knowledge of the configuration, we used a paradigm in which participants were asked to identify two numbers among several letters. The targets are located on elements (four squares) that share two basic properties: colour and form. In the first condition, observers are informed about the colour of the elements in which the target will appear. In the second condition, participants are given information beforehand about the organization of the elements. Finally, in the third condition, they are given prior information about the position of the elements. The results suggest that grouping is modulated not only by knowledge of the colour and position of these elements, but also by their organization.

◆ **StraViS 2.0: a revised model for visual feature search with graded target-distractor similarity**
G Mueller-Plath, U Hesse, A Melzer, C Wienrich (Department of Psychology, Martin-Luther-University Halle-Wittenberg, Germany; e-mail: gisela.mueller-plath@psych.uni-halle.de)
In visual search, questions arise regarding how many items are processed in one fixation, whether recurrent item visits occur due to incomplete memory (Horowitz and Wolfe, 1998 *Nature* **394** 575–577) or decision uncertainty (Peterson et al, 2001 *Psychological Science* **12** 287–292), and when the search is terminated (Chun and Wolfe, 1996 *Cognitive Psychology* **30** 39–78). Our model StraViS (strategies of visual search) (Müller-Plath and Pollmann, 2003) decomposes the response time in overt feature search into times of hypothetical cognitive subprocesses and yields individual estimates of the 'attentional focus size', 'attentional dwell time', and 'attentional movement time' for varying target-distractor similarities. However, StraViS relies on the assumption that each item is visited once at most. In the light of recent findings on the relationship between oculomotor and attentional processes, this seems no longer tenable. We thus formulated and tested a revised model, StraViS 2.0. The variants tested here include parameters for visiting items repeatedly, possibly due to perceptual uncertainty, and for terminating search prematurely, possibly due to individually determined speed-accuracy tradeoffs. In a second experiment we validated the revised model.

◆ **Influence of scene background and spatial arrangement of objects on gaze behaviour**
J R Helmert, R Mueller, S Pannasch, B M Velichkovsky (Applied Cognitive Research Unit, Institute of Psychology III, Technische Universität Dresden, Germany; e-mail: helmert@applied-cognition.org)
Within the first seconds of scene inspection characteristic changes in gaze parameters can be found: while fixation duration increases the amplitude of saccades decreases. This behaviour may indicate a transition from merely ambient to focal visual processing (Unema et al, 2005 *Visual Cognition* **12** 473–494). In the present study we investigated how background and spatial arrangement in a scene affect these metrics of gaze behaviour. Participants were presented computer generated images of interiors that consisted of (a) a complete scene with objects and background, (b) objects without background ,or (c) objects randomly arranged in the image. The subjects' task was to inspect the images for subsequent reporting of either the presence or the spatial distribution of objects. Changes in saccadic amplitude and fixation duration over time were reproduced independently from the type of presentation. Reliable differences were found for

saccadic amplitudes with higher values in (b) and (c) as compared to (a). Results are discussed in terms of a shifting balance between ambient and focal processing.
[Supported by EU FP6 NEST-Pathfinder PERCEPT- 043261.]

◆ **Attenuation of substitution masking by a local spatial pre-cue is not an artifact of spatial uncertainty**
I Luiga, T Bachmann (Estonian Centre of Behavioural and Health Sciences, University of Tartu, Estonia; e-mail: iiris.luiga@ut.ee)

Spatial uncertainty is known to prolong the time of directing attention to a target in substitution masking: the longer the time of directing attention, the larger the masking effect. Identification of the target does not depend on the mask delay when a spatially close local pre-cue indicates the location of the target. On the contrary, a centrally presented pre-cue pointing to the location does not help to overcome masking (Luiga and Bachmann, 2007 *Psychological Research* **71** 634 – 640). We studied whether differences in the effects of the central and local pre-cues come from differences in local spatial uncertainty. In the present study frames marked all locations of the target and distractors. Those constantly present frames did not change the relative effects of the pre-cues: a local pre-cue attenuated object substitution masking compared to the central pre-cue and no pre-cue condition. The results support the idea that a local spatial pre-cue effect does not come from reduced spatial uncertainty but could increase sensory saliency of a target.

◆ **Crowding affects letters and symbols differently**
I Tydgat, J Grainger¶ (Department of Psychology, University of Ghent, Belgium;
¶ LPC – CNRS, University of Provence, France; e-mail: jonathan.grainger@univ-provence.fr)

Letters in the first and last position of a string of random consonants are more accurately identified than letters in the second and penultimate positions. This is typically explained as the result of reduced crowding at the outer positions. One problem for this account is that symbol stimuli and simple geometric shapes do not reveal the same outer-position advantage. In order to salvage this crowding interpretation, we hypothesized that crowding effects are stronger with symbol stimuli than letter stimuli, and in particular that there is less release from crowding in symbol stimuli when one of the two flanking characters is removed. Support for this hypothesis was found in four experiments examining the effects of crowding in letter and symbol stimuli while varying the number of flankers. The results support the proposition that processing letter strings involves a specialized system developed to limit the spatial extent of crowding in such stimuli.

◆ **TMS over the intraparietal sulcus induces perceptual fading**
R Kanai, N Muggleton, V Walsh (Institute of Cognitive Neuroscience and Department of Psychology, University College London, UK; e-mail: kanair@gmail.com)

During prolonged fixation, visual objects presented in the periphery of visual field often fade from awareness, a phenomenon known as the Troxler effect. In the present study, we test the hypothesis that perceptual disappearance results from degeneration of feedback loops between high-level attention-related cortical areas and early visual areas. This hypothesis predicted that a brief disruption of intraparietal sulcus (IPS) would trigger perceptual disappearances. Our results show that a brief disruption of the IPS with a single pulse TMS is indeed sufficient to trigger perceptual disappearance. This finding supports the idea that conscious visual perception requires a coupling between the early visual areas representing sensory data and the parietal areas subserving spatial localisation functions.
[Supported by HFSP.]

◆ **Unconscious components of attention: monocular cueing effects in humans**
M W Self, P R Roelfsema (Netherlands Institute for Neurosciences, Amsterdam, The Netherlands; e-mail: m.self@nin.knaw.nl)

Visual attention can be captured by salient events in the visual scene. For example a sudden flash of light can be used as a cue to briefly capture attention, leading to improved performance at the location of the flash at the cost of performance at other locations. The neural mechanisms by which a salient event captures visual attention are not yet known. Here we show that part of the enhancement in performance that follows a salient cue is due to unconscious interactions between the cue and the target at monocular levels of the visual system. We show that a cue presented to one eye initially improves performance only when a target is subsequently presented to the same eye. By using cues which are invisible to binocular parts of the visual system, but visible at monocular levels, we demonstrate unconscious enhancement of processing by salient cues. These results suggest that much of the enhancement in performance seen in stimulus-driven attentional tasks is due to low-level interactions between target and stimulus.

◆ **Interactions of audiovisual attentional resources**
M Batson, T Watanabe¶ (Program in Neuroscience [¶ Department of Psychology], Boston University, USA; e-mail: melbats@bu.edu)

Many behavioural studies have previously shown that unimodal endogenous attention enhances perception. We have also recently shown that crossmodal exogenous covert attention enhances discrimination of a visual target occurring at the same location in space; and that the audiovisual mechanism driving this facilitation is spatially plastic (Beer et al, submitted *Nature Neuroscience*). We now investigate crossmodal attention further with complex cues combining two attentional resources by comparing previously observed covert cuing effects with effects from an additional unimodal or crossmodal endogenous cue. The interaction of attentional mechanisms will be enumerated using an orientation discrimination task with analysis of stepwise amplitude threshold determination. Comparison of magnitude changes in cuing validity effect and threshold differences for endogenous versus complex cuing trials will be analysed. If the exogenous crossmodal cuing mechanism plays the same role in perception as the endogenous mechanism we expect linear or multiplicative enhancement of facilitation (and/or lower threshold). However, an alternative hypothesis shown by one preliminary subject is that competition may exist between modalities and/or attentional resources.
[Supported by Preethi Nakappan.]

◆ **Eye-tracking decision behaviour in choice-based conjoint analysis**
M Messner, K Essig¶, T Pfeiffer¶, R Decker, H Ritter¶ (Department of Economics and Business Administration [¶ Neuroinformatics Group, Faculty of Technology], Bielefeld University, Germany; e-mail: mmeissner@wiwi.uni-bielefeld.de)

In a novel approach we investigated choice processes using eye tracking to improve research instruments in marketing research. Choice-based conjoint analysis (CBC) is the most widely-used tool for investigating consumer preferences on the basis of choice tasks. While CBC is highly appreciated for its realism (Haaijer and Wedel, 2007), marketing researchers have highlighted that respondents are easily exposed to the problem of information overload (Green et al, 2001). The question how much information is being processed during choice processes and how preference measurement is affected remains an open research issue. We investigated choice processes using eye tracking in a CBC on-line consumer survey. We showed (i) that the extent to which information is processed is decreasing in later choice tasks, (ii) in how far information overload changes the pattern of eye movements, and (iii) how the difficulty of a choice task influences information processing.

◆ **The spatiotemporal profile of feature and spatial attention: a psychophysical reverse correlation study**
N Megna, F Rocchi, S Baldassi (Department of Psychology, University of Florence, Italy; e-mail: nicolamegna@gmail.com)

We used psychophysical reverse correlation to investigate the effects of transient attention on temporal and spatial resolution during a detection and an identification task in three different conditions: neutral, spatial, and feature cueing. The target was a flashed bar embedded in 2-D (space – time) noise. The neutral (baseline) condition was identical to the experiment by Neri and Heeger (2002 *Nature Neuroscience* **5** 812 – 816) and we replicated their results, dissociating two different spatiotemporal mechanisms for detecting and identifying the target. Spatial and feature cues showed similar effects, consisting in a modification of the spatiotemporal profile of the classification image. Temporal resolution was impaired at the identification stage, while spatial resolution sharpened with attention. Our findings suggest that the main effect of attention could be an enhancement of temporal summation of sensory evidence, perhaps facilitating the activity of parvocellular neurons at the attended location. This mechanism would explain both our results and the results of other researchers on spatial resolution. We are currently performing the experiment with isoluminant stimuli to test the parvocellular hypothesis.

◆ **Two stages of visual processing during the free exploration of paintings: a study with eye movements and fixation-related ERPs**
S Pannasch, T Fischer, S T Graupner, B M Velichkovsky (Applied Cognitive Research Unit, Technische Universität Dresden, Germany; e-mail: pannasch@applied-cognition.org)

The anatomical distinction of two visual pathways is also reflected in different attentional stages; preattentive or ambient processing serves mainly to spatial orientation whereas attentive or focal processing is rather related to the analysis of object features. In previous work we demonstrated that the activity of one or other system is also expressed in eye movement parameters, ie the combination of fixation duration and the amplitude of the subsequent saccades [Velichkovsky et al, 2005 *Proceedings of the XXVII Conference of the Cognitive Science Society* (Hillsdale, NJ:

Lawrence Erlbaum Associates) pp 2283 – 2288]. In the current experiment, we recorded eye movements and EEG activity during the free exploration of masterpieces of European art. We show that the dominance of either ambient or focal mode of attention can be identified in fixations and saccades. Moreover, this conclusion is strengthened by the data on fixation-related ERPs. [Supported by EU FP6 NEST-Pathfinder PERCEPT- 043261.]

◆ **Cueing spatial visual attention by symbolic and directional auditory stimuli**
R Nasanen, L Ahonen, S Jagadeesan, K Müller (Brain and Technology Team, Finnish Institute of Occupational Health, Finland; e-mail: risto.nasanen@ttl.fi)

We studied the temporal effects of cueing visual attention with symbolic and directional auditory stimuli. The task of the subject was to search for and identify a letter target among a horizontally elongated rectangular array of numerals. Auditory cues indicated in which horizontal segment of the array the target would be presented. Directional cues appeared to come from the direction of the segment in which the target would be shown. The pitch of a symbolic cue indicated the location of the target. The time interval between the auditory cue and the start of the presentation of the visual array was varied. The results showed that cueing shortened search time progressively with increasing cue-to-stimulus onset interval. At short cue-to-stimulus onset intervals the effect of directional cueing was greater than that of symbolic cueing (100 – 200 ms). This suggests that, for guiding spatial location of visual attention, the processing of symbolic auditory cues lasts clearly longer than the processing of directional cues.

◆ **Suppressed visual awareness can be recovered by sounds presented in the relevant locations**
M Shibata, Y Kawachi, S Yairi¶, Y Iwaya¶, J Gyoba, Y Suzuki¶ (Department of Psychology [¶ Research Institute of Electrical Communication], Tohoku University, Japan; e-mail: shibatam@sal.tohoku.ac.jp)

Visual stimuli superimposed on moving pattern perceptually disappear (motion-induced blindness: MIB). We reported that sounds can recover visual awareness suppressed by MIB. We presented a square as a target in MIB and three pure tones of 1.8 kHz (duration: 50 ms). Participants were asked to press and release an assigned key corresponding to the disappearance and reappearance of the target. The sounds were presented immediately after the disappearance response. They were either presented on the same or a different side as the target on the screen to test the effects of spatial consistency across audiovisual stimulation (Experiment 1). We also varied the sound pressure level (45 to 85 dBA) to test the robustness of the recovering effect (Experiment 2). The results showed that the awareness of the disappearing target was quickly recovered only after the presentation of sounds of 65 dBA or above, on the same side as the target. We suggest that auditory signals interfere with visual suppression and modulate the status of visual awareness. [Supported by Grant-in-Aid of MEXT for Specially Promoted Research (19001004).]

◆ **Competition for awareness among visual events is modulated by sound in metacontrast masking**
S L Yeh, Y L Chen (Department of Psychology, National Taiwan University, Taipei, Taiwan; e-mail: suling@ntu.edu.tw)

In metacontrast masking, the visibility of a briefly shown suprathreshold target is reduced by a subsequent surrounding mask and the performance is characterized by a U-shaped function of accuracy over SOA. Past studies have focused on factors affecting the masking function and yet it remains unknown whether such competition for awareness among visual events is affected by an auditory signal. We examined this by adding a sound before, simultaneous with, or after the presence of the target. The results show that the addition of the sound effectively reduced metacontrast masking when it appeared before or after the target, with different changes in the masking functions in these two conditions. These results indicate that sound enhances the visibility of the visual target by orienting attention to the upcoming visual event, or by helping temporal segregation of the two visual events. We conclude that sound modulates the competition for awareness among visual events in metacontrast masking.

◆ **How do distractors distract in multiple object tracking?**
T S Horowitz, M A Cohen¶ (Department of Ophthalmology, Harvard Medical School, Boston, USA; ¶ Department of Surgery, Brigham and Women's Hospital, Boston, USA; e-mail: toddh@search.bwh.harvard.edu)

What role do distractors play in multiple object tracking? We devised an experiment in which distractors were optional. Twelve observers tracked 2, 4, or 6 targets with or without an equivalent number of distractors. Stimuli and background were Gaussian pixel noise textures, so items were only visible in motion. After a random tracking duration (mean 5 s), a white probe square was presented around a target, distractor, or random background patch. Observers indicated

whether the probe was a target. We assumed that false alarms (FAs) to distractors represent both tracking errors and attentional lapses, while FAs to background probes represent only lapses. If distractors affect performance only by being mistaken for targets, then background FAs should be constant whether or not distractors are present. However, we found that introducing distractors increased background FAs (in addition to introducing FAs to distractors). This effect increased with tracking load, and was not apparent with only 2 targets. Distractors do not simply act as foils, but require additional resources to suppress.
[Supported by NIH-NIMH 65576.]

◆ **Colour aids memorization—not detection—of rapidly presented natural scenes**
A Yao, W Einhäuser¶ (Institute of Computational Science, Swiss Federal Institute of Technology (ETH) Zürich, Switzerland; ¶ Department of Neurophysics, Philipps University Marburg, Germany; e-mail: yaoa@student.ethz.ch)
Colour has an unresolved role in natural scene recognition. Whereas rapid serial visual presentation paradigms typically find no advantage for coloured over greyscale scenes, colour seems to play a decisive role for recognition memory. The distinction between detection and memorization has not been addressed directly in one paradigm. Here we asked ten observers to detect animals in 2-second 20 Hz sequences. Each sequence consisted of two one-second segments, one of greyscale images and one of coloured; each segment contained one or no target, totalling 0, 1, or 2 targets per sequence. In single-target sequences, hit-rate was virtually identical for greyscale and coloured targets. If both targets in two-target sequences were identical or categorically related (same species), there were also no preferences for the coloured target when observers reported only one target. In contrast, if the two targets were of different species, observers preferentially reported the coloured target. Our findings suggest that colour has little effect on detection, but ensures preferential access to memory when distinct items must be rapidly remembered.

BINOCULAR VISION AND SPATIAL LOCALISATION

◆ **Relation between individual differences in dynamic and static vergence characteristic with changing viewing distance and size of disparity step stimuli**
A Svede, W Jaschinski¶ (Department of Optometry and Vision Science, University of Latvia, Riga, Latvia; ¶ Research Group Individual Visual Performance, Leibniz Research Center for Working Environment and Human Factors, University of Dortmund, Germany; e-mail: aiga.svede@lu.lv)
In previous experiments we supported the idea that fixation disparity results from an asymmetry of convergence vs divergence dynamics in response to disparity step stimuli (Jaschinski et al, 2008 *Vision Research* **48** 253 – 263) based on the neural network model (Patel et al, 2001 *Neural Computation* **13** 1495 – 1525). Our previous study referred to the viewing distance of 60 cm and the stimuli size of 60 min of arc. Is this relation still maintained for different viewing distances and sizes of the stimuli disparity? We used dichoptic nonius lines (flashed for 100 ms with various amounts of delay after stimulus onset) to estimate vergence step responses to 15, 30, 60, 120, and 240 min of arc disparity step stimuli at viewing distances of 30, 40, 60, 100 cm. Subjects with eso-fixation disparities had difficulties with divergence dynamics and subjects with exo-fixation disparity had difficulties with convergence dynamics especially at larger viewing distances. We describe the appropriate test conditions to establish the relation between static and dynamic vergence performance.

◆ **Information processing strategies are hemispheric independent**
B Skalska (Department of Cognitive Psychology, University of Finance and Management, Warsaw, Poland; e-mail: blandynaskalska@vizja.pl)
Some cues are more reliable than other ones and therefore need different processing strategies. It was shown that less/more reliable flankers exerted smaller/larger effect even if participants were exposed to two spatially separated sources of stimuli. The strategies were matched independently and it was attributed to the independent acting of two hemispheres as the stimuli were presented to the left and right of fixation (Corballis and Gratton, 2003 *Biological Psychology* **64** 191 – 209). We investigated how the selection of cue-processing strategy is organized. Two different ways were contrasted in which strategies might be controlled: a hemisphere-specific mechanism or a hemisphere-independent mechanism. We used four stimuli sources: one at each corners of an imaginary square. Less reliable flankers were in both right positions or in both upper positions. In all cases, flanker effect was smaller for those locations where only 20% flankers were valid. The strategies were developed in a hemisphere-independent way. Moreover, our findings suggest that participants can adjust a proper strategy independently for several stimuli sources. Perceptual load did not attenuate the effect.

◆ **Interchannel asymmetries during long and short dichoptic presentations**
J Corral, L Leirós¶, M Blanco¶, F Valle-Inclán (Department of Psychology, University of La Coruña, Spain; ¶ Department of Psychology, University of Santiago, Spain; e-mail: corraljose@yahoo.es)
Under long-term dichoptic viewing (binocular rivalry) the image presented to one eye is longer suppressed than the image presented to the other eye. Curiously, this asymmetric performance has been rarely reported during very brief presentations (dichoptic masking). This discrepancy might be important, as it would indicate the enrollment of different mechanisms as a function of presentation time. To investigate this issue, we foveally presented a target to one eye and a mask to the other eye during 20, 100, or 2000 ms. Two thirds of the observers ($N = 21$) identified the target much better when presented to one of the eyes, regardless of stimulus durations (the interocular differences were highly correlated across stimulus durations). Following up experiments demonstrated identical monocular masking functions and no differences in contrast sensitivity or acuity. We conclude that interocular asymmetry during dichoptic viewing is common and unrelated to stimulus durations, at least in the time range tested in our experiments. This asymmetry may reflect a biased network of inhibitory connections in early visual stages.
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◆ **Rivalry alternations bind together along entire contours**
E W Graf, D H Baker (School of Psychology, University of Southampton, UK; e-mail: erich@soton.ac.uk)
Dominance periods in binocular rivalry can be influenced by contextual information and spatial relationships. Recently, Alais et al (2006 *Vision Research* **46** 1473 – 1487) demonstrated that pairs of collinear elements tend to alternate together, suggesting a mechanism (contour integration) by which image features may be bound together during rivalry. To investigate this, we constructed curved monocular contours of between one and five Gabor elements (4 cycles deg^{-1}) equidistant from fixation in either the left or right hemifield, and rivalling with binary noise. Observers reported when all Gabors were either present or absent, giving an index of alternation coherency. Elements consistent with a continuous contour were coherent for a greater proportion of trials than expected by chance (calculated as $2/2n$, n is number of elements). Elements orthogonal to the contour were less coherent, though still greater than chance, whereas reported coherence for randomly oriented elements was at chance. These effects disappeared (or reversed) when successive elements were presented to different eyes, indicating that the binding effects are eye-specific.
[Supported by BBSRC grant no. BB-E012698-1.]

◆ **The effects of temporal noise on the perception of motion in depth**
H T Nefs, J M Harris (School of Psychology, University of St Andrews, UK; e-mail: htn@st-andrews.ac.uk)
We investigated the robustness of motion in depth perception against temporal noise. Stereograms moved smoothly in depth interspersed with noise blocks (total stimulus duration was 3 s). Blocks of noise and signal were periodically alternated in a duty cycle. We measured the proportions correct identification of the direction of motion as a function of the duty cycle and the noise duration in each duty cycle. We tested five different types of stimuli: random-dot stereograms (RDS) where the position of dots in signal blocks is either maintained across duty cycles or renewed, dynamic random-dot stereograms (DRDS), and time correlated random-dot stereograms (TCRDS) again with and without dot renewal after each duty cycle as for RDS stimuli. Performance for DRDS stimuli is significantly worse than for RDS but is better than for TCRDS. Performance on TCRDS is significantly above chance. Our findings suggest that IOVD cues are thus important for motion in depth perception and may play a role in enhancing its robustness against temporal noise.
[Supported by a grant from the EPSRC to JMH.]

◆ **Binocular rivalry from asynchronously flickering images: the temporal limit depends on trial duration and attention**
J J A van Boxtel, C J Erkelens, R van Ee (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: j.j.a.vanboxtel@phys.uu.nl)
Binocular rivalry may ensue between stimuli that are presented intermittently and asynchronously, as long as each of the rivalrous patterns are presented at > 3 Hz. We call this limit the temporal limit to rivalry. We show that the 3Hz limit is not reached instantaneously. At the beginning of the trial stimuli need to be presented at > 6 Hz to induce rivalry, only after > 8 s the 3 Hz limit is reached. This finding suggests that a rather slow process underlies the buildup of the temporal

limit to binocular rivalry. In a second set of experiments we show that this build-up of the temporal limit is dependent on the deployment of attention to the stimulus. When attention is diverted during the initial part of a trial with a secondary task, the maximum temporal limit is reached later. Therefore the slow process that underlies the build-up of the temporal limit is gated by attention, suggesting that the build-up of the temporal limit is not just due to autonomous adaptation of early visual neurons.

◆ **Stereo 'blind-sight' during online control of movement**
C M van Mierlo, J B J Smeets, E Brenner (Research Institute MOVE, Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands; e-mail: c.vanmierlo@fbw.vu.nl)

The stereo-blind perform most everyday actions without any problems. Do they use binocular information that is not revealed by standard tests for stereo-blindness to achieve this? We studied one stereo-blind subject (JS) who was treated for amblyopia during childhood. He cannot align the slants of two random dot surfaces. Nevertheless, when placing a cylinder on a virtual surface, he adjusted his movement only 175 ms after the surface's slant changed, although the change was only in binocular disparity. We verified that his responses were not based on motion parallax, and that he did not use the small distortions in each eye's image when the binocular disparity changed (he failed to respond if images were only presented to one of his eyes). JS did not respond to the change in slant if we blanked the image for a short period before the change (removing motion information). Our findings suggest that despite being stereo-blind, JS can use changes in binocular information to control his movements.

◆ **Evaluation of stereoscopic stills: beyond the 2-D quality model**
M Lambooij, H Heynderickx¶, W Ijsselsteijn (Human Technology Interaction, Eindhoven University of Technology, The Netherlands; ¶ Department Mediamatics – Human Computer Interaction, Delft University of Eindhoven, The Netherlands; e-mail: m.t.m.lambooij@tue.nl)

Subjective image quality is a standard evaluation criterion for 2-D imaging systems. However, when applied to 3-D imaging systems, it does not incorporate the added value of depth that is present in 3-D content. Higher level evaluation criteria are proposed that are sensitive to both image quality and depth. A 3-D quality model was constructed in which such higher level evaluation criteria (naturalness and viewing experience) were factored in a weighted sum of image quality and depth. An experiment was performed to evaluate this model. Two scenes were varied in depth (using came base distances) and image quality (using white Gaussian noise) and evaluated in terms of naturalness, viewing experience, image quality, and depth. Analysis revealed that both naturalness and viewing experience reflect image quality to a similar degree, yet the added value of depth was slightly more incorporated by naturalness than by viewing experience.

◆ **Spatially variant morphological skeleton representation interframe interpolation method**
R M Udrea, D N Vizireanu¶, R Preda, I Pirnog (Faculty of Electronics Telecommunications and Information Technology [¶ Communications Department], University Politehnica of Bucharest, Romania; e-mail: mihnea@comm.pub.ro)

In this paper, we presented a general theory of spatially-variant mathematical morphology skeleton and showed its enormous potential through image processing applications. One of the main image representations in mathematical morphology is the spatially-variant morphological skeleton (SVSK) representation, useful for image compression and pattern recognition. SVSK can be generalized, to extend the scope of its algebraic characteristics as much as possible. With these generalizations, the role of SVSK as an efficient image decomposition tool is extended to interpolation of images. This paper addresses the interframe interpolation by means of generalized SVSK representation. It consists of changing, step by step, the SVSK subsets of input frame with the SVSK subsets of output frame. After describing the algorithm we provide experimental results that are very encouraging. We applied the proposed scheme to real-word data. Some preprocessing method could improve results. The algorithm is fully morphological and can be applied very quickly. This entire process is efficient with respect to computational complexity. All of the experimental results showed that the proposed method could generate satisfactory interpolation.
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◆ **The noise puzzle in contrast discrimination**
R Alcala-Quintana, M A García-Pérez (Departamento de Metodologia, Facultad de Psicologia, Universidad Complutense, Madrid, Spain; e-mail: ralcala@psi.ucm.es)

The classic and yet unsolved question of whether the noise that limits discrimination performance is fixed or variable (ie whether it has contrast-independent or contrast-dependent variance)

has recently been tackled in a substantial number of papers from a goodness-of-fit perspective. However, the question cannot be solved by that strategy because noise mean and variance interact to produce psychometric functions in such a way that their individual effects are impossible to disentangle. Here we illustrate this point by fitting models of both types to a set of detection and discrimination data. Models tested imply different forms for the transducer function, the variance function, and the noise distribution. Our results clearly show that models assuming either type of noise perform indistinguishably when each is coupled with a convenient (and plausible) form for the transducer function; thus, success or failure at fitting a model cannot disclose the nature of the noise and merely illustrates the feasibility (or lack thereof) of some particular combination of transducer and variance functions.

◆ **Orientation tuned suppression in binocular rivalry reveals general and specific components of rivalry suppression**

S M Stuit, C L E Paffen, D Alais¶ (Helmholtz Institute, Utrecht University, The Netherlands; ¶ School of Psychology, University of Sydney, Australia; e-mail: Seth676@gmail.com)

When different visual stimuli are presented to each eye, a perceptual alternation called binocular rivalry (BR) arises as the conflicting monocular images are alternately suppressed. Although the suppressed image is phenomenally invisible, sensitivity loss is partial: thresholds for monocular contrast probes are raised $\sim 0.3-0.5$ log units relative to when the image is in dominance. Suppression during BR is thought to act uniformly on the whole eye without feature specificity. We tested this using orthogonal rivaling gratings and measuring contrast sensitivity to small grating probes at a range of orientations. Results indicate suppression depth is not uniform across orientation. Suppression increased for orientations close to that of the suppressed grating ($\sim$1 log unit). Interestingly, suppression also deepened for orientations close to the dominant grating. In both cases, the deepening of suppression was specific to a narrow range around the rivaling orientations of about $15-20^{\circ}$, similar to V1 orientation bandwidths. These results suggest two components to rivalry suppression: a nonspecific general component, and an additional component tuned to the rivaling features.

◆ **Protruding apparent 3-D images in depth-fused 3-D visual perception**

H Takada, M Date, S Suyama¶, Y Ohtani (NTT Cyber Space Laboratories, Nippon Telegraph and Telephone Corporation, Japan; ¶ Institute of Technology and Science, The University of Tokushima, Japan; e-mail: takada.hideaki@lab.ntt.co.jp)

We have found apparent 3-D images protrude outside the region of front and rear images in depth-fused 3-D (DFD) visual perception. In DFD visual perception, two images that differ only in luminance displayed at the front and rear planes are perceived as a single image at one depth. We perceived a continuous depth change when the luminance ratio between the two images is continuously changed according to the 3-D image depth. We perceived 3-D images between two image planes. We reported the perception of 3-D images protruding outside the region of the two planes when considering the luminance of the images and the luminance of the surroundings. Front and rear images have opposite signs of luminance difference between the image and the surrounding. When the front-image luminance is darker than the surrounding one, the rear-image luminance is brighter than the surrounding one, and vice versa. This enables a deeper 3-D imaging area in the DFD display.

◆ **Age dynamics of fusion capabilities assessed by means of RDS with markers for objective control of binocular image splitting**

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The measurements commonly used to assess fusion capabilities are based on the subject reports about the moments of the image splitting when the left and right visual stimuli are moving apart. Reliable data could only be obtained if the subjects were attentive and punctual. To improve the procedure, we used interactive software generating cyclopean test stimuli coded by random-dot stereograms and supplied with small markers changing in the course of stimulus movement. RDS provided more precise determination of the breaking points because subjects could not see the cyclopean test object after image splitting. The markers served to control the responses: subjects had to indicate the marker seen just before the image splitting. Fusion capabilities were studied in preschool children, junior school children, and students (> 200 subjects). The largest difference in results was found between preschool and 1st-grade school children. The results for students were not better than those of 2nd-grade children. Variability of data appeared to be minimal in preschool children.

◆ **Visual perception of gloom**
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The paper will outline the program of research that will form the basis for the author's doctoral dissertation. The research will focus on an aspect of the experience of visual environment—gloom—which has not formed part of the previous research in the area of the scientific study of human visual perception. Previous research has demonstrated that gloom is a shared experience and an experience involved negative emotion associated with particularly lighting conditions. One possible area of traditional research on vision could be relevant to gloom concerns adaptation level. Previous research indicated that the experience of gloom occurs when the observer cannot adjust the adaptation level to the overall lighting conditions. The hypothesis will be explored in the research by manipulating the adaptation by various levels through manipulating the ambient lighting conditions. However, adaptation level can be set by the whole visual field; it is also possible that it can be set not by the level lighting intensity in the overall visual field but by the part of the visual field.

CLINICAL ASPECTS

◆ **Subjective visual acuities with simulated and physical defocus**
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To investigate systematically factors that affect psychophysical acuity we have implemented a mathematical Fourier-optical model to simulate refractive errors by degrading the stimuli themselves. In the present study we assessed how well a simplified version of the model simulates lens-induced physical defocus in terms of acuity reduction in normal observers. We obtained acuity values by recording the psychometric function using Landolt C optotypes from seven subjects for refractive errors of 0 D to +8 D defocus both simulated and lens-induced. With large defocus, the acuities were lower with lenses, typically by 40%. The values did not depend on the initial acuity of the individual subjects when wearing their appropriate correction. With small defocus, acuities were often higher with lenses than with the simulation. This appeared to be due to characteristics of the lens-induced acuity reduction. Taken together, results suggest that different factors cause discrepancies between simulated and physical defocus. Despite differences in absolute values, acuities with the present simplified simulation and with lenses showed similar overall characteristics, eg regarding interindividual variability
.[Supported by Deutsche Forschungsgemeinschaft (BA 877.18).]

◆ **Pain relief, cognitive improvement, and EEG normalization after selective regulatory central lateral thalamotomy against chronic neurogenic pain**
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The thalamocortical dysrhythmic process has been proposed at the source of chronic neurogenic pain, and is characterized by an increase of production of thalamic low-threshold calcium spike bursts. These are correlated with increased EEG activities in the cortical pain matrix. We compared the EEG of neurogenic pain patients and healthy controls (HC) with eyes closed and during a working memory (WM) task before, 3 and 12 months after central lateral thalamotomy (CLT). Average power spectra maps during eyes-closed revealed an increase in all frequency bands before surgery as compared to HC. Average spectral power of the patients 12 months post-surgery was similar to that of HC. During WM, patients displayed a reduction of their performance only before treatment as compared to HC. Their power spectra were not different to HC 12 months post-surgery for two workload conditions. LORETA analysis revealed a difference for both groups (contrast low vs high workload) in the precuneus. Our results demonstrate a regulatory effect of the CLT on neurogenic pain processes and cognitive mechanisms.

◆ **Effects of the preceding 'history' of apparent motion on D_{max}**
S Mateeff, M Stefanova¶, J Hohnsbein§ (New Bulgarian University, Sofia, Bulgaria; ¶ Institute of Neurobiology, Bulgarian Academy of Sciences, Sofia, Bulgaria; § Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany; e-mail: smateev@nbu.bg)

The upper limit D_{max} for perceiving the direction of apparent displacement (A-motion) of a random-dot stimulus was measured when the displacement was preceded by another motion of the same dots (R-motion) The R-motion was vertical of 1 deg length; it imitated fairly well smooth, real motion. The A-motion consisted of a stimulus displacement in (i) upwards oblique and (ii) downwards oblique directions, to the left or to the right. Both motions alternated 12 times.

With same directions of the R-motion and the vertical component of the A-motion, D_{max} was lower than with opposite directions. The difference between the D_{max} in the 'same' and 'opposite' conditions significantly decreased with decreasing the speed of the R-motion. It is suggested that when the R-motion is sufficiently fast, it might be perceived as an entity, or as a 'motion event' (Johansson, 1950 *Configurations in Event Perception* (Uppsala: Almqvist and Wikssels). In this case a short-range process may register the displacements of the "events" rather than of the single dots of the stimulus.

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COLOUR AND BRIGHTNESS

◆ **Highest luminance appears white even at lowest illumination levels**

A Gilchrist (Department of Psychology, Rutgers University, Newark, USA; e-mail: alan@psychology.rutgers.edu)

According to anchoring theory, the highest luminance appears white and serves as the anchor, regardless of the illumination level. We tested very dimly lit Mondrians, both full range (black to white) and partial range (4 : 1), using both computer displays and paper displays. The highest luminance values in our first three experiments were 0.89, 0.068, and 0.055 cd m^{-2}, evoking median Munsell matches (by separate groups of ten naive subjects each) of 9.0, 9.0, and 8.5, respectively, clearly in the white zone. In our fourth experiment illumination was reduced to scotopic levels (highest luminance 0.001 cd m^{-2})—no colours could be seen. The highest luminance was seen as Munsell 8.2, still in the white range. When the target first appeared, after several seconds of dark adaptation, it appeared white, if a poor white. The highest luminance rule holds across a vast range of illumination, more than 100 million-to-one. It fails (weakly) only at the very low end.

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◆ **Estimation of individual human cone fundamentals from colour matching functions is as easy as 1-2-3?**

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A method originally proposed by Bongard and Smirnov, of estimating individual cone fundamentals based on individual colour matching functions (CMFs), is susceptible to noise and inaccuracies in the colour matching data. We propose a novel more robust cone estimation method based on dimensionality analysis of the CMFs, which yields five consecutive subintervals in the visual spectrum, in which the number of non-zero fundamental is one, two, three, two, and one. These intervals correspond to the overlapping of the fundamentals. The cone fundamentals are estimated by maximizing the length of a bounded linear combination of CMF's in either a short, medium, or long wavelength subinterval, subject to linear constraints corresponding to positivity of estimate and control of sign of slope and curvature outside the subintervals. Through a quadratic programming solution, estimations in close agreement with established cone fundamentals such as those of Stockman and Sharpe are found. The method was applied to Stiles and Burch ten-degree averaged observer (1959) as well as the ten individual (1955) two-degree observers.

◆ **Simultaneous lightness contrast with non-adjacent luminance ramps and Gelb illumination**

O Daneyko, D Zavagno¶ (Department of Psychology, University of Trieste, Italy; ¶ Department of Psychology, University of Milano-Bicocca, Italy; e-mail: olga.daneyko@gmail.com)

Simultaneous lightness contrast (SLC) has always been a ground of confrontation for lightness theories. Experiments that combine luminance ramps with SLC and Gelb illumination tested the predictions derived from three theoretical backgrounds: contrast theories (CT), the anchoring theory (AT), and illumination-lightness scission theories (ST). Stimuli consisted in standard contrast displays and in contrast displays with four squares forming crosses around the targets but not adjacent to them. The crosses were of three types: black or white (contrasting with the targets' backgrounds), positive luminance ramps (ramps inner-ends equivalent to the targets' backgrounds), negative luminance ramps (ramp inner-end contrast with the targets' backgrounds). Predictions from CT fit the results for SCL+monochromatic crosses; At can account for both standard SLC and SCL+monochromatic crosses; ST can account for positive ramps results. None of the theories can account for negative ramp results. Lightness theories need to address the role played by luminance ramps, which recent literature indicate as important features also for both luminosity and illumination perception.

◆ **Perceiving non-Hering mixtures in neon colour spreading configurations**
E Mingolla, G Livitz, A Yazdanbakhsh¶ (Department of Cognitive and Neural Systems, Boston University, USA; ¶ Department of Cognitive and Neural Systems, Boston University; also Harvard Medical School, Boston, USA; e-mail: ennio@cns.bu.edu)
Perceiving certain hues (eg red and green) as components of a single colour cannot be explained within Hering's opponent theory, still regarded as a cornerstone of our understanding of colour perception. Here we demonstrate that this theory cannot describe some readily perceived colours. While performing threshold detection tasks on the continuum of colours produced by a combined effect of complementary chromatic induction and neon spreading, subjects are asked to set bounds along the continuum on when they first (or no longer) see 'redness' or 'greenness'. The results demonstrate an overlap in red and green perceptual zones along the red – green continuum. In a control stimulus sequence, in the absence of complementary chromatic induction, the red and green perceptual zones are disjoint, consistent with perception of yellow colours with mutually exclusive red and green components. Showing that 'forbidden' hue combinations, previously reported only under artificial image stabilization, can be present in normal viewing conditions opens a new paradigm in the experimental study of the dimensionality and structure of perceptual colour space.
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◆ **Optimal nonlinear signal transmission: a comparison of mutual information and estimation error**
H P Snippe, J H van Hateren¶ (Department of Neurobiophysics, University of Groningen, The Netherlands; ¶ Institute for Mathematics and Computing Science, University of Groningen; also Netherlands Institute for Neuroscience, Royal Netherlands Academy of Arts and Sciences, Amsterdam, The Netherlands; e-mail: h.p.snippe@rug.nl)
Nonlinear signal transmission is ubiquitous in neural systems. Here we study a simple model system, in which a nonlinear transform $g(s)$ of a signal s [with pdf $p(s)$] is perturbed by additive noise n, resulting in a response $r = g(s) + n$. The optimal nonlinearity $g(s)$ depends on the goal of transmission. If the goal is to maximise the mutual information (MI) between the signal s and the response r, one should (at low noise) choose the steepness $\mathrm{d}g/\mathrm{d}s$ of transmission proportional to $p(s)$ (Laughlin, 1981 *Zeitschrift für Naturforschung C* **36** 910 – 912). However, if the goal is to minimise the mean-square error (MSE) of the estimate of s based on the noisy response r, one should (at low noise) choose the steepness $\mathrm{d}g/\mathrm{d}s$ proportional to the cube root of $p(s)$ (von der Twer and MacLeod, 2001 *Network* **12** 395 – 407). Here we show that optimising MI can lead to a strong increase of MSE, and optimising MSE can lead to a strong decrease of MI.

◆ **Uniform statistics yields non-uniform hue distributions**
J J Koenderink (Department Physics of Man, Helmholtz Institute, Utrecht University, The Netherlands; e-mail: j.j.koenderink@phys.uu.nl)
Do random spectra with distributions that are translation invariant with respect to the wavelength domain yield uniform distributions of hues? If not, then hue preferences based on frequencies of occurrence might be due to the structure of the visual system, and need not necessarily be sought in ecological statistics. In order to approach the problem one needs to define suitable generators of random spectra, taking nonlinear constraints (non-negativity of radiant power, finite (0 ... 1) range of spectral reflectance factors) into account. The hue statistics are determined by the nonlinear mapping of spectra on the interior of the colour solid. Spectra that yield vivid colours are necessarily close to Goethe edge colours or Ostwald semichromes. This implies a strong preference for red and blue shades, yellow and cyan tints, and red-yellow and blue-cyan, less so green and magenta hues. An analysis of colours in terms of their white, black and colour content emphasizes red and blue shades, yellow tints, and greenish blue and orange 'full colours'.

◆ **Individual differences in simultaneous contrast**
J M Bosten, J D Mollon (Department of Experimental Psychology, University of Cambridge, UK; e-mail: jmb97@cam.ac.uk)
Individuals differ in the extent to which they experience simultaneous contrast, but could there be a common neural mechanism determining their susceptibility across different stimulus dimensions? We measured the extent of simultaneous contrast on 10 dimensions: orientation, motion, spatial frequency, numerosity, luminance, 3 contrast dimensions and 2 colour dimensions. Each was measured by asymmetric matching: subjects were required to decide, for example, whether a standard patch or one surrounded by an inducing annulus was the redder. One hundred subjects gave consistent settings across two sessions separated by several weeks ($0.383 \leqslant r \leqslant 0.748$, $3.6 \times 10 - 20 \leqslant p \leqslant 0.0001$). We conclude that there are significant differences in the extent to which individuals perceive particular types of contrast. However, there may not be a general neural

mechanism determining susceptibility to contrast: subjects' matches across the different stimulus dimensions did not correlate significantly. Many correlations were very low, eg orientation with spatial frequency ($0.005 \leqslant r \leqslant 0.059$, $0.576 \leqslant p \leqslant 0.962$).

◆ **Modelling chromatic discrimination of chromatically variegated stimuli**
M Giesel, T Hansen, K R Gegenfurtner (Department of Psychology, University of Giessen, Germany; e-mail: martin.giesel@psychol.uni-giessen.de)

We present a chromatic discrimination model with multiple differently tuned higher level chromatic mechanisms. The model input is provided by cone opponent signals. Each mechanism has a half-wave-rectified cosine shaped sensitivity profile centred at a different chromatic direction. To estimate thresholds, the model's responses to a test and a comparison stimulus are determined. The excitation of the mechanisms is computed as the product of each pixel's chromatic amplitude and the sensitivity of the mechanisms to the chromatic direction of the pixel, summed across all pixels. The resulting excitation is then passed through a nonlinear response function. Finally, a detection variable is calculated by subtracting the responses to the two stimuli and a subsequent nonlinear combination of the responses of all mechanisms. The model was fitted to the data presented in Hansen et al, 2008 *Journal of Vision* **8**(1.2) 1 – 19. We found that a model with eight broadly tuned mechanisms provides a good fit to the discrimination thresholds measured for chromatically homogeneous and variegated stimuli.
[Supported by DFG grant Ge 879 5-2.]

◆ **Changes in colour perception due to sunglare protection filters evaluated by Wolter ellipses**
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Sun glasses reduce the power of the incoming light unequally across the spectrum. The impact of this relative reduction of light on colour perception is conventionally evaluated by *Q* factors that describe the attenuation of red, yellow, green, and blue signals (European Standard EN 1836). *Q* factors require complicated measurement and fail to accurately represent the observed distortions in the appearance of natural colours (Palmer et al, 1997 *Color Research and Application* **22** 24 – 31). Based on H Wolter's (1965 *Annalen der Physik* 7. Folge **16** 224 – 234) model of 'normal colours' (metrically represented by ellipses in colour space) an alternative approach of evaluating filter-induced colour changes is developed by transformations of normal colours. Only three parameters (the ellipse's shape, position and tilt in colour space) are sufficient to describe these colour changes. Wolter ellipses allow for easier and more precise prediction than *Q* factors of how a given filter will influence colour vision; it thus is a feasible alternative for comparative colour-quality evaluation of sunglare protection filters.

◆ **Perception and visualisation of the luminous environment in natural scenes**
S C Pont, A Mury, J J Koenderink (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: s.c.pont@phys.uu.nl)

Human observers are quite sensitive to the physical light field (the radiance as a function of location and direction). They generally arrive at close to veridical settings of the local direction, diffuseness, and intensity of the illumination of a matte white sphere at some arbitrary location in a stereoscopically presented scene. These parameters define low-passed structural properties of the light field (Koenderink et al, 2007 *Perception* **36** 1595 – 1610). Such properties change rather smoothly and systematically in natural scenes. We made a unique device that we named 'plenopter' which is designed to measure local light fields up to the second order in terms of spherical harmonics (it has been shown that this allows sufficiently accurate description of the shading of Lambertian surfaces). We demonstrate how plenopter measurement data can be used to derive the global, low-order structure of the light field in a scene and we show how this global structure may be visualized in an intuitive way, for instance by means of 'light tubes'.
[Supported by the Netherlands Organisation for Scientific Research (NWO).]

◆ **Colourful changes to the synesthetic colour experience**
T C W Nijboer, S F te Pas, T Gebuis, M J van der Smagt (Department of Experimental Psychology, Utrecht University, The Netherlands; e-mail: t.c.w.nijboer@uu.nl)

The synesthetic colour experience is often described as a fixed relationship between a grapheme and a colour. We investigated whether the synesthetic experience is indeed hard-coded, or whether it can be altered by surrounding colours (ie colour induction). Fourteen grapheme-colour synesthetes were presented with both a grapheme and a control stimulus that did not induce a

synesthetic colour experience (eg hash, yen). The colour of the control stimulus had to be adjusted to match the synesthetic colour of the grapheme. In the first experiment, the grapheme was presented on a grey background and the control stimulus on a coloured background. This layout of the stimuli was reversed in the second experiment. For both experiments, the distance (in colour space) of the colour given to the control stimulus to the synesthetic colour was calculated. This deviation was comparable to normal colour induction deviations, which means that the perception of synesthetic colours depends on surrounding colours in a way that is similar to normal perception of colours.

◆ **Colour induction effects are modelled by a low-level multiresolution wavelet framework**
X Otazu, M Vanrell, C A Parraga (Centre de Visio per Computador, Universitat Autónoma de Barcelona, Spain; e-mail: xotazu@cvc.uab.es)

Chromatic induction effects depend on the interactions between central stimuli and their surroundings. When the perceived colour of a stimulus shifts towards that of the surroundings, it is called 'chromatic assimilation' and when it shifts the opposite way it is called 'chromatic induction'. Here we present a wavelet-based, multiresolution computational framework to model chromatic induction effects (called the chromatic induction wavelet model or 'CIWaM'). The CIWaM incorporates some low-level attributes of the human visual system (ie separation into colour opponent and luminance channels, chromatic and achromatic contrast sensitivities, and other known non-linearities) and is an extension of our previous achromatic model (2008 *Vision Research* **48** 733 – 751). Like the previous model, the CIWaM is defined by just three general assumptions on the behaviour of the human visual system and does a good job at predicting the results obtained from our psychophysical experiments. The behaviour of the model may provide some useful insights on the properties of chromatic induction processes in humans.

EYE, HAND AND BODY MOVEMENTS

◆ **Time-to-contact estimation during visual self-motion: is second order information used for motion extrapolation?**
A Capelli, M Vidal, A Berthoz (LPPA, CNRS – College de France, Paris, France; e-mail: aurore.capelli@college-de-france.fr)

Previous studies showed that time-to-contact (TTC) estimations for accelerated objects moving towards a target are based on first-order information (Benguigui et al, 2003 *Journal of Experimental Psychology* **29** 1083 – 1101). We designed an experiment in order to assess how velocity variations are taken into account in TTC estimations for self-motion situations towards a target. Participants sat in front of a 190°-curved screen displaying visual motion simulations along a virtual street, according to three velocity profiles (constant, accelerated, and decelerated). After a while, the visual target (a flag) appeared at a certain distance and shortly after, the whole visual scene disappeared. Participants were instructed to extrapolate the motion in the environment and press a button once they believed having reached the target. Results showed an underestimation of TTC for decelerations and an overestimation for accelerations, except when the velocity variation was the strongest. We conclude that during visual self-motion, second order information is used for the TTC estimations only if the velocity variations are large enough.

◆ **Is inhibition in subliminal priming stimulus triggered?**
F Boy, K Clarke, P Sumner (School of Psychology, University of Cardiff, UK; e-mail: boyf@cf.ac.uk)

To explain the reversal in reaction time benefits between straight and reversed subliminal visuomotor priming, most researchers posit the existence of inhibitory processes acting on the initial motor activation by the prime. However they diverge regarding whether this inhibition is self-triggered within the motor system or launched in reaction to the appearance of stimuli that follow the prime (usually the mask). To disentangle these two hypotheses we designed a set of masked-priming experiments in which the mask object could appear before prime presentation and move toward the prime location so that it eventually masks it. In this condition, in which no new stimulus appeared after the prime, a positive priming effect was found. Conversely, in two control experiments in which the mask-object was not displayed before prime presentation, we retrieved the classical negative priming effect. Results are discussed in terms of the role of the mask in triggering inhibition of motor activation generated by subliminal primes.

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◆ **Searching for threat: eye movements during CCTV monitoring**
C J Howard, T Troscianko, I D Gilchrist (Department of Experimental Psychology, University of Bristol, UK; e-mail: Christina.Howard@bris.ac.uk)
Stimulus-dependent salience and goal-based relevance together determine the fixation priority assigned to scene locations (Fecteau and Munoz, 2006 *Trends in Cognitive Science* **10** 382 – 390). Tests of the stimulus-dependent salience component of this process tend to look for regions in the image that are consistently fixated and link this to the underlying image properties. However, when the task is common across participants, consistent fixation location can also indicate that that region has high goal-based relevance. Here we investigate these issues when an observer has a specific, and naturalistic, task: closed-circuit television (CCTV) monitoring. We recorded concurrently eye movements and ratings of perceived threat. We identified periods when threat ratings were consistently high, and when the between-subjects spread of fixation locations was low, as this is the signature of both a common part of the image being assigned a high fixation priority and, at the same time, the scene being threatening. This result provides important constraints on the mechanisms that might be used to train an artificial detection process.

◆ **The effect of shifted visual feedback of the hand on perceived reachability**
D D J de Grave, J B J Smeets, E Brenner (Human Movement Sciences, Research Institute MOVE, Vrije Universiteit Amsterdam, The Netherlands; e-mail: d.degrave@fbw.vu.nl)
The furthest distance that is judged to be reachable increases when subjects are given a tool. In this study we investigated whether judged reachability can be affected by providing visual feedback about the hand that was shifted closer or further from the body. A virtual target cube was presented at various distances and subjects had to judge whether they could reach it. The answer to their judgment was expressed by moving a real cube that they could feel but not see. They saw a simulation of the real cube, which had to be aligned with one of two virtual cubes (positioned in depth) that represented the answer possibilities (yes or no). The simulated cube was either shifted 5 cm in depth away from or closer to the subject. The perceived reachability increased when feedback of the hand was shifted away from the body and decreased when the feedback was shifted closer to the body. We conclude that visual feedback about the position of the hand can influence judged reachability.

◆ **Reaching in the dark: comparing dorsal vs ventral stream control in Williams syndrome and in infants**
E Babinsky, O Braddick, J Atkinson¶ (Department of Experimental Psychology, University of Oxford, UK; ¶ Department of Psychology, University College London, UK; e-mail: erin.babinsky@psy.ox.ac.uk)
When reaching toward an object occluded by darkness, the visual motor system must make use of stored visual information to guide that movement offline. In adults, it has been argued that the visual motor system is no longer able to make use of dorsal stream information when a movement is initiated in darkness and must instead recruit longer lasting ventral stream information (Westwood and Goodale, 2003 *Spatial Vision* **16** 243 – 254). We used an infrared motion tracking system to measure the reach trajectories of normal infants, and children with Williams syndrome (WS), in order to determine whether the decay or absence of current visual information in darkness produces characteristic signatures of dorsal and ventral stream control in reaching movements. Kinematic analysis reveals that both 9- and 13-month-old infants show significant changes in reaching behaviour when visual feedback is removed. Analysis of WS children shows no effective change in movement kinematics when reaching offline vs online.
[Supported by Williams Syndrome Foundation, MRC grant G0601007.]

◆ **One eye or two? Determining gaze direction in the horizontal and vertical plane**
K M Adams, B Redmill¶, P A Goddard (Department of Psychology, University of Lincoln, UK; ¶ Lincoln County Hospital, Lincoln, UK; e-mail: kaadams@lincoln.ac.uk)
Human observers are extremely accurate at determining the gaze direction of another person. The investigations reported here aimed to clarify discrepant data on whether gaze direction is easier to detect in the horizontal (Cline, 1967 *American Journal of Psychology* **80** 41 – 50) or vertical plane (Anstis et al, 1969 *American Journal of Psychology* **82** 474 – 489) and in monocular or binocular conditions (Symons et al, 2004 *Infant Behavior and Development* **21** 531 – 536). Observers viewed photographs of a looker and it was found that vertical eye movements were easier to determine than horizontal eye movements (thresholds 0.467 and 1.064 min of arc, respectively); in addition there was no difference between binocular and monocular thresholds (0.747 and 0.784 min of arc, respectively). These findings support Anstis et al's (1969) claim that vertical eye movements are easier to determine, furthermore they challenge Symons et al (2004) because presentation of both eyes is not needed to accurately determine gaze direction.

◆ **Switching between visuomotor mappings: learning absolute mappings or relative shifts?**
L C J van Dam, D J Hawellek, M O Ernst (Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: loes.van.dam@tuebingen.mpg.de)
Adaptation to specific visuomotor conflicts becomes faster with repetition. What is learned when repeatedly switching between different visuomotor mappings: the absolute mappings or the relative shift between the mappings? To test this, we trained participants in a rapid pointing task using a unique colour cue for each mapping between pointing location and visual feedback. After extensive training, participants adapted to a new mapping using a neutral cue. For catch trials (a change in cue and no visual feedback) different adaptation performances are predicted depending on how the mappings are encoded. When encoding an absolute mapping for each cue, participants would fall back to the mapping associated with the cue irrespective of the mapping prior to the cue switch. In contrast, for the cue switch, when a shift in mapping is encoded, pointing performance will shift relative to the mapping prior to cue switch by an amount equal to the difference between the previously learned mappings. Results indicate that the cues signal absolute visuomotor mappings rather than relative shifts between mappings.
[Supported by the Human Frontiers Science Program.]

◆ **Auditory footsteps affect visual biological motion orientation detection**
C Mendonça, J A Santos (Instituto Educação e Psicologia, Universidade do Minho, Portugal; e-mail: mendonca.catarina@gmail.com)
This study investigated audiovisual interaction in the perception of the direction of biological motion using point-light walkers (PLW). It continues the work of Vanrie and colleagues (Vanrie et al, 2004 *Perception* **33** 547 – 560) about the bistable character and the perceptual bias of PLW, which has shown that ambiguous PLW are preferably interpreted as being oriented towards the viewer. Each participant made judgements about the direction of a PLW's motion in three conditions: visual, audiovisual, and auditory. It was found that the auditory footsteps simultaneous and congruent with the visual representations diminished, but did not eliminate, the visual bias. The reaction times reveal a strong bimodal facilitation effect, even when both stimuli could be interpreted as incongruent.

◆ **Expression discrimination: faster and more sensitive with saccadic eye movements?**
R Bannerman, M Milders, A Sahraie (Vision Research Laboratories, School of Psychology, University of Aberdeen, UK; e-mail: r.bannerman@abdn.ac.uk)
When two images are flashed simultaneously in the left and right visual fields, humans can saccade towards a face target with a mean RT of approximately 140 ms [Thorpe et al, 2007 *Journal of Vision* **7**(9) 30a]. Previously we showed that brief (20 ms) bilateral presentation of emotional/neutral face pairs leads to a shorter discrimination (262 ms vs 355 ms) of emotional stimuli in saccadic localization task (Bannerman et al, 2007 *Perception* **36** Supplement, 34). When manual discrimination reaction times were employed, no emotional effect was observed. Here, we extend these findings by manipulating the quality of visual information by changing the stimulus duration (20 ms vs 500 ms). Results showed faster saccadic discrimination of emotional stimuli at both durations. However, for manual responses, faster discrimination of emotional stimuli was observed only at the longest duration (500 ms). The findings suggest that over time the quality of information about a visual display changes and that eye movements access this information earlier and in doing so show greater sensitivity for emotional stimuli.

◆ **Discussion on anticipated velocity slowdown of occluded object and eye movement**
M Takeichi, K Fujita¶, H Tanaka¶ (Faculty of Political Science and Economic, Kokushikan University, Japan; ¶ Institute of Symbiotic Science and Technology, Tokyo University of Agriculture and Technology, Japan; e-mail: takeichi@kokushikan.ac.jp)
It was reported in ECVP 2005 that the anticipated velocity of a moving object after occlusion is much less than the actual velocity. The eye movement velocity after occlusion in the anticipation task was also much slower than actual velocity as reported in ECVP 2007. This suggests that representational velocity slowdown occurs after the occlusion, as Steinbach reported that an eye movement reflects representational velocity. However, it was unclear whether the eye movement velocity slowdown causes anticipated velocity slowdown or eye movement slowdown simply reflects the representational velocity slowdown. In this study, the position-anticipation tasks in fixed-gaze and free-target tracking conditions were carried out. The anticipated velocities were 3.8 deg s^{-1} and 3.9 deg s^{-1}, respectively, and approximately 50% of the actual velocity (8.3 deg s^{-1}). The coincidence of the two velocities suggest that the eye movement velocity slowdown is not the cause but the result of the representational velocity slowdown.

This indirectly supports that the representational velocity slowdown being caused by the occlusion itself.
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◆ **Biomechanics, rather than visual information, determines finger placement in grasping spheres**
W D Schot, E Brenner, J B J Smeets (Research Institute MOVE, Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands; e-mail: w.schot@fbw.vu.nl)

When grasping an object, a person has to determine how the thumb and index finger should be placed to ensure that the opposing grip forces produce a stable grip (opposition axis). Which opposition axis is selected depends on the object's position in the workspace. Paulignan et al (1997 *Experimental Brain Research* **114** 226 – 234) proposed that grasping points were chosen that maintained the final posture of the forearm. However, they positioned their stimuli along a circle centred on the subject's head, so an invariant forearm posture coincided with invariant vision of the digits' paths towards the contact points. Therefore, it remained unclear whether final forearm posture or visual information was critical. In the present study, subjects made reach-to-grasp movements towards a marble that was at 1 of 27 positions on a 3×7 grid, starting at one of two positions. Results showed that subjects maintained an invariant posture of the forearm, rather than maintaining visual information. We conclude that grasping points are primarily selected for biomechanical reasons.

MOTION PERCEPTION AND TEMPORAL ISSUES

◆ **A local least squares estimate of the intersection of constraint global velocity**
A Johnston (Experimental Psychology, University College London, UK; e-mail: a.johnston@ucl.ac.uk)

Estimating 2-D motion is thought to be a two-stage process. First, the local velocity normal to contours is extracted. At the second stage, calculating the intersection of the set of possible velocities given two local estimates (intersection of constraints; IOC), the vector sum and the vector average have all been considered. Dense arrays of randomly oriented Gabor patches with speeds chosen to conform to a single global translation can appear to move with the correct global velocity although the vector sum speed is too large, the vector average speed too low, and no identifiable feature provides a reliable signal. Spatial pooling of image gradient components prior to velocity estimation (Weiss et al, 2002 *Nature Neuroscience* **5** 598 – 604) can also be effective, but this strategy does not allow segregation and grouping of local information consistent with more than one object within the integration zone. Here a simple, biologically plausible, least squares IOC strategy is offered that combines local estimates of velocity only if the error of the estimate is small.
[Supported by BBSRC and NTT]

◆ **Is visible persistence responsible for the flash-lag effect?**
A Gauch, D Kerzel (Department of Psychology, University of Geneva, Switzerland; e-mail: angelique.gauch@pse.unige.ch)

A stationary flash is perceived to lag a moving object that is physically aligned. A simple account for the misalignment (which has been rejected prematurely) goes as follows: The moving object has shorter visible persistence than the flash because of motion deblurring. If the offset of the flash, rather than its onset, is matched to the position of the moving object, a misalignment would result. However, one previous study has demonstrated that the flash-lag effect does not decrease when the offset phase of the flash was excluded. In our experiment, a moving bar was compared to a flash or to the onset position of a stationary bar that remained visible until the end of the trial. In accordance with an explanation in terms of visible persistence, we found the flash-lag effect to be reduced with onset-only stimuli. Additionally, we evaluated the contribution of participants' strategies (focus onset vs focus offset). Another experiment confirmed that the position of the moving object was indeed perceived without any blur.

◆ **Low-level motion as a cue to speaker identification in point-light displays of interpersonal conversation**
D Rose, T J Clarke, D T Field¶ (Department of Psychology, University of Surrey, Guildford, UK; ¶ Department of Psychology, University of Reading, UK; e-mail: d.rose@surrey.ac.uk)

Observers can identify which of two people is speaking during a conversation, even when the only cues are movements of point-lights attached to each person's body, and no auditory or facial cues are available (Rose and Clarke, 2007 *Perception* **36** Supplement, 76). This ability however varies with the emotional state of the speakers: for example identification is accurate when they are angry but not when they are afraid. Debate exists as to whether point-light displays of human

movement are comprehended on the basis of low-level motion cues or by their fit with high-level form templates. Here, we tested the first hypothesis by summing the total amount of movement across all 13 points on each person's body, calculating the ratio between the two, and correlating with the accuracy of speaker identification, as assessed across five different emotional states. The correlation was positive ($r = 0.86$, $p < 0.05$), thus supporting the hypothesis that observers implicitly assume that speakers move more than listeners.

◆ **Motion streaks cause spatial-frequency and orientation-tuned threshold elevation for static patterns**

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Neural temporal integration should cause fast-moving objects to leave 'streaks' parallel to the motion trajectory [Geisler, 1999 *Nature* **400**(6739) 65 – 69]. Although streaks are not perceived, they may still activate orientation units. We test this using fast-drifting Gaussian blob arrays as adapters and measuring contrast threshold elevation for static grating test patterns oriented parallel or orthogonal to the streaks. For fast motion (12.5 deg s^{-1}), threshold elevation was up to 3 times preadapted levels, and was spatial-frequency and orientation-tuned around the streak orientation. These effects were absent for orthogonal test patterns, and for slow adapters (2 deg s^{-1}) below the critical 'streak' speed (1 dot width per 100 ms). Threshold elevation showed spatial tuning, declining to baseline at ± 1.5 octaves. Orientation tuning was broader, declining to baseline at 35 deg from streak orientation. These results demonstrate that even though motion streaks are not perceived, they do produce strong orientation-specific aftereffects on static test patterns that are consistent with properties of orientation units in primary visual cortex.

◆ **Debility in higher level motion detection in Parkinson's disease: a clue for attentional rigidity?**

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First-order motion consists of moving luminance-defined attributes. Second-order motion, on the other hand, consists of moving patterns whose motion attributes are not luminance-defined. The detection of first and second-order motion is thought to be mediated by different mechanisms. Here, we compare the ability of Parkinson disease patients (PDPs) to detect first-order/second-order motion with normal subjects. Subjects had to discriminate the drift direction of first-order motion (luminance-modulated noise) and a novel second-order motion pattern (named as noised base motion) over a range of stimulus speeds and strength. The results show that although acuity of first-order motion detection in PDPs is almost the same as in normal subjects, but this is not the case for second-order motion detection. Regarding the lack of some certain neurotransmitters in PDPs, our results unveil some of the underlying mechanisms of the motion detection hierarchy. As some researchers have proposed, the tracking function of attention constitutes the high-level motion system. We propose that the deficit in PDPs motion detection system may indicate attentional deficit, which we chose to call 'attentional rigidity'.

◆ **Characterization of flickering-flanker induced blindness phenomenon**

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Flickering flankers around a static central target causes the subjective disappearance of the target (Kawabe and Miura, 2007 *Vision Research* **47** 913 – 918). We characterized various aspects of this phenomenon to determine the underlying mechanisms. Experiment 1 showed that the target disappeared for longer durations with increasing flanker frequency, which reached an asymptote at around 8 Hz. Target size, relative to flankers, had little effect on disappearance with two exceptions: disappearance was not observed as much when the flanker/target ratio was more than 1 or less than 0.5. Flankers with same polarity as the target induced stronger disappearance than those with opposite polarity. Targets with low luminance contrast, relative to the background, disappeared for longer durations than those with higher contrasts. Finally, there was no difference in the duration of disappearance when temporal coherence between groups of flankers was modulated. Taken together, these findings suggest that flickering-flanker induced blindness is a low level visual phenomenon, probably due to inhibition of the target induced in low spatial frequency channels.

◆ **An objective evaluation of temporal instabilities in amblyopic perception**
A Iftime, A Thiel¶, R Sireteanu§ (Department of Biophysics, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania; ¶ Department of Biological Psychology, Institute for Psychology, J.W. Goethe University, Frankfurt am Main, Germany; § Department of Neurophysiology, Max Planck Institute for Brain Research, Frankfurt am Main, Germany; e-mail: iftime@adius.ro)
The purpose of this study is to give a quantitative assessment of the temporal visual misperceptions in human amblyopia. Twenty-two subjects with strabismic, anisometropic, or mixed amblyopia were asked to describe their subjective percept of static geometrical patterns with different spatial frequencies and shapes, as seen with the amblyopic eye. On the basis of their descriptions, we generated digital movies that were validated by the subjects, using their fellow eye. We estimated the amount of relative distortions between frames using a Shannon entropy computing algorithm. In this way we could measure the perception variation over a given period of time. We found that nineteen of the twenty-two subjects perceived temporal distortions. In the majority of cases, the frequencies of the perceived temporal instabilities were below 2 Hz. The static stimuli with higher spatial frequencies yielded more frequently temporally unstable perceptions. In conclusions we suggest that occurrence and amount of temporal instabilities in amblyopic vision is correlated with the spatial frequency of the perceived stimulus and we intend to investigate their relationship with etiology and depth of amblyopia.
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◆ **Compensation for smooth pursuit eye movements in expanding, contracting, and rotating optic flow**
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Viewing expanding optic flow while tracking a moving target results in a retinal pattern of expansion with a focus that is displaced in the direction of the pursuit eye movement. This displacement results from the addition of retinal slip (due to the pursuit velocity) to the instantaneous flow field. To an observer, the focus appears somewhere between the physical and the retinal location, suggesting a compensation for the visual effects of pursuit velocity on the flow field. Here, we investigate compensation in other types of flow. In addition to expansion, we used contracting and rotating flow. This revealed a novel component of shift that did not depend on the pursuit velocity per se, but rather on the overall change in gaze direction. Interestingly, compensation appears to be more complete for the novel component of displacement than for the classic (pursuit-velocity-dependent) component. Correcting for the novel component showed that the compensation for the classic component of displacement was of similar magnitude in expanding, contracting, and rotating flow.

◆ **The crossmodal effect in time perception**
K M Chen, S L Yeh (Department of Psychology, National Taiwan University, Republic of China; e-mail: kmchen@ntu.edu.tw)
In daily life people often judge the duration of a visual or auditory event, and yet it remains unknown whether this duration judgment is affected by signals from the other modality. We used an oddball paradigm to examine the effect of sound on the visual-duration judgment and that of visual object on the auditory-duration judgment. In a series of standards and oddballs, the observers compared the durations of oddballs to that of the standards. Results indicated that a sound expanded the perceived visual duration but a visual object did not affect the perceived auditory duration (Experiment 1). Quantitative measures using a crossmodal index confirmed this asymmetrical effect (Experiment 2). The possible mechanisms (arousal or attention) proposed in the scalar expectancy theory (Gibbon et al, 1984 *Annals of the New York Academy of Sciences* **423** 52 – 77) were examined using different standard durations, and the attention mechanism was supported (Experiment 3). We conclude that audition dominates vision for the crossmodal effect in time perception.
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◆ **Motion direction biases in retinotopic cortex**
M Raemaekers, M J M Lankheet, R J A van Wezel (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: M.A.H.L.L.Raemaekers@uu.nl)
Several functional magnetic resonance imaging (fMRI) studies have shown that perceiving different motion directions results in changes in the blood oxygenation level dependent signal (BOLD) response in retinotopic cortex. However, no fMRI study has yet systematically investigated the

nature of these motion direction biases. We used a translating random dot pattern that slowly rotated its motion direction 360° in cycles of 54 seconds. In addition, we performed a polar and eccentricity retinotopic mapping task. This allowed us to measure the BOLD response for different parts of the visual field for all motion directions. We found that the BOLD response was enhanced for motion both towards and away from the fovea, relative to the other motion directions. The enhancement was largest for motion towards the fovea. These results are consistent with enhanced activation for expanding and contracting optic flow. Surprisingly, this enhancement is largest for contraction.

◆ **MEG response to visual social interaction through motion**
M Pavlova, M Guerreschi¶, W Lutzenberger§, A N Sokolov#, I Krägeloh-Mann (Children's Hospital, University of Tübingen Medical School, Germany; ¶ Departement of General Psychology, University of Padua, Italy; § Institute of Medical Psychology and Behavioural Neurobiology, MEG-Centre, University of Tübingen, Germany; # Department of Pathophysiology of Vision and Neuroophtalmology, Eye Hospital, University of Tübingen Medical School, Germany; e-mail: marina.pavlova@uni-tuebingen.de)
Veridical perception of social interaction through motion depends on intact communication between brain regions. Imaging and lesional data point to several brain regions involved in visual perception of social interaction (Pavlova, 2008 *Journal of Cognitive Neuroscience* **20** 494 – 504). However, temporal interrelations between regions are unknown. Here we assess induced gamma oscillatory MEG response to visual social interaction of two abstract geometric shapes revealed through their motion in Heider-and-Simmel-like animations. In healthy adults, enhanced peak of gamma activity (62 Hz) was observed over the right temporo-parietal junctions. Two further enhancements in gamma oscillatory response of lower frequency of 44 HZ occurred over the prefrontal and posterior temporal cortex in the right hemisphere. Consequent peaks of 44 Hz were found over the left temporo-parietal and right temporal cortices. The findings uncover the cortical network involved in visual processing of social interaction through motion. For the first time, the data show that gamma oscillatory cortical activity underlies visual processing of social interaction.
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◆ **Vestibular stimulation causes underestimation of visual velocity**
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We investigated the vestibular contribution to the phenomenon that object motion is underestimated during ego-motion (eg Pavard and Berthoz, 1977 *Perception* **6** 529 – 540; Wertheim and Reymond, 2007 *Experimental Brain Research* **180** 569 – 576). Subjects were placed inside a high-performance car driving simulator, equipped with a semicircular screen (150° field of view) and a 7×7 m moving base. Subjects viewed a large tunnel structure projected for 1 s, moving towards them at 0, 1, or 2 m s^{-1}. Subjects were then accelerated linearly (at 0, 0.5, or 1 m s^{-2}), while the tunnel was presented again. Subjects matched perceived tunnel velocity during that second presentation to perceived tunnel velocity in the first presentation. The results showed a strong underestimation of tunnel velocity that increases with the amplitude of ego-acceleration. This result confirms the existence of nonlinear processing of visual and vestibular cues in self-motion perception.
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◆ **Perception of biological motion in individuals with autism spectrum disorder**
P Murphy, N Brady, N F Troje¶ (School of Psychology, University College Dublin, Ireland; ¶ Department of Psychology and School of Computing, Queen's University, Kingston, Canada; e-mail: padraigmurchu@gmail.com)
The question of whether individuals with autism spectrum disorder (ASD) are impaired in the perception of biological motion is as yet unresolved. Here adults with high-functioning autism and neurotypical controls judged the direction of motion of a normal or spatially scrambled point-light walker which, on each trial, walked from the centre of the screen either leftward or rightward at $\sim$3 deg s^{-1} in a strip of scrambled walker noise of variable density. The walker appeared with variable onset time between 0 and 500 ms after the noise onset. While the ASD group showed slower reaction times and more errors in judging the direction of motion, their performance was otherwise comparable to controls; specifically, they showed superior performance for normal over scrambled walkers, for delayed over immediate onset, and they showed comparable increases in reaction time and error with noise density. Finally, error rates differed on left and rightward trials, an effect which distinguished ASD and control performance: this is discussed with reference to hemispheric asymmetry in local and global processing.

◆ **Detection of direction of biological motion in domestic chicks is affected by lateralisation caused by in-ovo light exposure of chicks' embryos**
R Rugani, L Regolin, G Vallortigara¶ (Department of General Psychology, University of Padua, Padua, Italy; ¶ Center for Mind/Brain Sciences, University of Trento, Rovereto, Italy; e-mail: rosa.rugani@unipd.it)
Naive chicks preferentially approach biological (a Johansson's point-light walking hen) rather than nonbiological (random or rigid) motion displays (Vallortigara et al, 2005 *PLoS Biology*). Visually-inexperienced light-incubated chicks are spontaneously sensitive to the dynamic relations specified by the kinematics of the motion of the point-light walking hen (Vallortigara and Regolin, 2006 *Current Biology*). Chicks oriented themselves in the same direction of the walking hen only when the display was presented upright, suggesting that the interpretation of biological motion is constrained by a gravity bias which does not require any learning. We found that dark-incubated (not lateralised, as light exposure of the embryo modulates brain asymmetry in this species) chicks ($N = 309$) also showed sensitivity to the direction of motion of the biological motion stimulus. However, differently from light-incubated chicks, they oriented their bodies in the opposite direction with respect to the upright stimulus' walking direction ($t_{160} = 3.981$; $p < 0.001$) as if facing rather than following the walking hen. Similarly to light-incubated chicks, dark-incubated chicks did not respond to the upside-down display ($t_{147} = 0.074$;$p = 0.941$).

◆ **Sensitivity and perceptual awareness increase with practice in metacontrast masking**
C M Schwiedrzik, W Singer, L Melloni (Max Planck Institute for Brain Research, Frankfurt am Main, Germany; e-mail: schwiedrzik@mpih-frankfurt.mpg.de)
Can practice effects on unconscious stimuli lead to awareness? Can we learn to see? Recent evidence suggests that blindsight patients trained for an extensive period of time can learn to discriminate stimuli that they cannot consciously perceive. It is unknown whether this effect generalizes to normal observers and whether an increase in discriminability is accompanied by higher conscious reportability. In this study we investigated practice effects in metacontrast masking. Perceptibility thresholds were assessed individually. Subjects were trained for five consecutive days on the stimulus onset asynchrony (SOA) that resulted in chance performance. Our results show a linear increase in sensitivity (d') but no change in criterion (c) for the trained SOA. This practice effect on sensitivity spreads to all tested SOAs. Additionally, we show that subjects rate their perceptual awareness of the target stimuli differently before and after training, exhibiting not only an increase in sensitivity, but also in the subjective quality of the percept. Thus, subjects can indeed learn to see.

◆ **Effects of crossmodal information on representational momentum and representational gravity**
T L Hubbard, J R Courtney (Department of Psychology, Texas Christian University, Fort Worth, USA; e-mail: t.hubbard@tcu.edu)
Whether representational momentum or representational gravity (ie, displacement in remembered location in the direction of target motion or gravitational attraction, respectively; Hubbard, 2005 *Psychonomic Bulletin & Review* **12** 822 – 851) in one modality could be influenced by a second modality was examined. In Experiment 1, targets consisted of ascending or descending visual stimuli paired with ascending or descending auditory pitches. Visual and auditory motion were congruent (both ascending, both descending) or incongruent (one ascending, one descending), and final visual location or final auditory pitch was probed. Congruency resulted in larger forward displacement for auditory pitches, but did not influence forward displacement for visual stimuli. In Experiment 2, horizontally moving visual stimuli were paired with ascending, descending, or no auditory pitches. Visual stimuli paired with descending or no auditory pitches were displaced downward, and downward displacement was larger for visual stimuli paired with descending pitches than for visual stimuli paired with ascending pitches. Effects of crossmodal information on displacement suggest representational momentum and representational gravity reflect high-level processing.

◆ **The effect of repetition on subjective duration at brief timescales**
V Pariyadath, D M Eagleman¶ (Department of Neuroscience, Baylor College of Medicine, USA; ¶ Department of Neuroscience and Department of Psychiatry, Baylor College of Medicine, Houston, USA; e-mail: vanip@cpu.bcm.edu)
Events that are repeated are sometimes perceived to last shorter in duration than novel events of equal length. We hypothesize that these subjective duration distortions are a consequence of differential neural responses to repeated and novel stimuli. Generally, the neural response to a stimulus diminishes with repeated presentation, an effect known as repetition suppression. We have leveraged these findings to develop a new psychophysical paradigm. When a single letter of

the alphabet was serially flashed onto different locations on the screen, several letters appeared to be present on the screen simultaneously due to persistence of vision. Participants' estimates of how many letters they perceived on the screen at any instant of time were significantly lower when the same letter was flashed repeatedly than when different letters were used for each flash. This result suggests that visual persistence is briefer for repeated than for novel stimuli. fMRI experiments are under way in our laboratory to further test the relationship between neural activity and perceived duration using this novel paradigm.

OBJECTS, FACES AND SHAPES

◆ **Helmholtz's checkerboard reviewed**
A H J Oomes, J J Koenderink, A J van Doorn¶, H de Ridder¶ (Men – Machine Interaction Group [¶ Industrial Design Engineering], Delft University of Technology, The Netherlands; e-mail: a.h.j.oomes@tudelft.nl)

What are the uncurved lines in the visual field? To answer this question Helmholtz devised his famous checkerboard pattern with pincushion distortion that he claimed looked perfectly regular while viewed monocularly at close range. So far, there is little more than anecdotal evidence of this effect. We tested twenty observers that could adjust the curvature of a checkerboard from barrel-shaped to pincushion-shaped. Their task was to adjust the curvature of the edges of the checks so that the checkerboard looked regular. In one condition they were asked to fixate the centre of the pattern, while in another they were encouraged to let their gaze wander. We find that in most cases observers indeed perceive a pattern with pincushion distortion as undeformed. They set a more strongly curved pattern in the fixation condition than in the free viewing condition, as also described by Helmholtz. Interestingly, the effect is about half as strong as Helmholtz predicted.

◆ **Different Gabor representations for face recognition by probabilistic neural networks**
M A Amin, H Yan (Department of Electronic Engineering, City University of Hong Kong, China; e-mail: ashramin@student.cityu.edu.hk)

The conventional Gabor wavelet representation [Liu, 2002 *IEEE TIP* **11**(4) 467 – 476] takes longer time to extract features from a facial image. We propose some other representations and show that the summed representation can identify human faces with more then 95% accuracy while classification is performed by probabilistic neural networks (PNN) and is 40 times faster than the conventional Gabor feature representation. Moreover, we also show that if features are extracted only by single scale and single orientation, then larger scales for instance, $n = 4$ and smaller orientations such as $m = 0$ can identify faces with about 90% accuracy. This research is motivated from the approaches taken by the behavioural scientists to study the aspects of face recognition by human, regarding special frequency (Ruiz-Sole and Beltran, 2006 *Psychological Research* **70** 273 – 292).

◆ **Seeing, tying, and untying knots**
B F M Marino, R Actis-Grosso¶, A Uras¶ (LAPCO, Università Vita-Salute San Raffaele, Milan, Italy; ¶ Dipartimento di Psicologia, Università di Milano-Bicocca, Italy; e-mail: barbara.marino@unimib.it)

We aimed at testing whether implicit motor knowledge facilitates visual recognition of 'closed flat knots' (CFK, Massironi and Bressanelli, 2002 *Acta Psychologica* **110** 35 – 61). In Experiment 1, right-handed participants were presented (Group 1) with an image of a right CFK (RCFK, a knot typically tied by right-handers), and Group 2 with that of a left CFK (LCFK, the mirror image of RCFK). Response frequencies were significantly different: RCFKs were recognized as such more frequently than LCFKs. In Experiment 2, we measured both reaction times and accuracy in recognizing the feasibility of a CFK. To this end we used a 2 (feasibility) × 2 (knot laterality) × 4 (knot orientation) × 2 (response-hand) × 16 (repetitions) crossed factors design. A significant interaction of Knot Laterality by Orientation was found. Overall, our findings suggest that to recognize the image of a CFK as such we rely on the action we make to tie it, whereas to recognize CFK feasibilty we rely on the action we make to untie it.

◆ **Lateralization of spatial relation processing: an fMRI study**
I J M van der Ham, R J A van Wezel¶, A Oleksiak¶, A Postma (Experimental Psychology [¶ Functional Neurobiology], Helmholtz Institute, Utrecht University, The Netherlands; e-mail: c.j.m.vanderham@uu.nl)

Spatial relations between objects can be represented either coordinately or categorically. The metric, coordinate representation is strongly associated with right parietal cortex activity, while the abstract, qualitative categorical representation has shown to have a somewhat weaker relationship with the left parietal cortex (Trojano et al, 2002 *Neuropsychologia* **40** 1666 – 1674).

This hypothesised lateralization effect has been examined thoroughly over the years, but mainly in behavioural experiments. Our functional magnetic resonance imaging (fMRI) experiment will provide a closer examination of this effect within a working memory paradigm. A visual half field task in a match-to-sample format was conducted to examine these lateralization effects with either a short (500 ms) or a long (2000 ms) interval between two stimuli, with either a categorical or a coordinate instruction. In the behavioural data, the hypothesized hemispheric specialization was found, but only for the short interval condition, suggesting that lateralization of spatial relation processing is time dependent. fMRI data will provide further insights in the neural correlates of the categorical and coordinate spatial mechanisms.

◆ **The effect of spatial frequency filtering and negation on age perception**

W H Jung, S Park¶ (Department of Psychology [¶ College of Social Science], Chungbuk National University, Chongju, Korea; e-mail: com4man@gmail.com)

This study examined how spatial frequency filtering and negation affect age perception. Sixteen undergraduate students were instructed to estimate the age of 50 pictures of female faces with age ranging from their twenties to sixties. Results showed that spatial frequency filtering affected age perception more than negation. Participants substantially underestimated the age of spatial-frequency filtered pictures of older faces (fifties and sixties) whereas they overestimated the actual age of negated pictures with younger faces (twenties and thirties). These results support Kemp et al's findings (1996 *Perception* **25** 37 – 52), who commented on the difficulty of recognizing faces presented in photographic negatives due to lack of shape-from-shading cues.

◆ **Towards a psychophysics of art perception**

M D Augustin, M Schild¶, C Gross¶, C C Carbon¶ (Department of Neurology, Campus Benjamin Franklin, Charité-University of Medicine Berlin, Germany; ¶ Faculty of Psychology, University of Vienna, Austria; e-mail: dorothee.augustin@charite.de)

Both style-related and content-related information have recently been shown to be relevant at early stages of art perception (Augustin et al, in press *Acta Psychologica*). Yet, little is known about their psychophysical bases, especially in the case of style. Starting from art historical considerations suggesting aspects of colour, brushstroke and treatment of space as major determinants of style, we systematically manipulated paintings according to ten levels of saturation, high-pass and low-pass filtering, and contrast, respectively. Participants judged the similarity of each manipulated picture to its original version in terms of (a) general similarity, (b) style-related similarity, and (c) content-related similarity. General and style-related similarity were more affected by the manipulations than content-related similarity, with style-related similarity being most sensitive to high-pass filtering. Moreover, contrary to saturation and contrast effects, the effects of spatial frequency manipulations differentiated between different artists. Thus, spatial frequency information seems to be a central source of stylistic information. The present experimental approach is intended as a first step towards systematic psychophysical research on art perception.

◆ **What role for gamma oscillations in the perception of ambiguous figures?**

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Several authors suggest that stable conscious object perception results from synchronous gamma oscillations in distributed brain areas. Ambiguous figures allow temporally stable percepts only, thus represent a suitable test case. We recorded EEG while participants indicated endogenous perceptual reversals between successively presented Necker cubes and between successive unambiguous stimulus variants. The hypothesis above suggests that stable percepts should come with sustained EEG activity in the gamma frequency range. Further, gamma power should decrease slowly before endogenous reversals, and collapse suddenly with exogenous ones. Gamma onset after reversals should occur later with ambiguous than with unambiguous stimuli. We found transient gamma modulation 200 ms after endogenous, and 50 ms earlier after exogenously-induced reversals. Periods of stable percepts were associated with sustained reduction of beta power rather than sustained gamma activity. Our results suggest that gamma activity potentially plays a role in integration of distributed object related neural activity (binding). However, sustained gamma activity is not necessary for stable object representation. Further, gamma modulation is not specific to endogenous perceptual changes.

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◆ **Topmost parts are more important when judging whether a composite object will fall**
F Samuel, D Kerzel (Psychology Section, FPSE, University of Geneva, Switzerland; e-mail: Francoise.Samuel@pse.unige.ch)

Do subjective equilibrium judgments correspond in an unbiased way to physical reality? In a forced choice task, observers had to judge whether a composite object would stay upright or fall sidewards. The objects consisted of three vertically abutting squares. We varied the size ratio of the squares as well as their relative position. The combination of the two variables determines whether an object falls or stays upright. Our results show two consistent biases. First, the subjective transition from 'stay upright' to 'fall' occurred before the object would have lost balance according to physical laws. Second, the transition occurred even earlier when the uppermost square suggested that the object would fall. For the same proximity to physical equilibrium, variation of the centre square affected judgments far less. Thus, observers give a higher weight to what happens at the top of an elongated object. Both biases seem adaptive for a safe interaction with the environment.

◆ **Rapid category-specific cortical activation revealed by stimulus inversion**
H K M Meeren, N Hadjikhani¶, S P Ahlfors¶, M S Hämäläinen¶, B de Gelder (Cognitive and Affective Neuroscience, Tilburg University, The Netherlands; ¶ Athinoula A. Martinos Center for Biomedical Imaging, MGH/MIT/Harvard Medical School, Boston, USA; e-mail: hanneke.meeren@uvt.nl)

There is a growing body of evidence that complex visual analysis may already start within the first 100 ms after stimulus onset. The neural basis of this proposed rapid initial stage of high-level analysis is poorly understood. We examined the cortical distribution of early category-specific processing within the first 100 milliseconds. To avoid low-level visual confounds we compared the inversion effect (IE)—ie differential responses between upright and upside-down presented images—of three stimulus categories. We used magnetoencephalography to monitor brain activity with millisecond-resolution while subjects performed an orientation task on photographs of faces, bodies, and houses. Significant IEs for all stimulus categories were found within the first 100-ms after stimulus onset with a highly category-specific cortical distribution. The face IE was found in face-selective areas of the inferior occipital cortex and right fusiform gyrus. In addition, early category-specific IEs were found well beyond visual areas. This suggests that category-specific processing in high-level visual and non-visual cortical areas already starts within the first 100-ms of visual processing.
[Supported by the National Institute of Health and the Netherlands Organization for Scientific Research.]

◆ **Categorical perception of male and female faces and the single-route hypothesis**
R Armann, I Bülthoff (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: regine.armann@tuebingen.mpg.de)

Categorical perception (CP) has been demonstrated for face identity and facial expression, while conflicting results have been reported for sex. Furthermore, the question whether processing of sex and identity information is linked remains open. Based on extensive ratings of faces and sex morphs from our face database, we created 'controlled' male and female faces with similar perceived degrees of 'maleness' and 'femaleness'. We then examined CP of sex for these faces with classical discrimination and classification tasks using sex continua. Participants were naive (1), or had been familiarized with average faces of both sexes (2), or with the 'controlled' male and female faces (3). Our results confirm the lack of naturally occurring CP for sex in (1). Furthermore, they provide more evidence for the linked processing of sex and identity, as only participants in (3) showed clear CP. We found no evidence that familiarization with sex information (as given by average male and female faces) transfers to individual faces.

◆ **An integrated framework for combining gist vision with object segregation, categorisation and recognition**
J Rodrigues, D Almeida, J A Martins, R Lam, J M H du Buf (Institute for Systems and Robotics, Vision Laboratory, University of the Algarve, Campus de Gambelas FCT-DEEI, Faro, Portugal; e-mail: jrodrig@ualg.pt)

There are roughly two processing systems: (i) very fast gist vision of entire scenes, completely bottom-up and data driven, and (ii) focus-of-attention (FoA) with sequential screening of specific image regions and objects. The latter system has to be sequential because unnormalised input objects must be matched against normalised templates of canonical object views stored in memory, which involves dynamic routing of features in the visual pathways. A recently developed architecture provides a framework to combine gist and FoA for obtaining object segregation, categorisation ,and recognition by a dynamic process in which coarse-scale information is applied

first, after which progressively finer scales are added for refining the process. This model employs multiscale keypoints based on end-stopped cells (Rodrigues and du Buf, 2006 *BioSystems* **86** 75 – 90) for FoA and dynamic routing, complemented by the multiscale line and edge representation extracted from responses of simple and complex cells to validate different categorisation levels. This architecture is now being extended with colour and texture (du Buf, 2007 *Image and Vision Computing* **25** 873 – 882).
[Supported by FCT funding of ISR-IST with POS-Conhecimento and FEDER; FCT project PTDC-EIA-73633-2006 SmartVision.]

◆ **Facial attractiveness in orthognathic surgery: physical aspects**
L M Silva, S S Fukusima (FFCLRP, USP, Brazil; e-mail: lumarias@hotmail.com)
Individuals who show dentofacial deformities have abnormalities of the mandible, maxilla, or both, with consequent disharmony in facial dimensions and traits. Orthognathic surgery is the surgical correction of these aesthetic and functional problems, changing facial characteristics and configurations. The aim of this study was investigate the facial attractiveness of patients submitted to orthognathic surgery. Pre- and postoperative facial photographs of ten patients were analyzed regarding symmetry, third and fifth parts, and were judged for attractiveness by psychophysical methods. Brazilians prototypical faces were used as parameter to these judgments. The results suggested that faces of patients were less attractive and prototypical faces more attractive than the patients. Facial analysis showed that slight physical differences of symmetry, third, and fifth parts of the faces pre- and postoperative were enough to regard postoperative faces more attractive in 60% of cases. The results showed that orthognathic surgery brings aesthetic improvement for patients with dentofacial deformities and that any modifications in facial physical traits should take into account the facial pattern of the local population.
[Supported by CNPq.]

◆ **Correlation between figural symmetry detection and salient connectivity paths in dot pattern displays**
A Shinba, Y Nakano, G J van Tonder, Y Ohtani (Graduate School of Science and Technology, Kyoto Institute of Technology, Japan; e-mail: m7631007@edu.kit.ac.jp)
Symmetry is a significant cue for pre-attentive perceptual grouping (Julesz, 1971 *Foundations of Cyclopean Perception*). Here, we investigate the relevance of perceptually salient connectivity paths in dot patterns as a possible cue in symmetry detection. Using reaction times (RT) to rank a large set of randomly generated symmetrical dot pattern stimuli, we found that the top ranking stimuli were characterized by the most persistent connectivity paths across subjects. For comparison, this trend was even more pronounced in hand-designed symmetrical dot patterns created by a team of design experts: top ranking stimuli showed the same correlation with connectivity paths, but with even shorter RTs, suggesting that connectivity paths were subliminally 'crafted' to suit symmetry perception. Assuming that salient connectivity in dot patterns is independent of symmetry perception per se, we suggest that symmetry detection is a more elaborate perceptual process that depends, at least partly, on the completion of more rudimentary pre-attentive stages in vision.

◆ **Neural decoding of human-body perception from observer's electroencephalogram signal**
M Kitazaki, S Hariyama¶, Y Inoue§, H Shigemasu#, S Nakauchi‡ (Research Center for Future Vehicle [¶ Department of Knowledge-based Information Engineering; § Department of Electronic and Information Engineering; ‡ Department of Information and Computer Sciences], Toyohashi University of Technology, Japan; e-mail: mich@tutkie.tut.ac.jp)
Natural posture is recognized more efficiently than unnatural posture we cannot have, and the advantage of natural posture decreases with inverse presentation [Kitazaki and Inoue, 2004 *Journal of Vision* **4**(8) 233a]. We aimed to decode human-body perception from observer's electroencephalogram signal. Ten observers' EEG were recorded at 19ch (10 – 20 system, 1 kHz) with presenting a body posture in gray-scale computer graphics for 500 ms per trial. Combination of natural/unnatural postures, upright/inverse bodies, 9 different postures, and 10 different viewpoints were repeated 10 times in random order. We applied the support vector machine to classifying natural/unnatural postures, and upright/inverse postures, with leave-one-out cross-validation. The upright/inverse classifications were higher than the chance-level for both natural and unnatural postures ($p < 0.01$). The performance was higher at occipital cortex. The natural/unnatural classifications were higher than the chance-level for upright body ($p < 0.05$), but not for inverse body ($p = 0.08$). These neural-decoding results were analogous to our behavioural data, suggesting biomechanical constraint for human body perception works in our brain.
[Supported by Grant-in-Aid for Scientific research (B) MEXT, Nissan Science Foundation.]

◆ **Viewpoint invariance in the recognition of 3-D depth-rotated figures**
V Chikhman, Y Shelepin, N Foreman¶, P Passmore¶ (Pavlov Institute of Physiology, Russian Academy of Sciences, St Petersburg, Russia; ¶ Department of Psychology, Middlesex University, London, UK; e-mail: niv@pavlov.infran.ru)
The aim of our experiments was to investigate the central mechanisms of visual perception involved in the identification of 3-D objects. We have made psychophysical measurements of the recognition thresholds of incomplete 2-D images of 3-D objects, varying their perspective during a participant's learning and testing, using the Gollin test. The results we obtained showed a dependence of recognition thresholds of a 3-D object upon (i) the number of times it had been previously presented and (ii) the viewing angle of the 3-D object. The threshold was about 20% of contour length at first presentation. Recognition was improved at the second presentation, irrespective of whether a different angle of viewing was used, after which recognition was constant. It appears that a template forms immediately after the first presentation of a 2-D projection of an object. This template has invariance properties since its use for object identification does not depend on the object's orientation when subsequently presented, at least up to an angle of 60 degrees.
[Supported by RFBR grant 06-07-89137a and RFH grant 06-06-00252a.]

◆ **Stereoscopic information affects object representation**
A Pasqualotto, W G Hayward (Department of Psychology, University of Hong Kong, China; e-mail: pasquala@hkucc.hku.hk)
Research on object recognition has generally neglected the role of stereo depth information. Experimental investigations have usually been performed using stimuli displayed on flat monitors that provide only pictorial depth information. Nevertheless, most of our visual experience is enriched by depth information provided by stereo and motion cues; additionally, some recent studies have indicated that such information might be important for object recognition. In a series of experiments, we investigated the role of stereoscopic information using a same/different sequential matching task using real objects that were displayed under different sets of orientations and depicted using grey-scale images or silhouettes. We found that under a variety of conditions, performance at 180° was better in mono than stereo conditions; we attribute this counterintuitive result to the salience of outline information in mono but not stereo presentations. Taken together, these findings support the hypothesis that mono and stereo object representations are not identical and suggest mono presentations of objects may contain artefactual cues that are not present in stereo presentations.
[Supported by a grant from the Hong Kong Research Grants Council.]

◆ **The eyes touch what the hand sees: amalgamating modality-specific reference frames**
R Volcic, M W A Wijntjes, E Kool, A M L Kappers (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: r.volcic@phys.uu.nl)
The simple experience of a coherent percept while looking and touching an object conceals an intriguing issue: different senses encode and compare information in different modality-specific reference frames. We addressed this problem in a crossmodal visuo-haptic mental rotation task. Two objects in various orientations were presented at the same spatial location, one visually and one haptically. Participants had to identify the objects as same or different. The relative angle between viewing direction and hand orientation was manipulated (aligned versus orthogonal). In an additional condition (orthogonal delay), a temporal delay was introduced between haptic and visual explorations. Whereas the phase shift of the response time function was close to 0° in the aligned condition, in the orthogonal conditions we observed phase shifts in the hand's direction of 40.4° (no-delay) and 19.9° (delay). Counterintuitively, visuo-haptically misaligned objects were identified quicker. Conforming with our previous findings, these results suggest that object's information is acquired in separate eye- and hand-fixed reference frames which are directly comparable and which combine in a time-dependent manner.

◆ **Saccading towards faces in 100 ms. What's the secret?**
S Crouzet, H Kirchner, S J Thorpe (CerCo, CNRS – Université de Toulouse, France; e-mail: sebastien.crouzet@cerco.ups-tlse.fr)
When two natural scenes are displayed left and right of fixation, human subjects can initiate saccades towards the side containing an animal target in just 120 – 130 ms (Kirchner and Thorpe, 2006 *Vision Research* **46** 1762 – 1776), but processing is even faster when the target is a human face. Accuracy can be around 90%—even when the mean saccadic reaction time is only 140 ms— and the fastest saccades can start 100 – 110 ms after image onset. Here we explored the mechanisms used by the visual system to initiate such fast responses. We ran two experiments in which (i) we rotated the images to one of four possible orientations, (ii) we equalized the

amplitude spectrum information across images and categories. Our results suggest that these very fast responses are by no means artefactual and could indeed have considerable functional significance. Nevertheless, the heuristics used by the visual system could be quite low-level, possibly involving particular combinations of energy in different orientation and frequency tuned channels. [Supported by DGA and EU Project Decisions in Motion.]

◆ **Effects of background texture patterns on the reverspective illusion**
K Suzuki, M S Tada¶ (Faculty of Human Studies, Taisei Gakuin University, Sakai, Japan; ¶ Department of Clinical Psychology, Kansai University of Welfare Science, Kashiwara, Japan; e-mail: suzuki@tgu.ac.jp)

Reverspective is a robust illusion caused by pictorial depth cues painted on a 3-D canvas with inverted depth. Suzuki (2007 *Perception* **36** Supplement, 205) investigated how the painted texture patterns of the ground plane and the ceiling plane affect the illusion. To assess the effect on the illusion, we measured the critical distance at which a perceptual switch occurs, but the viewing distance and visual angle were not controlled in that study. In the present study, we measured the illusory percept as a percentage of the total viewing time to assess the effect on the illusion. Eight subjects participated in the study and viewed the stimulus under monocular conditions. The viewing distance was 2 m. The within-subject independent variable was the painted patterns of the ground and ceiling planes: compressed, convergent, grid, or solid colours. This variable was found to be significant, indicating that the background pattern of a reverspective stimulus has a strong effect on the illusion.

◆ **Processing of natural images is feedforward: a simple behavioural test**
T Schmidt, F Schmidt (Department of General and Experimental Psychology, University of Giessen, Germany; e-mail: thomas.schmidt@psychol.uni-giessen.de)

Natural images can be classified so rapidly that it has been suggested that their analysis is based on a first single pass of processing activity through the visuomotor system. We tested this theory in a visuomotor priming task where speeded pointing responses were performed towards the one of two target images containing a prespecified stimulus (eg, animal vs non-animal, ellipse vs rectangle). Target pictures were preceded by prime pictures of the same or opposite category, linked to either the same or opposite pointing response. We found that pointing trajectories were initially controlled by the primes alone, but independent of information in the actual targets. Our data indicate that prime and target signals remained strictly sequential throughout all processing stages, meeting unprecedentedly stringent behavioural criteria for feedforward processing (rapid-chase criteria). Our findings suggest that visuomotor priming effects capture the output of the very first pass of information through the visuomotor system, before output is affected by recurrent information.
[Supported by the German Research Foundation.]

◆ **Temporal dynamics of the gaze aftereffect**
Y D Wiepen, M Persike, G Meinhardt (Methods Section, Johannes Gutenberg University Mainz, Germany; e-mail: wiepen@students.uni-mainz.de)

The gaze aftereffect is a striking example of how previous exposure to eye gaze modulates subsequent gaze perception. When exposed to strongly averted gaze for some time, subjects' ability to detect the gaze direction of probe stimuli is significantly impaired. Despite accumulating evidence about the neural processes underlying the gaze aftereffect, little is known about the temporal dynamics of the adaption response. A series of psychophysical experiments was conducted to determine the temporal characteristics of the emergence and extinction of the gaze aftereffect. We show that brief adaption durations of mere seconds suffice to elicit the gaze aftereffect. Even when the adaption direction alternates between trials, a few seconds presentation time still induce a pronounced gaze aftereffect. Extinction is comparably rapid. After continuous adaption over several minutes, gaze detection performance returns to normal within seconds. Moreover, we found no difference in the temporal extinction gradient between different lengths and modes of adaptation phases. This points to remarkably fast adapting and recovering neural circuits underlying the perception of eye gaze in humans.

◆ **The influence of priming on the interpretation of an ambiguous figure**
M O Hartendorp, S Van der Stigchel, H Burnett¶, T Jellema¶, A Postma (Helmholtz Institute, Experimental Psychology, Utrecht University, The Netherlands; ¶ Department of Psychology, University of Hull, UK; e-mail: M.O.Hartendorp@uu.nl)

Ambiguous figures can lead to different perceptual interpretations. We examined the dynamics of this perceptual interpretation in a priming experiment. Ambiguous figures containing either 80% of one interpretation and 20% of another, or 70% and 30%, or 60% and 40%, were preceded

by three types of primes, namely congruent, incongruent, and unrelated. Participants responded by choosing one of the two interpretations. A strong preference for the dominant interpretation was found. Furthermore, going from a lower degree of ambiguity (80%–20%) to a higher degree (60%–40%) meant an increase in reaction times. Most interestingly, a priming effect was found: in the congruent condition a facilitation effect was found compared to the unrelated condition. In contrast, the incongruent condition showed an interference effect. We conclude that priming influences the processes underlying interpreting ambiguous figures. These results provide insights in how context influences the speed of the interpretation of ambiguity in our visual environment.

SEGMENTATION AND GROUPING

◆ **Mapping the similarity space of paintings: is there a role for image statistics?**
D J Graham, J N Friedenberg¶, D N Rockmore, D J Field§ (Department of Mathematics, Dartmouth College, Hanover, USA; ¶ Department of Psychology, Manhattan College, New York, USA; § Department of Psychology, Cornell University, Ithaca, USA; e-mail: artstats@gmail.com)

It has been shown that basic image statistics are significantly different for paintings of various content and provenance. Though such statistics are crude for the purpose of classification, they may be useful for predicting perceptual judgments such as similarity or preference, since these statistics are relevant to efficient coding strategies in the visual system. To test this notion, we mapped the similarity space for digitized landscape paintings from a major university museum by collecting pairwise similarity ratings from observers ($N = 24$). The 20 paintings tested had previously been defined as landscapes in a forced-choice test. Multidimensional scaling of the ratings revealed that the first scale was significantly correlated with whether the painting included humans in the foreground. The second scale was significantly correlated with the slope of the amplitude spectrum of the painting, a basic image statistic. These two scales accounted for 34% of the variance of the ratings. We discuss these results in terms of the coding of natural scenes and the prediction of perceptual judgments for artworks.

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◆ **Pre-attentive visual object formation is revealed by differential processing of deviances related to same or different objects**
D Müller, I Winkler¶, U Roeber, S Schaffer§, I Czigler¶, E Schröger (Institut für Psychologie, Universität Leipzig, Germany; ¶ Institute for Psychology, Hungarian Academy of Sciences, Budapest, Hungary; § Institut für Psychologie I, Universität Erlangen-Nürnberg, Germany; e-mail: dagmar_mueller@uni-leipzig.de)

Deviances from a regular sequence of visual stimuli elicit the visual mismatch negativity (vMMN) component of the event-related brain potential. As the vMMN is elicited even when the stimuli are ignored, we used this component to investigate the pre-attentive formation of simple visual objects. We composed visual objects by connecting two coloured circles with a bracket line and presented four of these objects evenly distributed around the fixation point. Deviances were characterised by an irregular colour affecting two circles belonging either to the same or to different objects. Participants were engaged in a change detection task at the central fixation with the peripheral objects being task-irrelevant. Deviance-related negativities were elicited at occipito-temporal electrode sites between 205 and 235 ms and between 250 and 280 ms. Whereas vMMN amplitudes were similar in the earlier time window, in the later time window higher vMMN amplitudes were elicited by same- as compared to different-object deviances. This differential processing of same-versus different-object deviances supports the hypothesis of pre-attentive formation of simple visual objects.

◆ **Crowding and visual complexity**
E Põder (Laboratory of Experimental Psychology, University of Leuven, Belgium; e-mail: endel.poder@ut.ee)

At the last ECVP (Põder, 2007 *Perception* **36** Supplement, 41) I suggested that visual complexity may be an important determinant of the crowding effect. In the present study, I attempted to test this idea using stimuli that could vary in three feature dimensions: orientation, spatial frequency, and colour. A group of 7 objects was presented briefly at 4 deg eccentricity (in a random position around the fixation). The task was to identify the target—the object located in the centre of a group. The groups of objects were varied from very simple (homogeneous in all three feature dimensions) to very complex. In two experiments, two different rules for selection of the target and distractor objects were used. The results show reduced crowding with simpler groups of stimuli. These results, however, can be explained by different possible mechanisms.

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◆ **Perceptual region detection method for image segmentation**
I Pirnog, C C Oprea, R M Udrea, R O Preda (Faculty of Electronics, Telecommunications and Information Technology, University Politehnica of Bucharest, Romania; e-mail: ionut@comm.pub.ro)

Image segmentation represents the partition of images into regions that are homogeneous or similar. There are many image segmentation methods and algorithms because no unifying method has been found. Our image segmentation method uses the Minkowsky metric and consists in choosing different parameters for different region colours. These parameters are determined in an experimental manner, so that regions obtained are not necessarily homogeneous but are closer to the regions detected by the human vision. In order to obtain these kinds of regions we used different thresholds for different colours. The selected thresholds were determined experimentally and used for the image 'Claire'. The simulation results show that the implemented segmentation method is more efficient in splitting images into regions and objects if the parameters chosen depend on the colour of the regions. Nevertheless, this method is not finalized and more work needs to be done. Future work will focus on finding a relation between colours and the segmentation parameters.

◆ **Classifying local image symmetry using a co-localised family of linear filters**
L D Griffin, M Lillholm (Department of Computer Science, University College London, UK; e-mail: L.Griffin@cs.ucl.ac.uk)

We model V1 simple cells as linear filters and consider what their responses signal about the image. Filters can be individually sensitive to an image symmetry, eg a non-zero response from a horizontally anti-symmetric filter signals that it is not on a vertical line of reflection. A criterion for filter symmetry-sensitivity is that transforming the filter by each element of the group describing the symmetry and summing, should cancel out. A filter family is sensitive if the span contains a sensitive filter. A criterion for this is whether the matrix formed by the outer product of the family of filters with the group-transformed-and-summed vector of filters has deficient rank. Using these criteria, we have determined the symmetry-sensitivity of a 'column' of V1 simple cells modelled as a family of derivative-of-Gaussian filters. Within the span of a second-order family of six filters, we find sensitivity to 13 classes of image symmetry. We conclude that 'columns' of co-localised simple cells are well suited to classifying local image structure according to symmetry type.

◆ **Isotropic surround suppression in human vision**
M Kilpeläinen, P Laurinen (Department of Psychology, University of Helsinki, Finland; e-mail: markku.kilpelainen@helsinki.fi)

Ample psychophysical and electrophysiological data suggest that in surround suppression, suppression can gain strength by integrating over large visual areas. In this study we measured the effect of surround area on suppression strength, while keeping the centre – surround distance constant. We measured psychophysically the apparent contrast of a circular centre and varied the angular size of two opposing surround sectors (45 – 180 deg each). The sectors were positioned vertically, diagonally or horizontally in relation to the centre. All diameters were constant (centre 1 deg, surround inner 1.2 deg, outer 2.1 deg). All stimuli were vertical sinusoidal gratings (4 cycles deg^{-1}). Centre contrast was 0.2, surround contrast 0.3. Suppression strength increased with sector width following a saturating function. The location of the surround sectors had no effect, save that the smallest surrounds caused suppression only in diagonal position. The results indicate that integration of collinear surround suppression is extremely isotropic (including the diagonal position) in human perception and the non-linearity of integration holds even if all distances are kept constant.

◆ **Highly scalable image watermarking in the wavelet domain**
R O Preda, D N Vizireanu, C C Oprea, R Udrea (Faculty of Electronics Telecommunications and Information Technology, University Politehnica of Bucharest, Romania; e-mail: radu@comm.pub.ro)

Scalable watermarking algorithms consist of combined watermark embedding and detection schemes intended for use with scalable content and possessing the following two properties: the watermark is detectable in any portion of the scaled content which is of acceptable quality and increased portions of the scaled content provide reduced error in watermark detection appropriate to the improved content quality. This paper proposes a digital watermark embedding and extraction method based on multi-resolution wavelet decomposition to achieve these goals. The embedded watermark is a greyscale image of different sizes. The wavelet transform is applied to the host image and to the watermark image to obtain the wavelet coefficients. A number of N wavelet coefficients of the original image decomposition are selected depending on the size of

the watermark. The wavelet coefficients of the watermark are embedded in these coefficients. The main idea is to embed the lower resolution watermark coefficients into the lower resolution layers of the original image. Computer simulations show that our method provides good quality scalability and watermark detection.

◆ **ERP correlates of detection in visual segregation**
S Straube, M Fahle (Institute of Human Neurobiology, University of Bremen, Germany; e-mail: sirko.straube@uni-bremen.de)

Detection is the ability to discern between signal and noise, a process often considered as purely sensory. How is detection accuracy represented in the event-related potential (ERP)? In a figure detection task, we addressed this question using psychophysical and electrophysiological measurements. We tested how ERPs are influenced by (i) the saliency of the figure and (ii) the combination of visual cues. Stimuli consisted of a matrix of Gabors, with the elements of the figure differing from background elements either in orientation, spatial frequency, or both (cue combination). Subjects indicated the figure-position in a two-alternative forced choice task. Figures were presented at three levels of saliency, adjusted according to individual psychometric functions of single cues. Performance improved significantly for cue combination, exceeding linear summation. Earliest differences in the ERP were found at 200 ms. Here, the posterior P2 component decreased with increasing performance irrespective of cue condition. Our results strengthen the hypothesis that amplitude changes of the posterior P2 reflect changes of perceptual saliency in visual paradigms.

◆ **From grouping to visual meanings: a new theory of perceptual organization**
L Albertazzi, B Pinna¶ (Department of Cognitive Science and Education, Trento University, Rovereto, Italy; ¶ Department of Science of Languages, University of Sassari, Italy; e-mail: liliana.albertazzi@unitn.it)

The aim of this work is to introduce three different kinds of perceptual organization called 'form of grouping', 'form of shape', and 'form of meaning'. Psychophysical experiments have suggested a continuum between grouping, shape, and meaning and have demonstrated that perceptual meaning (i) is an emergent result normally and spontaneously conveyed by vision, (ii) is the extreme reduction of the information load, ie many disparate components are reduced to a minimum number, (iii) is the result of an organization process that complements Gestalt principles of grouping with at least two perceptual levels (modal and amodal), (iv) is the basic component of the primitive language of vision used before spoken language and containing at least a subject, a predicate, and a complement, and (v) creates other meanings, one hierarchically included in the other. The meanings emerge whenever homogeneous and heterogeneous conditions are present within a stimulus. These opposite stimulus conditions trigger two opposite but complementary tendencies of amodal wholeness and modal partialness that represent the basis of the perceptual language.

ORAL PRESENTATIONS

BINOCULAR DEPTH PERCEPTION

◆ **Cortical integration of multiple cues to 3-D motion**
B Rokers, L K Cormack, A C Huk (Imaging Research Center, Neurobiology, Center for Perceptual Systems, Department of Psychology, University of Texas at Austin, USA; e-mail: rokers@mail.utexas.edu)

We studied the cortical processes supporting percepts of 3-D motion. At least three binocular cues may contribute to 3-D motion perception: changes in stimulus disparities over time, retinal velocity differences between the two eyes, and extra-retinal vergence signals. We measured BOLD responses in visual cortices while subjects viewed moving stereoscopic displays. To characterize the contributions of disparity- and velocity-based cues to 3-D motion, we (i) manipulated binocular anticorrelation, (ii) rotated displays from horizontal to vertical, and (iii) compared monocular and dichoptic motion opponency. To characterize the contribution of vergence, we independently manipulated vergence angle and visual motion through depth, under viewing conditions that minimized or eliminated peripheral retinal motion. We found that all three cues are processed by the visual system, but only a parietal area (putative human VIP) demonstrated robust responses to all three cues that were consistent with perceptual reports of 3-D motion across the range of stimulus manipulations. Dorsal regions beyond MT+ may be critical in extracting cue-invariant representations of motion in a dynamic 3-D world.
[Supported by NSF CAREER award, the Mind Science Foundation, the UT IRC, and NWO Grant 2006-11353-ALW.]

◆ **Different weights at the same place**
C Muller, E Brenner, J B J Smeets (Faculty of Human Movement Science, Vrije Universiteit Amsterdam, The Netherlands; e-mail: c.muller@fbw.vu.nl)
Humans combine different kinds of visual information to estimate slant. Such cues are combined through weighted averaging, with more weight being attributed to more reliable cues. A cue's reliability depends on many factors, such as the viewing distance and the specified slant, which can differ across a scene. Are cue weights determined for regions of the scene, or for objects within the scene? We addressed this question by asking observers to match the slants of two cue conflict objects that were at the same place in the scene. The cue conflicts were the same in both objects, but the cues' reliabilities differed for the two objects. Despite the fact that setting the same slant meant that both cues matched perfectly, observers did not set the objects to the same slant. We can only explain this by asserting that the weights that were assigned to the two cues differed for the two objects. Thus cues can simultaneously receive different weights for different objects at the same location in the scene.

◆ **Frontal slope perception: effects of viewing distance and height**
H E Ross (Department of Psychology, University of Stirling, Scotland; e-mail: h.e.ross@stir.ac.uk)
Frontal slope angle might be judged through the distance to the top and bottom of the slope, using binocular and other information. Foreshortening should make distant uphill slopes appear too steep, and downhill slopes too flat. Alternatively, the 2-D information in the image could specify the 'optical angle' (angle between the slope and the line of regard). A raised regard reduces the optical angle for uphill slopes, and might make the upper part appear flatter if observers only partially compensate for angle of regard; and a less depressed regard with viewing distance might make downhill slopes appear steeper. Outdoor experiments with moderate viewing distances gave similar uphill and downhill numerical estimates of slope angle for observers standing on the slopes. With increased distance uphill slopes were judged steeper, and downhill slopes flatter. Increased viewing height increases the angular size subtended by the slope, and both uphill and downhill slopes were judged steeper. These results support the distance foreshortening account, but contravene the changes in optical angle.

◆ **Integration of shape and surround across cue modalities**
K van der Kooij, S F te Pas (Helmholtz Institute, Universiteit Utrecht, The Netherlands; e-mail: k.vanderkooij@uu.nl)
Context can bias shape perception, as in illusions of shape contrast. Shape is perceived from a combination of depth cues and cue-dependent as well as cue-independent representations exist. We answer the question whether the integration of shape and surround is mediated by both types of representations. To this end, we presented shape and surround in the same or different depth cues and compared context biases in both conditions. A central hinged plane and larger flanking plane were defined by binocular disparity or motion. In a 'within-cue' condition, shape and flankers were defined by the same cue and in a 'cross-cue' condition they were defined by a different cue (binocular disparity or motion). Subjects compared the dihedral angle of the central shape with a constant reference. This way, we could compute the bias. In the within-cue condition there was a contrast bias whereas we found an attraction bias in the cross-cue condition. We conclude that the integration of shape and surround is mediated by both cue-dependent and cue-independent representations.

◆ **Dramatic insensitivity for surface orientation from binocular disparities**
P Mamassian (Laboratoire Psychology de la Perception, CNRS & Université Paris Descartes, France; e-mail: pascal.mamassian@univ-paris5.fr)
Do we have a genuine representation of slant for planes rotated about a vertical axis or is our impression of slant merely a gradient of depth values? To address this issue, we measured slant and depth discrimination thresholds for stimuli that were almost identical. A series of vertical lines was presented such that two consecutive lines had crossed disparities, the next two uncrossed disparities, the next two crossed, and so on. When the crossed disparity lines all had the same colour (eg black) and the uncrossed lines another colour (eg white), the lines grouped together in pairs seen in front or behind the fixation plane. When instead one colour was given to crossed-uncrossed pairs and the other colour to uncrossed-crossed pairs, the lines grouped together in pairs that appeared slanted to the right or to the left. Even though the colour manipulation did not change the disparity information, depth thresholds were ten times smaller than slant thresholds, suggesting that slant is very poorly represented.

◆ **Helmholtz's celestial sphere and the perception of straight lines**
B J Rogers (Department of Experimental Psychology, University of Oxford, UK; e-mail: bjr@psy.ox.ac.uk)
Helmholtz, 140 years ago, asked the question of how we judge the straightness of extended lines and he used his pincushion chessboard figure to show that straight lines can be perceived as curved (and vice versa). However, despite our familiarity with Helmholtz's figure, few studies have investigated the effect. Simple geometry shows that straight lines project to great circles on a spherical projection surface (Helmholtz's celestial sphere) and hence an obvious strategy for judging straightness would be to use extended receptive fields lying along great circles (Rogers and Brecher, 2008 *Perception* **36** 1275 – 1289). In this study, we measured the perceived straightness of lines as a function of eccentricity using large stereoscopic images. Results showed (i) there are systematic distortions: peripheral lines perceived as straight are curved convex towards the fixation point, (ii) the magnitude of the distortion depends on eccentricity and the regularity of the background texture (chessboard/random), (iii) straightness judgements are not based on retinal location alone but depend crucially on the depth/distance of the figure's surface.

OBJECTS/SHAPE PERCEPTION

◆ **Spatial constancy in haptic length perception**
I Fasiello, V Hayward¶, G Campion¶, M Wexler§ (CMLA, ENS Cachan, CNRS, UniverSud, France; ¶ Department of Electrical and Computer Engineering, McGill University, Montreal, Canada; § Laboratoire Psychologie de la Perception, CNRS, Université Paris Descartes, France; e-mail: irene.fasiello@cmla.ens-cachan.fr)
In vision, where the same point on the retina does not always correspond to the same point in space, the problem of taking into account eye movements in order to perceive objective geometric properties is known as spatial constancy. Here we investigate the equivalents of spatial constancy for the sense of touch. When exploring an object larger than the fingertip, if we take into account finger position and speed, we have a metrically accurate estimate of its size. Otherwise, we have access only to temporal information, and perceive the object smaller if we run over it faster. We evaluate the extent of spatial constancy in touch by simulating tactile objects of different lengths during finger movements of different speeds, with subjects reporting object size. For these open-loop movements, our results are incompatible with perfect spatial constancy, but are compatible with lack of spatial constancy: subjects appear to evaluate the size of an object mostly based on the time they take to run their fingertip over it.

◆ **Multisensory combination for movement timing**
A E Welchman, M T Elliott, M Doumas¶, A M Wing (School of Psychology, University of Birmingham, UK; ¶ Department of Psychology, Katholieke Universiteit Leuven, Belgium; e-mail: a.e.welchman@bham.ac.uk)
Synchronising our movements with environmental events is vital for everyday activities as diverse as dancing tango and keyhole surgery. Often the brain has access to multiple sensory cues useful for timing actions (eg, the auditory beat, flashing lights and touch of a dance partner), yet previous studies suggest that auditory signals dominate other modalities when controlling movement timing. Here we test a maximum likelihood model (MLE) of multisensory combination for the temporal control of action. We asked participants to tap their index finger in time with a beat provided by an auditory, haptic or visual metronome. Further, we added external noise to manipulate the reliability of individual metronomes. Performance in multimodal settings was largely predicted based on a MLE combination of the component signals: metronome-tap asynchronies were intermediate between the components and variability was lower. Analogous to work on spatial estimation, our results suggest that the brain exploits signals in a quasi-optimal way by using all the available information to provide the best foundation for timing movements.
[BBSRC project grant (E0095651) to AEW and AMW and a BBSRC fellowship to AEW (C5206201).]

◆ **Visual and haptic perceptual representations of complex 3-D objects**
N Gaissert, C Wallraven, I Bülthoff (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: nina.gaissert@tuebingen.mpg.de)
In this study we combined two new techniques to investigate visual and haptic perceptual representations of three-dimensional, parametrically-defined shapes. We generated a 3-D object space of shell-shaped objects by altering three model parameters defining shell shape. We created 21 equidistant plastic models of the objects with a 3-D printing device. Haptic exploration was done by having blindfolded participants explore these objects with both hands and no restrictions to the exploratory procedure. To ensure visual interaction without any haptic information, visual representation of these objects were presented to participants via a head-mounted display.

Participants manipulated a position-tracked physical substitute to rotate the objects on the display. Pairwise similarity ratings were performed and analysed using multidimensional scaling techniques. Both visual and haptic perceptual representations were highly consistent with the underlying physical three-dimensional parameter space. Interestingly, haptic exploration resulted in a more precise perceptual representation than the visual condition. Additionally, very similar MDS maps of the visual and the haptic exploration provide evidence that one shared perceptual space is underlying both modalities.

◆ **Comparison of spatiotemporal exploration of everyday objects in touch and vision**
P Tripathi, S Panchanathan (School of Computing and Informatics, Arizona State University, Tempe, USA; e-mail: pia.tripathi@gmail.com)

We conducted a study that compared exploration strategy of humans in touch and vision in a top–down and bottom–up manner. Fifteen participants explored 48 objects (3×4 matrix of class and features) in a within subject study with randomized blocks. Spatiotemporal maps of hand movement and eye movement were analyzed. A correlation of 88% was observed across subjects in directed exploration and 69% in undirected exploration. A number of loci were low (average being 3 in vision and 5 in touch) and distinct for directed exploration across all subjects. The visual verification was quicker (average time in vision was approximately 90 ms) than touch (average time taken was approximately 200 ms) but the path followed for such verification was spatially similar. On average, subjects fixated more on specific features such a handle of the cup (63% of the total time) and quickly perused over the body of the object in vision. In touch, the time spent on specific features was lower (only 42%) and overall exploration was higher.

◆ **Pedestal effects in tactile amplitude discrimination**
C W G Clifford, E Arabzadeh, J A Harris (School of Psychology, University of Sydney, Australia; e-mail: colinc@psych.usyd.edu.au)

Early visual processing of luminance or contrast is typically described as a transducer function with a sigmoidal shape converting the stimulus into a neuronal response. A sigmoidal transducer function exhibits an accelerating nonlinearity at low stimulus values (near detection threshold) and a compressive nonlinearity for higher stimulus values. Adding a fixed increment to the stimulus (as a pedestal) can thus decrease (for small pedestal values) or increase (for large pedestal values) the smallest stimulus difference detectable by the subject. This gives the subject's sensitivity a characteristic biphasic profile (the 'dipper' function). Here, we report a pedestal effect within the tactile modality. All five subjects produced a dipper function for tactile amplitude discrimination. Furthermore, a dim visual stimulus consistently caused a leftward shift in the tactile dipper function. Control experiments indicated that this was not a consequence of uncertainty reduction due to temporal cueing. Instead, we suggest that this crossmodal pedestal effect indicates a merging between visual and tactile signals, perhaps in the context of a multimodal gain control process.

◆ **Haptic object recognition and squeeze strength**
V Morash, B Balas (Department of Brain and Cognitive Sciences, MIT, Cambridge, USA; e-mail: valmo@mit.edu)

An object can undergo certain transformations, such as enlargement or skewing, that do not change its visual identity. For example, the face of a dollar bill is recognizable whether viewed up close or far away, straight on or at an angle. Such invariant properties of recognition provide essential information about the nature of representation. Similarly, an object can undergo certain transformations that do not change its haptic identity. Because the pressure of an exploring hand can vary, haptic object recognition may be pressure invariant. To test whether haptic object identity was invariant to grip strength, we asked subjects to do a match-to-sample task with toy cars. The subjects squeezed a sample car and two possible matches, and then reported which of the matches they believed to be the sample car. We varied the pressure that the subjects used to grip the sample and match cars. We discuss our findings in the context of models of haptic object recognition, and compare them to models of visual object recognition.

MARBURG + 30

◆ **Filtered versions of illusory patterns**
B Lingelbach (Department of Optometry, HTW-Aalen, Germany; e-mail: bernd@leinroden.de)

The first talk at the Marburg (1978) ECVP meeting, presented by Fergus Campbell on spatial vision, followed the quasi-epidemic fashion of those days to filter every pattern. In fact it was a filtered version of the Hermann grid (by Bergen) which showed a most powerful illusory effect. To our great surprise an even stronger illusion resulted when we directly produced the

corresponding figure without any filtering. Seventeen years later we presented this scintillating grid at the Tübingen meeting. Another nine years on (ECVP Budapest) the interest had turned to extinguishing the illusion. But modifications other than curved lines result in new effects. If selected dots are omitted, then illusory lines appear looking like filtered versions of lines, closing the loop to the Marburg meeting.

◆ **30 years of studying the visual perception of form**
I Rentschler (Institute of Medical Psychology, University of Munich, Germany; e-mail: ingo.rentschler@med.uni-muenchen.de)

Form perception including object recognition is investigated using (i) perturbation, (ii) categorisation, and (iii) formal analysis. Perturbation results from the interaction of figural elements, filtering, or shift of target patterns across the visual field. Under the assumption of form perception being a hierarchical process of feature extraction and integration, the perturbation approach essentially serves the estimation of receptive field characteristics. Perceptual categorisation is the assignment of multiple occurrences to learned class concepts. It warrants a model-based approach for analysis that depends on the quantification of pattern similarity. This is best achieved using an approach of recognition-by-parts, where patterns, or object views, are decomposed into constituent parts and part relations are established. Structural pattern descriptions are generated thereof through machine learning and adapted to psychophysically observed categorisation performance via optimization. Thus, it is possible to determine the type of relational features used for form perception under specific conditions of stimulus information and prior knowledge or context. Such types of procedure provide formal solutions to the hitherto somewhat vague problem of 'Gestalt'.

◆ **What eye movements can tell us about the working brain**
J Zihl (Department of Psychology – Neuropsychology, University of Munich, Germany; e-mail: zihl@psy.uni-muenchen.de)

There are different ways of monitoring brain functions during visual perception. Eye movements has been found a useful tools to study implicit processes involved in visual information processing. Visually-guided scan paths mirror the different levels of processing and cognitive activities during scene and object perception, and the interaction between attention and vision. The study of scan paths in patients with acquired focal brain injury can contribute to the understanding of the role of brain networks, which are crucial for the visual spatial guidance of eye movements. In addition, the plasticity of these networks can be challenged by providing patients with systematic practice to compensate for their visual deficits. The main message is that the brain uses scan paths in close correspondence to the material to be processed and the task to be carried out. Thus eye movements are used in a material- and task-specific manner.

◆ **Do unique hues originate within us or in the outside world?**
J D Mollon, R J Lee¶ (Department of Experimental Psychology, Cambridge University, UK; ¶ Department of Psychology, Durham University, UK; e-mail: jm123@cam.ac.uk)

Subjectively, the four 'unique hues'—red, green, yellow, blue—enjoy a special status: most observers report that these colours cannot be reduced to component hues. The origin of the unique hues has traditionally been sought in the wiring of the visual system, but physiology has not so far revealed structures or processes that correspond to the red/green and yellow/blue axes of phenomenological space. Lee and Shepard have raised the possibility that the yellow/blue axis coincides with a line passing through the two natural illuminants of our world, skylight and sunlight. Traditional measurements of daylight fall on a curved line in the CIE chromaticity diagram, a line that follows the Planckian locus. At any one time and place, however, we find that the spectroradiometrically measured chromaticity of a white plaque moves along a straight line as the plaque is held at different azimuths and different elevations. This 'Caerulean line' passes tightly through wavelengths that match the average values of unique blue and yellow, typically 476 nm and 576 nm.

CONSTRUCTING THE VISUAL WORLD

◆ **'Trinocular rivalry'?**
R P O'Shea, S Tep, U Roeber¶, E Schröger¶ (Department of Psychology, University of Otago, New Zealand; ¶ Institut für Psychologie I, Universität Leipzig, Germany; e-mail: r_oshea@otago.ac.nz)

Sometimes, astoundingly, we briefly cannot see one of two clear images: monocular rivalry or binocular rivalry. One theory is that rivalry acts to resolve visual ambiguity. If so, then rivalry should also occur when three or more different images are competing for visual consciousness: 'trinocular rivalry'. We showed observers three different sine-wave gratings, either with all three

visible to both eyes (pure monocular rivalry) or with two visible to one eye and one visible to the other (monocular plus binocular rivalry). To give all gratings an approximately equal chance in rivalry, we made them low contrast, helping monocular rivalry and handicapping binocular rivalry. Observers readily reported rivalry among three gratings. We also presented four gratings, two per eye. Observers readily reported rivalry among four gratings. The durations of exclusive visibility from three or four gratings were stochastic and were distributed as gamma functions. We conclude that rivalry can occur among three or four images, consistent with there being a general mechanism for resolving visual ambiguity.

◆ **Reported evidence for widespread synchronized networks in visual rivalry is unconvincing**
R van Ee (Helmholtz Institute, Utrecht University, The Netherlands; e-mail: r.vanee@uu.nl)
Integrative theories of brain function propose that, although local cortical areas contribute to distinct aspects of conscious perception, global integration is required to establish perceptual awareness of our environment. Experimentally, several authors claimed to have found a widespread network of synchronised areas that are entrained by visually ambiguous stimuli, reaching up to frontal regions. Our experimental results using both MEG and fMRI dovetail nicely with previous findings as we also replicated stimulus entrained activity across the entire scalp. However, for MEG a novel phase analysis revealed that the spatially extended nature of activity was produced by a limited set of occipital sources; we provide evidence that the coherence results from earlier studies are ambiguous in that they possibly measured coherence between different sensors whose signals were dominated by the same sources. For fMRI we found that an observer bias towards one of the two alternative percepts may explain away reported widespread differential activity. We conclude that the claims about widespread networks engaged in visual rivalry are currently unconvincing.

◆ **On the neural mechanisms of binocular rivalry**
A Bartels, N K Logothetis (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: andreas.bartels@tuebingen.mpg.de)
We will discuss our attempts to study neural correlates of the perceptual alternations experienced upon viewing of ambiguous figures, and relate them to new psychophysical evidence offering a new twist in the eye-versus-percept debate. Our studies over the last decade indicated that perception-responsive cells are concentrated in cortical areas near the top of the processing hierarchy, but that they can be found all along the visual pathway. Similarly, psychophysics has shown that both, monocular as well as binocular, percept based neural representations contribute to perceptual dominance. Our new psychophysical evidence suggests a time-dependence of eye and percept contributions in binocular rivalry: initially a given monocular channel has greater influence on dominance, regardless of the percept. Over time, this reverses, with percept-related (ie eye-independent) processes increasingly 'urging' for a perceptual switch. We suggest this may reflect a single process, where monocular as well as binocular neural stages affect each other in a feedback-loop that evolves over time. Understanding rivalry thus calls for the study of networks rather than single neurons.

◆ **Pupil dilation and rivalry: a link between multistable perception and behavioural decision making**
W Einhäuser, J Stout¶, C Koch¶, O Carter§ (Department of Neurophysics, Philipps University Marburg, Germany; ¶ Division of Biology, California Institute of Technology, Pasadena, USA; § Vision Sciences Laboratory, Harvard University, Cambridge, USA; e-mail: wet@physik.uni-marburg.de)
During sustained presentation of ambiguous stimuli, an individual's perception will switch between the different alternatives. In behaviour, the locus coeruleus (LC)—the brainstem nucleus responsible for releasing noradrenaline (NA)—plays a crucial role in consolidating the selection of a response and ensuring continual reassessment of available options. We hypothesized that the LC-NA system plays a similar role in selecting between perceptual alternatives. Since pupil dilation under constant illumination reflects LC activation, we recorded pupil diameter, while observers viewed 4 different rivalry stimuli. For all stimuli, pupil dilation was seen prior to the report of a perceptual transition. The relative dilation 600 ms prior to the transition correlated with the subsequent duration of perceptual stability. These effects could not be explained by eye movements or blinks, the motor response or by stimulus-driven changes in retinal input. This link between pupil dilation and perceptual switches suggests that the LC-NA complex plays the same role in perception as in behavioural selection, and that transitions in rivalry may be interpreted as perceptual decision making.
[Supported by the Swiss NSF (to WE), Darpa, NIMH (to CK), National Health and Medical Research Council, AUS (to OC)]

◆ **A perplexing interplay between binocular rivalry and attention**
U Roeber, S Veser, R P O'Shea¶ (Institute for Psychology I, University of Leipzig, Germany; ¶ Department of Psychology, University of Otago, New Zealand; e-mail: urte@uni-leipzig.de)
Binocular rivalry causes perceptual awareness to fluctuate between two dissimilar monocular images. Devoting attention to a secondary task slows down these perceptual alternations. We investigated this using event-related potentials. We presented one grating to one eye and another to the other eye. The gratings could either be the same orientation (fusion conditions), or different orientation (rivalry conditions). Our events were transitions from fusion to fusion, fusion to rivalry, rivalry to fusion, and rivalry to rivalry. The observers either had to report changes in perceived orientation of the gratings or had to report changes in a fixation cross. The changes in the fixation cross were not time locked to the transitions and served only to take attention away from them. We found that withdrawing attention enhanced the N1-component to the transitions, but only when the transitions followed binocular rivalry. This is opposite to the usual effects of attention on N1, suggesting that when observers have reduced awareness of binocular rivalry due to another task, transitions evoke involuntary attention.
[Supported by the German Research Foundation (DFG)]

◆ **When our brain is impressed but we do not notice it—evidence for an unconscious reliability estimation of the perceptual outcome**
J Kornmeier, C M Hein¶, K Krüger§, S P Heinrich§, M Bach§ (Sektion Funktionelle Sehforschung, Universität-Augenklinik Freiburg, Germany; also Institut für Grenzgebiete der Psychologie, Freiburg, Germany; ¶ Fakultät für Biologie, Universität Oldenburg, Germany; § Sektion Funktionelle Sehforschung, Universität-Augenklinik Freiburg, Germany; e-mail: juergen.kornmeier@uni-freiburg.de)
Normally, we perceive the world as visually stable. However, a stable conscious percept has to be constructed out of limited, ambiguous information. In the case of ambiguous figures, our perceptual system creates only temporarily stable percepts that suddenly switch to alternative interpretations. In the present studies we asked whether and how the event related potential (ERP) to ambiguous figures, evoking such instable percepts, differ from ERPs to unambiguous figure variants, evoking stable percepts. Results: (i) Tiny figural changes, rendering an ambiguous figure unambiguous, cause a sizable positivity at about 400 ms after stimulus onset ('P400'). (ii) This P400 was found for two different categories of ambiguous figures (Necker cube and old/young woman). (iii) This strong ERP difference was only found with attended stimuli. These results suggest the existence of an unconscious neural instance that evaluates the reliability of the perceptual outcome, given limited and ambiguous visual input. High reliability may have been evolutionary advantageous for action planning, low reliability may have been a trigger for invention and cognition.
[Support by the Deutsche Forschungsgemeinschaft (BA 877 16-2) is gratefully acknowledged.]

Thursday

ORAL PRESENTATIONS

BINOCULAR SPACE PERCEPTION

◆ **Probabilities of binocular half-occlusions in 3-D cluttered scenes**
M S Langer (School of Computer Science, McGill University, Montreal, Canada; e-mail: langer@cim.mcgill.ca)

Here I consider a model of natural scene statistics in 3-D cluttered scenes such as the branches and leaves of a tree or a set of trees in the woods. The model assumes that the scene consists of a large set of small surfaces that are distributed randomly over a 3-D view volume according to a Poisson process. The main contribution is a mathematical expression for the probabilities of binocular half occlusions in such scenes. I show that the conditional probability that a surface point is visible to one eye given that it is visible to the other eye is an exponentially decreasing function of depth, and that the decay rate depends both on the size and the density of the surfaces present. I present several simulations using computer graphics that illustrate these probabilities both qualitatively and quantitatively. I also discuss the implications of these probabilities for the visual system when solving the binocular correspondence problem in 3-D cluttered scenes.

◆ **Conscious and unconscious influences of spatial memory and eye movements**
A Postma, R Stotteler, I Hooge (Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands; e-mail: a.postma@uu.nl)

When we search for an object in the visual world, we may profit from a conscious memory of the object's location. However, when we don't remember where it was, we might still start looking in the right direction. In this case, an unconscious process could guide our behaviour. Conscious and unconscious influences of spatial memory can be separated by means of the process-dissociation procedure (PDP). Pictures of objects in natural surroundings are shown. During test subjects have to relocate objects in either the old or in a new location. In the former, conscious and unconscious influences are supposed to strengthen each other whereas in the latter they conflict. Previous neuropsychological work demonstrated spared unconscious influences against severely impaired conscious influences of memory in groups of patients, In the study presented here, the PDP method was combined with eye movement recordings. The results show a tendency to look in the old direction even when a new location for an object has to be found. This signals an unconscious influence of spatial memory.

◆ **The focal blur gradient affects perceived absolute distance**
D Vishwanath (School of Psychology, University of St Andrews, UK; e-mail: dv10@st-andrews.ac.uk)

Metric estimates of depth and size must be derived by scaling relative depth cues and retinal image size using absolute distance information. Traditionally, only extra-retinal cues (accommodation and vergence) have been thought to provide this. We find that the focal blur gradient can also act as a powerful cue to absolute distance. Distance information is available in the rate of blurring around fixation since it varies systematically with change in fixation distance [Vishwanath, 2007 *Journal of Vision* **7**(9) 845a]. Observers judged the perceived distance of a movable display surface, or the perceived size of slanted planes with blur simulating different fixation distances in the presence of vergence and/or accommodation information. A large effect of blur was obtained where a blurred image was matched to a closer no-blur comparison. The effect depended on the reliability of judgments determined in no-blur controls suggesting a weighting relative to the reliability of other signals. Surprisingly, vertical blur gradients inconsistent with simulated slant also showed an effect. The results may explain the vivid size perception phenomena in tilt-shift miniaturization.

◆ **Stereoscopic attentional tracking of independently moving objects embedded in optic flow**
M Raabe, D Bernhardt, C Beck¶, M W Greenlee (Department of Experimental Psychology, University of Regensburg, Germany; ¶ Institute for Neural Information Processing, University of Ulm, Germany; e-mail: markus@raabe.tv)

In 1998 Culham et al identified which brain regions are involved in attentional tracking of moving objects. We use fMRI to address the question if additional processing efforts are necessary when local objects are embedded in a coherently moving background simulating the observer being in motion. We used anaglyphs to present an expanding 3-D optic flow field of spheres already described in our previous studies (Kovacs et al, 2007, CerCort, in press). After initial adaptation to the optic flow two regional groups of spheres with a common faith moved independently to the left and right. Subjects were instructed to fixate the centre and attentionally track these independently moving objects (IMOs). Compared with a control condition we found

significant effects of the optic flow on the IMO tracking task ($p_{\text{corrected}} < 0.05$) in spatial motion (posterior occipital intraparietal sulcus, hV3a, V7) and object (inferior temporal lobe) processing regions. We conclude that the extraction of IMOs from optic flow in 3-D necessitates additional processing efforts in these networks.
[Supported by the German Federal BMBF (project 01GW0653) to DB, MR, and MWG.]

◆ **Illusions destroy visual space**
J B J Smeets, R Sousa, E Brenner (Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands; e-mail: J.Smeets@fbw.vu.nl)
It has been reported that our systematic misperceptions of visual space comply with an affine geometry and that perceptual space is homogeneous. In this paper, we investigated whether this was also the case in displays with well-known visual illusions. We propose an alternative description whereby perceptual space is Euclidean except for a single visual attribute that is influenced by the illusion. In a display with two parallel Judd figures as sides of a rectangle, the judged centre of the rectangle depended on which sides were bisected first, so visual space is not always affine. In a display with two parallel lines in the Poggendorff illusion, we showed that visual space is not always homogeneous. The misperceptions induced by visual illusions are thus of a different nature than our everyday misperceptions. We argue that the concept of visual space is not very useful in describing human performance, and discuss the consequences of this finding for the use of illusions to study streams of visual information processing.

◆ **Contrast is summed across eyes and space, and in that order**
T S Meese, R J Summers (Life and Health Sciences, Aston University, Birmingham, UK; e-mail: t.s.meese@aston.ac.uk)
To investigate neural convergence across eyes and space we modulated sine-wave carriers (2.5 cycles deg^{-1}) with cosine- and anticosine-phase 'raised' plaids. This produced patchy gratings, with patches located on either 'black' or 'white' checks of a notional checkerboard. The check-width was $\sim$3.5 carrier cycles. Monocular stimuli had one set of check-locations in one eye and dichoptic stimuli had different sets of check-locations in different eyes. Psychometric functions were measured using a method of constant stimuli, revealing two main results: psychometric slopes were steep (Weibull $\beta > 3$) for all conditions, and dichoptic sensitivity was about a factor of $\sim$1.7 greater than monocular sensitivity. We considered 192 model architectures containing each of the following four elements in all possible orders: (i) linear summation or a MAX operator across eyes, (ii) linear summation or a MAX operator across space, (iii) linear or accelerating contrast transduction, and (iv) additive Gaussian stochastic noise. The best model was: linear summation across eyes followed by accelerating contrast transduction, linear summation across space $\geqslant$ 7 cycles, and late noise.
[Supported by the Wellcome Trust and EPSRC.]

SACCADES AND PERCEPTION

◆ **Interaction between masked priming and flanker interference**
P Sumner, F Boy, M Husain¶ (School of Psychology, Cardiff University, UK; ¶ Institute of Cognitive Neuroscience, University College London, UK; e-mail: sumnerp@cardiff.ac.uk)
Masked priming tasks and the Eriksen flanker paradigm have been separately influential in the study of sensorimotor processes elicited by visual stimuli. In masked priming, target stimuli are preceded by non-discriminable masked stimuli associated with the same (compatible) or different (incompatible) response. In the Eriksen flanker task, the target is flanked by clearly visible compatible or incompatible stimuli. It remains unknown whether the mechanisms evoked by each paradigm are the same. Both primes and flankers are assumed to activate motor representations, and for masked primes at least, this activation phase appears to be followed by an automatic and unconscious inhibitory phase, such that compatible primes now slow down, rather than speed up, responses (a negative compatibility effect, NCE). Here we attempt a unification of the two paradigms and find that the NCE interacts with flanker interference, such that it is enhanced when the flankers conflict with the target. Moreover, primes can reverse the flanker effect, so that responses become faster with conflicting flankers than with compatible flankers.
[Supported by the BBSRC and the Wales Institute of Cognitive Neuroscience (WICN).]

◆ **Saccadic eye movements in two-stimulus visual displays: foveal and peripheral distractor stimuli are not equal**
F Vitu, S Casteau (Laboratoire de Psychologie Cognitive, CNRS, Université de Provence, Marseille, France; e-mail: Francoise.Vitu-Thibault@univ-provence.fr)
In several papers it has been assumed that saccade generation results from competition between fixation and move systems, the former depending mainly on foveal stimulation and the latter

depending on peripheral stimulation. To test this assumption, we compared the influence of a foveal vs peripheral distractor stimulus (circle) on the latency and accuracy of saccades towards a more eccentric saccade target (letter or triangle), ipsi- or contra-lateral to the distractor; the distance between distractor and target was systematically manipulated. Results showed that distractor stimuli displayed outside of a central foveal region (about 1-degree radius) and in the same hemifield as the target deviated the eyes in a centre-of-gravity manner (ie the global effect). In contrast, distractors in the 1-degree foveal region, ipsi- or contra-lateral to the saccade target, did not affect saccade accuracy, but strongly increased saccade latency, with the effect being greater when the target also fell in the critical region. These findings are consistent with the fixation/move competition hypothesis, but alternative interpretations will be discussed.

◆ **Interactions between perceptual dimensions in the remote distractor effect**
S Born, D Kerzel (Faculté de Psychologie et des Sciences de l'Education, Université de Genève, Switzerland; e-mail: sabine.born@pse.unige.ch)

It is well known that a distractor stimulus presented simultaneously with the saccade target prolongs saccadic latency (remote distractor effect, RDE). We examined the influence of target and distractor dimensions on the RDE. Subjects were asked to make a saccade to a target that was defined by either luminance or colour. Simultaneous with the target, distractors were presented that either did or did not share the target's defining dimension. Results show that distractors sharing the target's dimension were much more efficient in perturbing the saccade than distractors of a different dimension. Two explanations that might account for these results are discussed: the contingent capture hypothesis states that attentional capture by an irrelevant stimulus (eg a distractor) only occurs when stimulus properties are contingent on the attentional set adopted by the observer (eg to a specific stimulus dimension). Alternatively, differences in saccadic latency to colour and luminance targets coupled with differential latencies in distractor processing might explain the results.

[Both authors were supported by the Swiss National Foundation PDFM1-114417.]

◆ **Post-saccadic target influences pre-saccadic compression**
F Maij, E Brenner, J B J Smeets (Research Institute MOVE, Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands; e-mail: f.maij@fbw.vu.nl)

Flashes presented around the time of a saccade are often mislocalised in the direction of the endpoint of the saccade. This compression towards the saccade target was found in many studies, but in other studies such compression was not evident. Here, we show that the presence of the saccade target after the saccade is critical in avoiding such mislocalisation. We performed the experiment in a normally illuminated room. Just after saccade onset the saccade target was either removed or remained visible at the same position. When the saccade target remained visible we found no compression. When the target was removed at saccade onset we found a clear compression. Our findings suggest that the target of the saccade is used as a reference point for retaining estimates of objects' locations when the eyes move.

◆ **Investigating the locus of trans-saccadic remapping using invisible aftereffects**
D Melcher (Centre for Mind/Brain Studies, University of Trento, Italy; e-mail: david.melcher@unitn.it)

Saccadic eye movements can dramatically change the location in which an object is projected onto the retina. One mechanism that may underlie the perception of objects across saccades is the remapping of receptive fields. Here we investigated the locus of visual feature remapping by measuring the trans-saccadic tilt aftereffect for adapting stimuli made invisible by crowding or by using high spatial frequency adapters. The results of both studies showed a strong dissociation between awareness and the resolution of remapping. The pattern of findings implicates intermediate visual processing areas. Overall, these results are consistent with the theory of object-based remapping for salient stimuli across glances.

◆ **Hitting a moving target: interaction between 'when' and 'where' in saccade programming**
P J Etchells, C P Benton, C J H Ludwig, I D Gilchrist (Department of Experimental Psychology, University of Bristol, UK; e-mail: peter.etchells@bristol.ac.uk)

Individual saccadic reaction times (SRTs) vary widely even when all other factors are held constant. Consequently, for a given saccade, landing position may depend on the SRT—particularly when orienting accurately to moving targets. We investigated to what extent saccade endpoints were adjusted to take into account this timing variability. Participants were presented with two moving Gaussian patches and asked to make a saccade if a patch changed brightness. Participant expectation was kept constant as far as as possible by varying movement direction, whether and when a brightness change occurred. Despite an inability to predict target onset, participants

were still able to make accurate saccades to the target: saccade landing position took into account trial-by-trial variation in the interval between brightness change and saccade onset. Our results suggest that the saccade generation system has accurate knowledge of the saccade latency on a trial-by-trial basis and uses this information to update the response. This ability is clearly important in a dynamic world that necessitates accurate eye movements to moving targets.

POSTERS

ANALOGOUS CONCEPTS IN HAPTICS AND VISION

◆ **What finger movements reveal about braille reading**

B Hughes, A W A Van Gemmert¶ (Department of Psychology, University of Auckland, New Zealand; ¶ Department of Kinesiology, Arizona State University, Temple, USA; e-mail: b.hughes@auckland.ac.nz)

Braille reading is a sophisticated form of haptic texture perception in which the texture possesses linguistic meaning. We hypothesised that as eye movements reveal much about the nature and timing of visual reading processes, finger movements may do the same for Braille reading. Finger velocities during reading are neither smooth nor constant; indeed, they can involve rapid, large and frequent changes. We compared the velocity profiles when fluent readers read sentences comprising either high- or low-frequency words, in sentences with or without meaning, and compared such profiles to those produced by scanning lines of Braille cells. Various kinematic indices suggest that while important movement characteristics (such as regressions) are based on text comprehension, most of the fluctuations in velocity are owing to motor control factors. Hence understanding Braille reading will involve understanding the active, motor aspects of haptic texture perception. We relate the findings to models of visual reading, where eye movement control, text processing, and saccadic programming are key points of difference.

◆ **Visual object recognition by prehension movement**

F Campanella, G Sandini (IIT, Italian Institute of Technology – DIST , University of Genoa, Italy; e-mail: francesco.campanella@iit.it)

Object motor representation is strictly linked to prehension movements control. In particular the influence of some visual intrinsic object features on hand preshaping during reach to grasp movements is known. In this study we propose a new paradigm to investigate human skill in object features extraction from visually presented actions. Performance analysis in an object recognition task, in which stimuli are point-based representations of hand prehension movements, suggests how spatial information content of object directed actions varies in time. Furthermore these experiments could provide new insights about the problem of agency in the domain of hand biological motion perception. In our preliminary results recognition errors did not seem randomly distributed among simple objects, and response distribution supports the idea that the action of grasping an object encodes information about the shape and size of the object. Moreover performance in object recognition is affected by the perspective from which subjects look at recorded grasping movements, and this effect is mainly found when subjects are shown their own previously recorded actions.

◆ **Tactile and visual contributions to the perception of naturalness**

K E Overvliet, S Soto-Faraco (Parc Científic de Barcelona, Universitat de Barcelona, Spain; e-mail: krista.overvliet@gmail.com)

Most people prefer natural over artificial things, and therefore 'naturalness' is a highly appreciated material characteristic. For instance, a natural wooden floor is seen as more valuable than a replica, though they may be comparable in quality and durability. It is therefore surprising that the amount of research into which sensory modalities may influence the perception of naturalness is minimal. In the present study we investigated how vision and touch contribute to perception of naturalness in wood. Participants rated samples of wood or imitations thereof, such as vinyl and veneers. We used four measurement methods (labelled scaling, magnitude estimation, binary decision, ranked ordering) and three exploration modalities (vision only, touch only, bimodal). The results show a high degree of consistency across measurement methods. However, the estimations from the unimodal conditions, vision and touch, were not highly correlated; thus their contributions to this perception may be independent. Finally, the results of the bimodal condition can be approximated by a weighted average model, in which vision and touch have similar weighting.

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◆ **The weight of representing the body: factors influencing multisensory integration**
M P M Kammers, H C Dijkerman (Helmholtz Institute, Experimental Psychology, Universiteit Utrecht, The Netherlands; e-mail: m.p.m.kammers@uu.nl)
Perception and action have been functionally dissociated within the visual system. Here we investigate whether the somatosensory system shows a similar dissociation. So far the most commonly used dissociation is between the body schema underlying actions, and the body image used to make perceptual judgments. In a number of experiments using several somatic bodily illusions, we show that: (i) action is robust against bodily illusions that do affect perceptual body judgments, (ii) additional proprioceptive information provided by actions reduces illusory perceptual displacement, and (iii) this dissociation is likely to have distinct neural substrates, as evidenced by reduced illusion sensitivity for perceptual judgments after transcranial magnetic stimulation. Although these results are in line with a perception/action dissociation, the question remains whether we need multiple body representations to explain these functional differences. We propose an alternative approach in which multisensory information is weighted and integrated differently depending on whether we use our body as a goal (perceptually), or as a means to a goal (action).

◆ **Scenario-based crossmodal touching: How top – down processes influence tactile and visual appreciation**
M Zachhuber, M Jakesch, H Leder, C C Carbon (Faculty of Psychology, University of Vienna, Austria; e-mail: martina.zachhuber@univie.ac.at)
Research in cognitive psychology on the tactile appreciation is still very limited, for two major reasons: (a) lack of standardized and well-established tactile reference test frames, (b) absence of clearly defined standard procedures for testing. Here we develop a new scenario-based test procedure utilizing a tactile test frame from the automobile industry (Sensotact) with 3 top-level tactile qualities (thermal, orthogonal, tangential) and 10 second-order qualities with 5 levels each. In a sight and a blind-folded condition, sixty-four participants had to evaluate their appreciation of the whole material without specific instruction (base condition) and with instruction reflecting four everyday life scenarios. The resulting pattern of data of the base condition differed strongly from the scenario-based instructions, with more inter-rater reliability for scenarios showing indifferent answering for the non-specific instruction. In both modality conditions similar effects were found. These findings underline the strong influence of top – down processes on tactile and visual appreciation AND help to develop a more ecological valid test for applied research.

◆ **Modality-specific involvement of occipital cortex in the early blind**
R H J van der Lubbe, C M van Mierlo¶, A Postma§ (Cognitive Psychology & Ergonomics, University of Twente, The Netherlands; ¶ Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands; § Experimental Psychology, Utrecht University, The Netherlands; e-mail: r.h.j.vanderlubbe@gw.utwente.nl)
What happens in occipital cortex when neuronal activity is no longer evoked by regular visual stimulation? Studying brain activity induced by tactile and auditory stimuli in the blind may provide an answer. Several studies indicate that occipital cortex in the blind is recruited in simple tasks, like auditory localization, and complex tasks, involving verbal memory. The goal of the current study was to establish whether or not this occipital recruitment is modality-specific when highly comparable tactile and auditory tasks are carried out. Early-blind subjects performed auditory and tactile duration discrimination tasks while their EEG was being measured. Source localization on secondary activity, after about 250 ms, revealed an occipito-parietal and occipito-temporal locus in case of auditory and tactile stimuli, respectively. This modality-specific result was underlined by a correlation between right occipital activity and performance on auditory targets. These findings suggest that specific parts of occipital cortex are more suitable for the takeover of modality-specific functions, which may possibly be related to the distinction between dorsal and ventral visual pathways.

◆ **Psychophysical evidence for face-centered visuotactile neurons in humans**
U Wolfe, C Carpinella (Department of Psychology, Hobart & William Smith Colleges, New York; e-mail: uwolfe@hws.edu)
Information from different senses, such as vision, audition, and touch, is neurally integrated to provide a unified perception of our world and body. For example, certain bimodal, face-centered neurons in monkeys are driven by both tactile and close visual stimuli in congruent regions thus mapping the immediate peripersonal space. Receptive fields of such neurons often involve large regions of the face. Here we provide evidence for similar neural substrates in humans by inducing crossmodal conflict between vision and touch. Participants inserted an occluder contact lens into one eye thus inducing monocular blindness without any somatosensation, such as that of the eye being closed or covered, that could explain such blindness. Observers reported

parasthesia (numbness, tingling) in wide regions of the face ipsilateral to the occluder. The effect decreased when reducing visual asymmetry (by dimming the light) or when actively covering or closing an eye. Results are consistent with a theory in which crossmodal conflict causes activation of face-centered visuotactile neurons that is experienced as parasthesia in the neurons' receptive fields.

ATTENTION AND RELATED ISSUES

◆ **Predictive coupling between attention and eye movements**

A Belopolsky, J Theeuwes (Department of Cognitive Psychology, Vrije Universiteit Amsterdam, The Netherlands; e-mail: A.Belopolsky@psy.vu.nl)

A long line of research has shown that the mechanisms subserving spatial attention and saccadic eye movements are intricately related. The present study investigated the relationship between endogenous spatial attention and saccades. This issue was examined in a novel paradigm, allowing simultaneous measuring of attentional allocation and oculomotor preparation. If maintenance of attention results in activation of an oculomotor program, then it should result in facilitation of saccades to that location. In Experiment 1 the probability of making a saccade to the attended location was 50% and we found that saccades were executed faster to the attended location than to the unattended location. However, when the probability was decreased to 25% in Experiment 2, saccades were executed slower to the attended location than to the unattended location. The results suggest that effects of endogenous attention can be dissociated from oculomotor preparation. The oculomotor system is engaged during attentional allocation, but can either be activated or inhibited depending on the need of making an eye movement to the attended location.

◆ **Visual attention while riding motorcycle: improving traffic hazard perception using a riding simulator**

A Bastianelli, A Spoto, G Vidotto (Department of General Psychology, University of Padua, Italy; e-mail: alessia.bastianelli@unipd.it)

Riding a motorcycle is a task in which visual system plays a dominant role. Perceiving one's own motion and the speeds of and distances to other vehicles are essential. Research proved that novice riders fail in perceiving hazard situation more often than their experienced counterparts. The accounts suggested that (i) novices are unable to allocate sufficient cognitive resources to visual search; and (ii) novices have an inadequate mental model in detecting traffic hazards. Furthermore, it has been suggested that increased skill is associated with an increase in the ability for acquiring information from traffic events. The present research aimed to show whether a rider simulator could improve the selective attention for detecting hazard situations in novice riders. Participants performed twelve tracks using a rider simulator in different traffic situations and environments. The results show that participants' significantly increasing proportion of avoided hazards is depicted by a three-stage learning curve as a function of the number of tracks performed. Findings are discussed in the light of space-based theory of visual attention.

◆ **Visual memory storage of objects depends on their spatial organization**

A Ben Abbes (Laboratoire Psychologie Cognitive, Université de Provence, France; e-mail: aymenpsy@yahoo.fr)

Visual short-term memory (VSTM) is severely deficient in storage capacity, estimated to approximately four items. To overcome these limitations, the visual system is equipped with sophisticated mechanisms that permit the selection and the transfer of the important inputs into the VSTM itself. We thought that this attentional selective capacity is strongly influenced by the spatial status of visual information. To test this hypothesis, we used an original paradigm in which subjects had to memorize objects combined with previewed distractors. We found that the selective capacity was very sensitive to the spatial distribution of targets. Indeed, they were better memorized when presented at separated locations. It appeared that the regularity of the targets' organization may constitute an important factor probably involved in such phenomenon. A second experiment was performed to test such impact. The results showed that the extraction and storage of targets are affected by the uniformity of their spatial repartition. We concluded that visual memory storage is highly dependent upon the spatial configuration of targets.

◆ **Sexual differences in pattern recognition: effect of visuospatial discrimination or decision-making behaviour?**

C Devaud, C Brandner (Institute of Psychology, University of Lausanne, Switzerland; e-mail: Cedric.Devaud@unil.ch)

This study investigates the ability of males and females to recognize the direction of target visual patterns from non-target patterns. First, participants (15 females, 15 males) memorized 4 targets that varied in direction (0°, 90°, 180°, 270°). Next they had to discriminate targets from

non-targets that varied around the original direction (10°, 20°, 30° clockwise and counterclockwise). Following each presentation, participants had to evaluate their confidence level of their answer. General results showed a significant decrease of target recognition in women compared to men. Such decrease was also observed in non-target patterns that varied in a clockwise direction, although no difference was observed in counterclockwise non-target patterns. This effect was not due to a difference in decision making since SDT results showed no effect of sex either on c or d' indexes as well as in the subjective evaluation of answer confidence. These results seem to agree with the hypothesis of a sex difference in cognitive style where females rely more on detailed information, whereas male style relies on global information.

◆ **Space and time modulate faster visual detection in the profound deaf**
D Bottari, E Nava¶, P Ley§, F Pavani# (Department of Cognitive Science [¶ Centre Mind and Brain], University of Trento, Italy; § Department of Psychology, University of Hamburg, Germany; # Department of Cognitive Science, and Centre Mind and Brain, University of Trento, Italy; e-mail: davidebottari@yahoo.it)

Previous literature suggests enhanced visual skills in profound deafness. We examined visual detection and discrimination abilities in profound deaf and normal hearing people, as a function of target occurrence in time and space. Time modulations were obtained by presenting visual targets at one of two intervals after a warning signal: 600 ± 200 ms (short) or 2000 ± 200 ms (long). Space modulations were obtained by presenting targets at one of two eccentricities: 3 or 8 degrees. In Experiment 1 (detection) profound deaf people were overall faster (40 ms on average) than hearing people. Reactivity enhancements were mostly pronounced for targets occurring at short interval and towards the periphery. In Experiment 2 (discrimination) deaf people displayed faster responses only at the expenses of accuracy. Moreover, no modulation of visual responses emerged as a function of time and space. We suggest that reactivity may be a core aspect of deafness that can be modulated as a function of space and time. However, reactivity may reflect faster transmission of visual input (or motor preparation) than enhancement of late perceptual processes.

◆ **When does roving disrupt perceptual learning?**
E M Tartaglia, K Aaberg, M H Herzog (Laboratory of Psychophysics, EPFL, Lausanne, Switzerland; e-mail: elisa.tartaglia@epfl.ch)

Training with one type of a visual stimulus usually improves performance. When observers train with two or more stimulus types presented in random order (so-called roving), performance improves for certain stimulus types but not for others. To understand when roving hinders perceptual learning, we conducted four experiments, using four different pairs of stimulus types. Performance improved when a bisection and a Vernier stimulus were randomly interleaved. However, no learning was found when we randomly interleaved this bisection stimulus with another one being twice as long. Our results suggest that roving impedes perceptual learning when the stimulus types are perceptually clearly distinct but, still, excite overlapping neural populations.

[Supported by Pro-Doc Processes of Perception of the SNF.]

◆ **Effects of crowding on temporal order judgement**
F Fährmann, A Köpsel, T Bachmann¶, A Huckauf (Media Systems, Faculty of Media, Bauhaus University Weimar, Germany; ¶ Department of Psychology and Estonian Center of Behavioral and Health Sciences, University of Tartu, Estonia; e-mail: felix.faehrmann@medien.uni-weimar.de)

Flanking letters with others leads to impairments in recognition, usually referred to as crowding. It is still under debate how crowding is related to attention effects. In our study, we adopted a rapid serial visual presentation (RSVP) task in which two streams of letters are presented. In both streams, a target was presented, and the observer had to specify the side on which a target appeared first (temporal order judgement, TOJ). Streams were displayed either with flankers for one stream or for both streams. Relative to the unflanked condition, flanking affected the TOJ function: In the case of flankers for one stream only, the point of subjective simultaneity was shifted so as to indicate slowing down of processing flanked target. Flankers for both streams resulted in a flatter slope of TOJ function. These data indicate that flankers slow down target processing and impair temporal order discrimination.

◆ **Searching among illusory stimuli to probe the interplay of intrinsic and extrinsic uncertainty**
G Paggetti, N Megna, S Baldassi (Department of Psychology, University of Florence, Italy; e-mail: giuliapaggetti@gmail.com)

Pop-out of a luminance target has been explained as the effect of intrinsic uncertainty rather than of a parallel mechanism (Baldassi and Burr, 2004 *Vision Research*). Here we extend the investigation by using illusory distractors (Kanizsa, Ehrenstein, White and simultaneous contrast illusions). These illusions evoke illusory objects of different strength. The target contained a physical luminance decrement or increment while 1 to 7 distractors were pure illusory stimuli. We measured luminance discrimination thresholds and found differential set-size effects with different stimuli. Weaker illusory forms 'popped-out', while the slope of the set-size function increased with increasing strength of the induced form. The slope of the psychometric functions was shallower with increasing slope of the set-size function. By using an uncertainty framework, we interpreted these data, and the phenomenon of search pop-out in similar tasks, as showing that weaker objects—physical or illusory—are less defined and a target needs to be detected, implying high intrinsic uncertainty. Stronger objects instead create more solid representations and extrinsic uncertainty dominates the effect.

◆ **Adaptive displays for compensating pathological nystagmus**
H Koesling, M Johannfunke¶, E Carbone§ (CRC 673 Alignment in Communication [¶ Faculty of Technology; § Faculty of Psychology and Sports Science], Bielefeld University, Germany; e-mail: hendrik.koesling@uni-bielefeld.de)

Physiological nystagmus, an involuntary, rhythmic, oscillating motion of the human eyes, normally stabilises the retinal image, for example, of objects moving across the visual field. In pathological nystagmus, however, patients have difficulties in generating a stable view even of stationary environments. In order to compensate for pathological nystagmus effects, we developed an adaptive, gaze-contingent display that dynamically adjusts the position of visual stimuli according to the current nystagmus frequency and amplitude. An EyeLinkII eye tracker obtains this data from the patients' eye movements on-line. Display adaptation occurs instantaneously within the subsequent display refresh cycle, ie almost in real time. We evaluated user performance in two different tasks, namely text reading and visual search, and compared the adaptive display condition to a normal viewing condition. Preliminary results indicate a significant decrease in error rates and task completion times for the adaptive display condition. Patients also judge this novel method as less tiring and generally a considerable improvement over normal viewing.
[Supported by German Science Foundation (DFG SFB673-A5).]

◆ **Assessment of visual function in non-responsive subjects using automated eye-tracking: methodology and repeatability**
J Pel, J Manders, M Vermaak¶, H Evenhuis¶, J van der Steen (Department of Neuroscience, Erasmus MC, Rotterdam, The Netherlands; ¶ dept. of General Practice, Intellectual Disability Medicine Erasmus MC, Rotterdam, The Netherlands; e-mail: j.pel@erasmusmc.nl)

At present, no tests are available that assess the degree of visual function, especially in young and/or disabled children. It is known that eye responses are automatically induced towards a visual feature when it is detected, so-called preferential looking. In the present study, we combined stimuli displayed on a monitor and automated eye-tracking to objectively determine visual function, without active communication between investigator and subject. We measured the eye and head movements of fifty healthy children (age range 0 – 9 years) in two subsequently measured sequences. Attractors appeared in random order in one of the monitor quadrants, followed by a standardized visual test; competitive and non-competitive dot, form coherence or smooth pursuit. When plotted against increasing age groups of 1 year, mean latency (monotone decrease from 0.9 s to 0.3 s), gaze fixation area (constant at 40% of attractor area), 90% form coherence (monotone increase from 50% to 60%), and pursuit gain (constant at 100% of pursuit area) showed to be promising and reliable diagnostic markers (ICC $>$ 0.7).

◆ **Task-dependent functional connectivity between the pulvinar and working memory circuits**
J Fischer, D Whitney (Center for Mind and Brain, University of California at Davis, USA; e-mail: jtfischer@ucdavis.edu)

Despite its widespread connectivity with visual cortex, the role of the pulvinar in vision is unclear. Here, we tested the hypothesis that the pulvinar provides task-relevant visual information to working memory (WM) circuits. Using fMRI, we measured the functional connectivity between the pulvinar and two areas known to support working memory maintenance, the ventrolateral prefrontal cortex (VLPFC), and the hippocampus. In separate trials, subjects either performed a high working memory load counting task, or a low maintenance load position discrimination task that required subjects to maintain spatial information in working memory. For both tasks,

functional connectivity between the pulvinar and both the VLPFC and the hippocampus was extraordinarily strong. Further, we found a task-by-area interaction whereby functional connectivity between the pulvinar and the hippocampus was greater during the high load WM task, and connectivity between the pulvinar and the VLPFC was greater during the spatial WM task. The results suggest that the pulvinar may be involved in creating and maintaining the task-relevant visual representations that are held in working memory.

◆ **An empirical study on the roles of asymmetry and balance in aesthetics**
K Saraschandra, B Indurkhya (Cognitive Science Laboratory, International Institute of Information Technology, Hyderabad, India; e-mail: ksaras@gmail.com)

Our goal is to investigate how spatial arrangement of elements affects one's aesthetic perception of a visual composition. We focused on compositions of rectangles generated by varying structural properties of Mondrian paintings. In the first experiment, two sets of variations of a Mondrian were created by rearranging the rectangles and altering the colour configuration, respectively. Thirty-six participants rated these compositions for visual balance on a 1 – 7 Likert scale. It was found that the arrangement of rectangles had little impact on visual balance, thereby implying that the sizes and aspect ratios of the rectangles play a dominating role in determining balance. To verify this, we conducted a follow-up experiment where sizes and aspect ratios of rectangles in six Mondrians were altered such that a vertical or a horizontal line divided the composition in equal halves. Alterations where a horizontal line divided the composition into equal halves was given the least rating for visual balance. Overall, the aspect ratios of the rectangles seem to play a major role in determining visual balance.

◆ **Seen or not seen: effects of memory for unseen items in repeated visual search**
M Höfler, C Körner (Department of Psychology, University of Graz, Austria; e-mail: ma.hoefler@uni-graz.at)

Körner and Gilchrist (2007 *Psychonomic Bulletin & Review* **14** 846 – 851) demonstrated a short-term memory effect in repeated visual search. When subjects searched the same letter display twice for two different target letters they showed a response time benefit for the second search compared with the first search. They had remembered recently inspected letters of the first search and therefore found them faster later on when they became the target. In the presented experiment we recorded eye movements and investigated whether search performance can benefit even if the target of the second search had not been fixated earlier. Therefore, in half of the trials, we presented a target letter in the second search which had been inspected during the first search, while on the other half the target letter had not been fixated. For both conditions we found a search benefit for the second search. This suggests that memory for both seen and unseen items can guide search behaviour although the specific memory mechanisms may be different.

◆ **Perceptual learning by mental imagery**
M H Herzog, E M Tartaglia, L Bamert¶, F W Mast¶ (Laboratory of Psychophysics, EPFL, Lausanne, Switzerland; ¶ Department of Psychology, University of Lausanne, Switzerland; e-mail: michael.herzog@epfl.ch)

In perceptual learning, performance improves when stimuli are presented over and over again. In a bisection task, for example, two vertical outer lines delineate an interval which is bisected by a centre line. Observers indicate whether this centre line is closer to the left or right outer line. Perceptual learning in this task is usually assumed to be mediated by smooth synaptic changes driven by the stimuli. Here, we show that perceptual learning can also occur via mental imagery, ie in the absence of physical stimulation. We presented only the two outer lines of the bisection stimulus and asked observers to imagine the centre line to be closer to the left or right outer line. Surprisingly, performance improved also in this task. Control experiments showed that this improvement of performance cannot be explained by unspecific aspects, such as adaptation to the experimental conditions, etc Hence, perceptual learning can occur without proper physical stimulation, possibly driven by top – down processing only.
[Supported by Pro-Doc Processes of Perception of the SNF.]

◆ **The attentional blink in reverse: retro-active interference in encoding masked visual targets**
M R Nieuwenstein, B Wyble¶ (Department of Cognitive Psychology, Vrije Universiteit Amsterdam, The Netherlands; ¶ Department of Brain and Cognitive Sciences, MIT, Cambridge, USA; e-mail: MR.Nieuwenstein@psy.vu.nl)

Identification of a masked visual target is impaired if it appears within 150 – 500 ms from a preceding target. This attentional blink effect is commonly thought to serve a protective function: Report of the first target is assumed to require a slow and capacity-limited process of working memory consolidation that has to be protected against interference from following stimuli.

Thus far, however, there has been no direct evidence to support this claim. In the present study, we examined how the execution of a demanding task (a speeded odd/even discrimination of a digit) affects identification of a preceding masked target (a letter). We reasoned that if the letter identification task indeed requires a slow and capacity-limited process, then execution of the digit task might interfere with identification of the preceding letter. The results corroborate this prediction: Performance for the letter task was impaired when the digit appeared within less than 400 ms from the letter. This reversed attentional blink confirms that encoding a masked visual target takes about 400 ms.

◆ **Object-based effects of attentional selection due to low-level curvature-based perceptual singularities**

L Diesendruck, O Ben-Shahar (Department of Computer Science and Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Israel; e-mail: nigri@cs.bgu.ac.il)

Recently, textures composed of smoothly varying dominant orientations were shown to generate striking non-smooth percepts. Having no acute feature contrasts, the perceptual singularities in these orientation-defined textures (ODTs) are accurately predicted by a model based on two texture curvatures. Such curvature-based perceptual singularities preattentively segregate textures into perceptually coherent regions which could interact with attentional selection processes as high-level discrete objects have been observed to do. In the current research, textures consisting of either piecewise constant or smoothly-varying orientations were used in a divided attention discrimination task. Participants were asked to determine whether two probes displayed over the textures were identical or not. For both types of textures, participants' discrimination accuracy was found to be significantly higher when the probes were located in the same perceptual area compared to when they were separated by a perceptual singularity. Our results indicate that perceptual singularities in both discontinuous and smoothly varying ODTs interfere with attentional selection processes and hence can be seen as separating the visual field into primitive low-level objects.

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◆ **Electrophysiological correlates of unconsciously triggered inhibitory control**

S van Gaal, K R Ridderinkhof ¶, J J Fahrenfort, V A F Lamme (Cognitive Neuroscience Group [¶ Amsterdam Center for the Study of Adaptive Control in Brain and Behavior (Acacia)], Department of Psychology, University of Amsterdam, The Netherlands; e-mail: S.vanGaal@uva.nl)

To further our understanding of the function of consciousness we need to know which cognitive processes require awareness and which do not. We combined the masking tool with the stop-signal task to test whether masked stop-signals can initiate prefrontal inhibitory control mechanisms, associated exclusively with consciousness. Participants responded as fast as possible to go-stimuli, but were instructed to abort their response when an occasional stop-signal was presented after the go-signal. Awareness of stop-signals was manipulated by masking stop-signals efficiently or inefficiently. Behaviourally, the impact of masked (invisible) stop-signals was reflected in an increase in response times to masked stop trials, compared to a control condition. EEG recordings showed that masked stop-signals elicit two neural events: (i) an early visual event representing the visual encoding of masked stop-signals, and (ii) a somewhat later frontal event, probably reflecting the initiation of inhibitory control mechanisms in the PFC. This finding suggests that unconscious stimuli can influence task interruption, and thus exert a form of cognitive control.

◆ **Load and space exert interacting effects on visual selective attention**

S Caparos, K J Linnell (Department of Psychology, Goldsmiths College, University of London, UK; e-mail: s.caparos@gold.ac.uk)

Many studies have examined the profile of visual attention and how distractor interference depends on the spatial separation between distractors and a target located at the focus of attention (eg, Müller et al, 2005). Using a flanker paradigm with central target presentation, we have recently shown that both perceptual and cognitive load affect the spread of attention (Caparos and Linnell, submitted). We tested the generalizability of this finding to peripheral-target paradigms like those used by most studies of the spatial profile of attention. We replicated our previous findings: attention was more focused with high perceptual load and more spread with high cognitive load. These findings clarify the long-standing debate as to whether the attentional profile is shaped like a gradient or a Mexican hat and imply that: (i) the effect of spatial separation is sensitive to perceptual and cognitive load, and vice versa; (ii) manipulation of cognitive load affects early-selection mechanisms (cf McDonald and Lavie, 2008); (iii) load and space manipulations exert interacting effects.

◆ **Cortical magnification factor and flexibility of visual sampling**
A Shirama, A Ishiguchi¶ (Graduate School of Humanities and Sciences [¶ Department of Human and Social Sciences], Ochanomizu University, Japan; e-mail: shirama@jcom.home.ne.jp)
Is the cortical magnification factor (CMF) a mere constraint of an anatomical structure in the primary visual cortex? We studied several aspects of visual sampling accompanied by CMF through visual search tasks and some methods for scaling CMF. To compensate for the loss of visual acuity, the peripheral stimuli were magnified in inverse proportion to CMF (M-scaling). M-scaling yielded efficient search performance across the visual field in an easy search task, but inaccurate performance regardless of eccentricity in a hard search task. In D(dual)-scaling, the largest stimuli in M-scaling were presented for all eccentricities. Under this condition, the reduction of peripheral visual acuity was compensated while maintaining inhomogeneity of the visual field. D-scaling also brought about efficient performance in an easy search task, but unexpectedly-strong eccentricity effect in a hard search task. In sum, CMF only causes a preference for central vision in a hard search task and achieves a balance between simultaneous sampling over a wide area of the visual field and attentional prioritization on central vision.
[Supported by a JSPS Research Fellowship for Young Scientists.]

◆ **Change blindness: the longer the better**
S Wilson, P A Goddard (Department of Psychology, University of Lincoln, UK; e-mail: swilson@lincoln.ac.uk)
Arrays of 8, texture-defined rectangles were used as stimuli in a one-shot change blindness (CB) task where there was a 50% chance that one rectangle would change orientation between stimuli. The effects of CB were reduced by cueing the spatial location of the change in either the first stimulus or, importantly, the interval. This supports the idea that a representation of the first stimulus is formed and persists through the interval before being 'overwritten' by the second presentation of the stimulus (Landman et al, 2003 *Vision Research* **43** 149 – 164). Previously we used eighty-five naive observers to investigate task difficulty using large and small rectangles (Wilson et al, 2005 *Perception* **34** 146 – 147). Here we used two experienced observers to test if the representation remains robust across longer intervals. Observers showed steady performance across the interval suggesting a robust representation up to an interval of 5000 ms. We consider two possible explanations: (i) a pre-attentional representation may last much longer than previously expected; (ii) observers are using a strategy.

◆ **Your eyes go before you know**
M Donk, W van Zoest (Department of Cognitive Psychology, Vrije Universiteit Amsterdam, The Netherlands; e-mail: w.donk@psy.vu.nl)
The aim of the present study was to investigate how saccadic target selection is related to people's awareness concerning the saliency and identity of a target. Observers were presented with displays consisting of multiple homogeneously oriented line segments and two differently oriented line segments. They were instructed to make a speeded eye movement to either the most salient line segment in the display (Experiment 1) or the only right-tilted element in the display (Experiment 2). Simultaneously they had to manually indicate whether they believed they had correctly selected the target. The results demonstrated that, irrespective of instruction, short-latency eye movements were saliency driven whereas long-latency eye movements were not. People's awareness concerning the saliency of the saccadic target was generally low whereas their awareness concerning the identity of the target was high. There was no relationship between saccadic target selection performance and people's awareness concerning target saliency (Experiment 1) and target identity (Experiment 2), suggesting that saccadic target selection is primarily driven by subconscious processes.

◆ **Luminance effects of competing cues on facilitation and inhibition of return (IOR)**
Y Zhao, D Heinke, G W Humphreys (Behavioural Brain Sciences, School of Psychology, University of Birmingham, UK; e-mail: yxz440@bham.ac.uk)
Current theories of visual attention posit that stimuli in the visual field compete for detection and, broadly speaking, features of the winner, eg its spatial location, have a stronger effect on subsequent processing than 'losers' (eg Heinke and Humphreys, 2003 *Psychological Review* **110**(1) 29 – 87). Applied to a spatial cueing paradigm, this account predicts that, when there are competing cues at different levels of luminance, only locations associated with the winner (ie, the brighter cue) should show facilitation or IOR (depending on the SOA). We tested this prediction using high and low luminance cues which yielded identical effects when presented in isolation. However, when the cues were placed in competition there was facilitation and IOR only for the brighter cue, while effects with the dimmer cue disappeared. The data are consistent with competitive models of attention which propose that selection is based on a winner-take-all process.

BINOCULAR VISION AND SPATIAL LOCALISATION

◆ **Visual search in head-worn displays**

A Huckauf, M H Urbina, J Tümler¶, F Doil§, R Mecke¶ (Faculty of Media, Bauhaus-Universität Weimar, Germany; ¶ Fraunhofer IFF, Magdeburg, Germany; § Volkswagen AG, Wolfsburg, Germany; e-mail: anke.huckauf@medien.uni-weimar.de)

Head-worn displays allow the presentation of information in addition to the usual visual stimulation. Although respective systems have been developed for years now, users still complain about visual fatigue and eye strain. In order to investigate visual requirements, we employed a visual search task in which a '0' had to be searched amongst 'O's. The head-worn display, an optical see-through (OST) virtual device (Microvision Nomad) which leaves the visual field relatively unaffected, and a monitor were adjusted so that information was displayed at comparable places in the visual field. We compared searching performances in a pure head-worn display and a pure monitor condition with a switching condition in which half of the stimuli were displayed on each medium. The head-worn display produced worse performance than the monitor. In switching conditions, performance was even worse (although half of the targets were shown on the monitor) suggesting that switching between various media produces costs. Results further suggest that visual attention in depth is rather restricted.

◆ **The number of perceptual alternations occurring during binocular rivalry is limited by attention**

C L E Paffen, I T C Hooge (Experimental Psychology & Helmholtz Institute, Utrecht University, The Netherlands; e-mail: c.l.e.paffen@uu.nl)

Paffen and Alais (2006) recently showed that drawing away attention from a target engaged in binocular rivalry reduced the number of alternations reported. Their finding suggests that the number of alternations is highest when attention is fully available. Based on this, we hypothesize that increasing the number of rival targets in a single display does not increase the number of alternations. We used a display containing either 1, 2 or 3 rival targets. Targets consisted of Gabors with orthogonal orientations placed around the fixation point. Observers were instructed to press a button whenever a perceptual alternation was perceived. Results showed that the number of alternations reported increased only slightly with increasing number of rival targets. Control experiments ruled out the possibility that observers were unable to report alternations occurring at high frequency. We conclude that, as hypothesized, the number of alternations is independent of the number of rival targets in the display. We suggest that the number of perceived alternations is limited by the amount of attention paid to each rival target.

◆ **Differences in orientation judgments made in upper and lower visual space point to upper visual space being specialised for perceptual vision**

R Dyde, L Harris¶ (Centre for Vision Research [¶ Department of Psychology], York University, Toronto, Canada; e-mail: dyde@hpl.cvr.yorku.ca)

Differences in upper and lower visual space have been found in measures of acuity, temporal and contrast sensitivity, attentional resolution, and motor and perceptual response time. It has been suggested that this reflects a specialisation in upper space for extrapersonal (perceptual) tasks with peripersonal lower visual space being more for visuomotor tasks. Is there evidence for a similar differentiation in orientation judgments? Visual space was divided into four quadrants formed by the imagined intersection of the gravitational vertical/horizon. We measured the perceived angular bisector of each quadrant in twenty-four observers against a visual background which was either grey or a natural scene tilted $\pm 22.5^{\circ}$. Against both tilted backgrounds, bisectors within upper visual space were shifted more towards the background orientation than those in lower space. Observer variance was consistently lower in the upper visual space for all three background types. As such, judgments in upper visual space were more labile yet more precise. Our results support the suggestion that upper visual space may be specialised for context dependent, perceptual processing.

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◆ **Psychophysical point**

H Ono, E G González, P Najafi (Centre for Vision Research, York University, Canada; e-mail: hono@yorku.ca)

In geometry, a point has a location but no area; therefore, a geometrical point is an abstraction and does not exist in the physical world. A series of experiments showed that the visual system treats a small dot as a point. In Experiment 1, Emmert's law failed for a small point afterimage; the apparent size of the dot afterimage did not change for different distances. In Experiment 2, a constant retinal image size was placed in conflict with convergence eye movements. A fused small dot consistently appears to move in depth, whereas a fused large disc appears to be stationary.

In Experiment 3, we placed the constant retinal image size in conflict with a motion parallax cue. Motion parallax was an effective cue to depth for small dots but not for larger discs. We hypothesize that the discriminability of a dot as indicated by its Weber's fraction is low in comparison to that of larger discs (we may have tested this by the time of the ECVP meeting).

◆ **Perception of depth from linear perspective and binocular information in a chimpanzee**
T Imura, M Tomonaga, A Yonas¶ (Primate Research Institute, Kyoto University, Japan; ¶ Institute of Child Development, University of Minnesota, Minneapolis, USA; e-mail: imura@pri.kyoto-u.ac.jp)

We examined the perception of depth from linear perspective and binocular information in a chimpanzee by using a real Ames trapezoidal window. When viewed monocularly, the window appears to be slanted in depth for humans, although in reality the display is not slanted (it is presented perpendicular to the line of sight). That is, the larger side of the trapezoidal window appears to be closer than the smaller side under monocular viewing, while binocular viewing provides information for the actual slant. We tested the effect of linear perspective and binocular depth cues on depth judgment on a chimpanzee. The chimpanzee was first trained to point at the closer of two objects with only binocular information for depth available. When tested, the chimpanzee pointed more often to the larger side of the trapezoidal window with monocular viewing. In contrast, the chimpanzee showed no significant preferential pointing under binocular viewing. These results suggest that the chimpanzee perceived the slant in depth of the display by using linear perspective and binocular information.

◆ **Influence of saccadic eye movements and stimulus jumps on perceptual state changes in binocular rivalry**
J P Kalisvaart, S Rampersad, H H L M Goossens (Department of Biophysics, Donders Centre for Neuroscience, Radboud University Nijmegen Medical Centre, The Netherlands; e-mail: j.kalisvaart@science.ru.nl)

Models of binocular rivalry typically assume that percept alternations arise from (synaptic) adaptation processes that influence the competition between retinotopically-organised cell populations. Here we studied how retinotopic imprints of adaptation states influence rivalry by comparing conditions in which the retinal location of rivalling stimuli jumped to the opposite hemisphere either through a saccade or a stimulus displacement. Stimuli were viewed through a stereoscope, and eye movements measured with search-coils. The probability of switching between states depended strongly on pre-jump states and idiosyncratic eye preferences. When the preferred eye was dominant before a stimulus jump, switching probability was low, but when the non-preferred eye was dominant beforehand, switching probability was comparatively high. In the saccade condition, transition probabilities changed such that the preferred eye was less likely to become/stay dominant after a saccade than after a stimulus jump. Dominance 'survival times' changed accordingly. These results indicate involvement of extra-retinal signals in binocular rivalry, as one might expect from the fact that visual stimuli are perceived stable in space despite eye movements. [Supported by NWO grant 864.06.005 (ALW VIDI to JG).]

◆ **Perceived number of depth layer defined by discrete motion parallax**
T Kayahara (School of project design, Miyagi University, Japan; e-mail: kayahara@myu.ac.jp)

The motion parallax is one of important monocular cue for our visual depth perception, and the animation movie has traditionally used this cue to build virtual 3-D space on 2-D screen, because the traditional animation is drawn on the multi-layered transparent sheet and the method is suitable to provide motion parallax cue. In this study, perceived number of depth-layer defined by the discrete velocity-difference of the abstract content (small square patch) on the CRT screen like a traditional animation movie was examined to evaluate whether the perceived number of depth-layer is in proportion to physical number of that when the variation of velocity difference (the number of physical depth-layer) and the number of content in one depth-layer increased. In the results, the perceived number of depth-layer was not in proportion to physical number of layer defined by motion parallax, and was saturated at a number which depends on subjects and the number of content in one layer. When the physical number of content decreased, perceived number of depth-layer also decreased.[Supported by MIC, Japan (SCOPE 061303034)]

◆ **Feature-selective inhibition during binocular suppression: evidence for pattern rivalry**
M L T Vergeer, R van Lier (NICI, Radboud University Nijmegen, The Netherlands; e-mail: m.vergeer@nici.ru.nl)

It has been argued that binocular rivalry occurs as a result of competition between monocular channels (eg eye competition). However, some recent literature favours a pattern competition

account of rivalry, in which rivalry occurs between incompatible (binocular) pattern representations. In this current study, we investigated feature-specific aspects of dichoptic suppression. Three coloured gratings were presented simultaneously next to each other to one eye on a dichoptically presented grid. One of the two flanking gratings had the same colour and orientation as the central grating. All three gratings were suppressed by presenting high-contrast elements to the other eye. After 600 ms, the flanking suppressors were removed and the flanking gratings became visible. Results show that the grating dissimilar to the suppressed central grating became visible first, both for the intraocular and interocular condition. This is evidence for feature-specific inhibition during binocular suppression. These findings support the idea that all presented visual information reaches higher visual areas and favour a pattern competition account of binocular rivalry.
[Supported by an NWO grant (to MV).]

◆ **Interaction of occlusion cues with stereo disparities: texture captured by occlusion cues and its breakdown by stereo cues**
N Kogo, V Froyen, J Wagemans (Department of Psychology, University of Leuven, Belgium; e-mail: nkogo@esat.kuleuven.be)
The 3-D reconstruction of the 2-D retinal images is a vital function for the visual system. It uses several depth cues which must be integrated properly. We investigated the interaction between occlusion cues and stereo disparities using various occlusion-based illusory figures (eg, the Kanizsa square and its variations), as well as arbitrary or silhouette surfaces surrounded by inducers that suggest occlusions. When a texture with repetitive patterns was given in the background, the texture within the central area was perceived to be higher than the background (closer to the viewer) as if it was lifted up by the illusory surface. Changing the stereo disparities of the inducers resulted in lifting up or down the captured texture along with the changing height of the inducers. Furthermore, when disparities were given in the central area in the direction opposite of the occlusion cues, it was able to bring down the texture to the background. We report this phenomenon and its dependency on the sequence of the disparity changes.

◆ **Quickly finding a different slant: search before or after cue combination**
R Sousa, E Brenner¶, J Smeets¶ (Instituto de Educação e Psicologia, University of Minho, Portugal; ¶ Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands; e-mail: ritass@gmail.com)
A single target with a different slant than the other objects is found very quickly in a visual search task, irrespective of the number of other objects (parallel search). Surface slant can be inferred from the 2-D images on the retinas in various ways. The different cues are then combined to get a single estimate of slant. Are the individual cues or is the combined percept responsible for us quickly finding the target with a different slant? To find out we compared combinations of two slant cues. The cues that we chose are retinal shape and binocular disparity. We compared search times for conditions with the same differences between the target and the other objects in each individual cue, but the two cues either indicated the same slant or opposite slants. Subjects systematically found the target faster when the cues indicated the same slant. We conclude that the fast visual search for slant is based on the combined percept, rather than on the individual cues.

◆ **The illusion of misalignment in the Poggendorff figure is modulated by early visual processing**
I Shoshina, L Medvedev¶, E Olada, E Fedorova¶, E Lubgan (Faculty of Psychophysiology, Siberian Federal University, Krasnoyarsk, Russia; ¶ Faculty of Physiology, Krasnoyarsk Staat Pedagogical University, Russia; e-mail: shoshinaii@mail.ru)
Features of the geometrical figures causing the Poggendorff illusion in the Jastrow modification were investigated. We recorded event-related potentials of thirteen right-handed females in a visual classification task. We used a set of different stimuli which were all composed of five identical elements. Figures differed from each other only by angle of inclination of lateral segments. The control figure had an inclination angle of lateral segments 0.164 radians and did not cause the Poggendorff illusion. These stimuli allow us to differentiate the processing of collinear elements and illusory figures. The subjects reacted to a figure causing illusion by pressing a button. The visual P100 in response to the illusory figure was significantly larger compared to the other collinear stimulus. The visual N170 in response to the illusory figure was significantly smaller compared to the other collinear stimulus (symmetric parietal, occipital, and temporal areas). This is taken to indicate that the illusion of misalignment in the Poggendorff figure is modulated by early visual processing.
[Supported by Siberian Federal University.]

◆ **Stereopsis contingent on binocular rivalry suppression phase**
T Knapen, J van Boxtel (Physics of Man, Helmholtz Institute, Utrecht University, The Netherlands; e-mail: tknapen@gmail.com)
In normal vision, the visual system takes advantage of dissimilarities between the images in the two eyes to reconstruct 3D structure in the outside world. However, when the dissimilarities are increased above a certain value, rivalry between the eyes' images ensues. Normally it is thought that the occurrence of rivalry precludes stereopsis in a given spatial frequency band. We use a binocular rivalry stimulus in which one eye receives a tilted grating and the other eye receives a plaid consisting of a matchable grating and an orthogonal grating. These half-images engage in binocular rivalry. Controlling perceived state by use of flash suppression we show that stereopsis does not occur when the plaid percept is dominant, whereas stereopsis is unhindered when the grating is perceived. In a second experiment we show that the elevation of disparity discrimination thresholds is highly dependent on the contrast of the plaid's unmatched grating. Our results suggest that suppression of stereopsis in binocular rivalry may be orientation-dependent.

◆ **A closer look at Hering's law: eye dominance relates to deviations under different conditions of vergence and smooth pursuit**
M Wagner, WH Ehrenstein¶, H Eichenstein, B Ben-Moshe, T Shamir (Ariel University Center of Samaria, Ariel, Israel; ¶ Leibniz Research Center for Working Environment and Human Factors, University of Dortmund, Germany; e-mail: wag.michael@gmail.com)
A single generator is supposed to drive both eyes by identical amounts of innervation (Hering's law) for binocular vergence and smooth pursuit to achieve symmetrical left- and right-eye movements. Here we report slight, but systematic deviations from Hering's law related to functional and cortical eye dominance (Shapiro's test). Twenty participants tracked circular targets moving horizontally at sinusoidally modulated or constant velocities ($2^\circ\ s^{-1}$ to $5^\circ\ s^{-1}$) on a 35° trajectory, or fixated at a looming target (a circle increasing in diameter from 0.5° to 7.8° within 6.9 s). Recorded eye movements (EyeLinkII system) showed that the non-dominant eye lagged behind the dominant and exhibited higher saccade rates and amplitudes. Virtual motion in depth (looming) elicited vergence responses similar to those elicited by real motion in depth, again with interocular differences (higher initiating saccade amplitude components in the dominant eye). Contrary to Hering's law, our results support Helmholtz's notion that movements of each eye are programmed independently; they further suggest that eye dominance is functional in achieving binocular coordination.
[Supported by the Smith Foundation for Psychobiology (Project 803530).]

◆ **The effect of foveal contour interaction on a spatial resolution task under dichoptic, half-binocular, and binocular conditions**
X Masgoret, C M Suttle, L J Asper, J Alexander (School of Optometry, The University of New South Wales, Sydney, Australia; e-mail: z3197496@student.unsw.edu.au)
Previous masking research in contrast detection demonstrates masking due to the presentation of a peripheral stimulus (Meese and Hess, 2005 *Vision Research* **45**(1) 9 – 15). This effect was reduced by interocular feature matching of the mask (half-binocular condition) and further still by interocular feature matching of both test and mask (binocular condition). The purpose of the present study was to determine the effect of a similar masking paradigm, on a spatial resolution task in which a Landolt C is masked by contour interaction (CI) bars. The CI effects that occur during dichoptic, half-binocular and binocular viewing were investigated in twenty normally sighted adults using a 2/1 double staircase. Our results indicate that resolution acuity is degraded when CI bars are presented to the fellow eye (dichoptic condition), and this effect is reduced in the half-binocular condition. Our findings are consistent with the aforementioned previous work, suggesting that there are common mechanisms underpinning these masking effects in contrast detection and spatial resolution tasks.

CLINICAL ASPECTS

◆ **Cortical haemodynamic response to coloured gratings**
A J Wilkins, P Tang, J Irabor, L Baningham, L Coutts (Department of Psychology, University of Essex, Colchester, UK; e-mail: arnold@essex.ac.uk)
We measured the haemodynamic response to achromatic and isoluminant coloured gratings using near infrared spectroscopy of the occipital cortex. The response to coloured gratings was generally greater than that to achromatic gratings. The size of the change in the oxygenated haemoglobin signal in response to a coloured grating increased with the difference between the two component colours, (i) when the difference was expressed as CIE UCS delta E*, and also, to a lesser extent, (ii) when the difference was expressed as cone contrasts. In three further studies, using gratings with a wide variety of colour pairs, the difference in colour (CIE delta E*) was

positively correlated with the rated aversiveness of the grating, the relationship explaining 10 – 60% of the variance. Given the elevated haemodynamic response to gratings in migraineurs, and their greater discomfort from gratings, the results may help to explain the efficacy of coloured filters in reducing visual discomfort.
[Supported by C Cooper, C Elwell, W Collier.]

◆ **Spatial alignment over foveal scotomas**
M D Crossland, P J Bex¶ (UCL Institute of Ophthalmology, London, UK; ¶ Schepens Eye Research Institute, Harvard Medical School, Boston, USA; also UCL Institute of Ophthalmology, London, UK; e-mail: m.crossland@gmail.com)
The absence of short wavelength cones in the human fovea causes a blue scotoma of approximately 20′ diameter. We explored properties of spatial completion over this blue scotoma using a Vernier task and a modified Kanizsa figure within and outside the scotoma. Alignment thresholds on a blue Vernier task with line separation of 10′ (inducing filling-in) were not significantly different across the foveal scotoma and at 16′ eccentricity. In a control condition using green bars, performance was better at the fovea than at 16′ eccentricity. In our second task, subjects were unable to complete an illusory contour over the foveal blue scotoma. Preliminary clinical data show that people with macular disease are able to perceive illusory contours over their scotoma. These data indicate that filling-in over the foveal blue scotoma does not improve spatial alignment, and that completion over the blue scotoma is more qualitatively similar to that over the physiological blind spot (Maertens and Pollmann, 2007 *Journal of Cognitive Neuroscience* **19** 91 – 101) than to that over a retinal lesion.
[Supported by the Wellcome Trust (UK).]

◆ **Can synesthetes count on colours?**
T Gebuis, T C W Nijboer, M J van der Smagt (Experimental Psychology, Utrecht University, The Netherlands; e-mail: T.Gebuis@uu.nl)
Grapheme-colour synesthetes explicitly report seeing a colour when a number is perceived but not vice versa. Recent studies revealed that these interactions are, in fact, bidirectional. In an event-related potential (ERP) study, using both a number/colour and a colour/number priming task, we investigated which neuronal processes (eg early perceptual or late attentional) underlie these interactions. In addition, we compared two distinct groups of synesthetes (projectors vs associators) to investigate whether different mechanisms underlie these two forms of grapheme-colour synesthesia. The results show that priming in both directions leads to increased reaction times for incongruent compared to congruent trials. This congruency effect was also present in the ERP data with prolonged P3 latencies for incongruent compared to congruent trials. No early perceptual effects were found, indicating that priming in both directions affects the same ERP component. In addition, the ERP correlates did not differ between projector and associator synesthetes, suggesting that synesthesia might be a more unitary phenomenon than previously thought.

COLOUR AND BRIGHTNESS

◆ **The role of spatial articulation in Agostini and Galmonte reversed lightness induction Necker cube**
A C G Galmonte, A Gherzil¶, T A Agostini¶ (Department of Psychology and Cultural Anthropology, University of Verona, Italy; ¶ Department of Psychology, University of Trieste, Italy; e-mail: alessandra.galmonte@univr.it)
Agostini and Galmonte (2002 *Psychological Science* **13** 88 – 92) offered a display in which a gray surrounded by black is perceived as darker than an identical gray surrounded by white because of global induction effects elicited by grouping factors, showing that, at least under certain conditions, higher-level factors prevail on lower-level factors, ie the lightness induction produced by the global organization principle of perceptual belongingness prevails on retinal lateral inhibition. The present study was aimed to test whether the lightness induction produced by perceptual grouping does depend on the configuration spatial articulation. In order to test this hypothesis we systematically manipulated the spatial articulation, starting from the original Agostini and Galmonte configuration and then gradually decreasing its complexity. Observers had to perform a global judgment, matching the lightness of the induced elements on a Munsell scale. We found that the lightness induction produced by belongingness is modulated by the spatial articulation level. Results are interpreted in the light of previous studies on the relationship between lightness induction and spatial articulation.

◆ **Width of colour categories predicted by discrimination thresholds**
C Witzel, K R Gegenfurtner, T Hansen (Department of Experimental Psychology, Justus-Liebig-University of Gießen, Germany; e-mail: Christoph.G.Witzel@psychol.uni-giessen.de)
In order to investigate how the perceptual continuum of colours is translated into categories we studied how discrimination thresholds are distributed among colour categories. In particular, discrimination thresholds can be considered as local distance units for perceptual equality in that the threshold of a particular test colour is comparable to the one of another test colour. Therefore, our method allowed to test whether category boundaries are tuned to equalize the discriminative power of each basic colour category. We measured the hue discrimination thresholds along a colour circle in the Derrington – Krauskopf – Lennie (DKL) colour space with approximately equal saturation. We also determined the boundaries of the colour categories that correspond to the basic colour terms. We found that the correlation between the width of the categories and the discrimination threshold within each category was above 0.9 for our two observers tested so far. However, discrimination thresholds did not completely determine category extensions, so that the numbers of discrimination thresholds per category still vary substantially from 5 to 11 for the different categories.
[Supported by a stipend of the Justus-Liebig University (to CW) and by the German Science Foundation (DFG).]

◆ **Visual texture affects the perceived unpleasantness of colours**
D R Simmons, C L Russell (Department of Psychology, University of Glasgow, UK; e-mail: david@psy.gla.ac.uk)
Yellowish and greenish browns are generally perceived as unpleasant colours, whereas saturated hues are pleasant [Simmons, 2006 *Journal of Vision* **6**(6) 251a]. To what extent is this result independent of visual texture? Ten close-up photographs of visual textures (rabbit fur, water, human skin, marble, apple, tree bark, feathers, mud and vomit) were presented three at a time in all possible combinations. Participants were asked to choose which of the three they found most unpleasant in each trial. Ten matched homogeneous colours were presented in the same way. Consistent with previous data, the brownish homogeneous colours were ranked as most unpleasant whereas the more saturated colours were the least unpleasant. However, the addition of texture significantly changed these rankings (eg rabbit fur changed from highly unpleasant to pleasant, but human skin became highly unpleasant). Most participants were unable to name the textures accurately at debriefing. These results suggest that there may be universal emotional reactions to certain texture classes, as well as to certain colours, that probably have their roots in early development.

◆ **Decoding higher order colour signals in human visual cortex**
E Goddard, D J Mannion, J S Mcdonald, S G Solomon¶, C W G Clifford (School of Psychology [¶ School of Medical Sciences], University of Sydney, Australia; e-mail: ering@psych.usyd.edu.au)
We used fMRI to test for higher order cortical representations of colour capable of classifying stimuli that cannot be distinguished by the postulated red – green (L-M) and violet – yellow (S) subcortical opponent channels. Subjects viewed each of two patterns modulating in colour between orange – cyan or lime – magenta. Multivariate pattern classifiers restricted to each of several visual areas were trained to discriminate the two patterns. The classifiers were trained on signals from 9 trials and tested on a tenth; this procedure was repeated 10 times. Classifiers performed significantly better than chance—impossible on the basis of signals from the opponent channels alone—as early as V1. The success of the classifiers implies: (i) subcortical chromatic channels are recombined early in cortical processing to form novel representations of colour; (ii) non-uniform spatial mapping of these representations of colour in striate and extrastriate cortical areas.
[Supported by grants from the Australian Research Council and The University of Sydney (to CC).]

◆ **The influences of local and lateral cone modulation on rod thresholds**
H Sun, R C Baraas (Buskerud University College, Department of Optometry and Visual Scienses, Kongsberg, Norway; e-mail: hao.sun@hibu.no)
Signals from rod and cone photoreceptors do not have separate pathways. If stimulation of rods affects cone-mediated thresholds, then cone stimulation should affect rod-mediated thresholds [Buck, 2004 *The Visual Neurosciences* volume 1, Eds L M Chalupa, J SWerner (Cambridge, MA: MIT Press) pp 863 – 878]. Here, the influence of local and lateral cone modulation on rod thresholds was investigated. Rod and cone isolating stimuli were generated with a 2-channel 4-primary Maxwellian view system using method of silent substitution. Detection thresholds for a 100-ms 1-deg rod-isolating pulse were measured at 6-deg extrafovea (nasal) against an adapting background which

was either (i) a 12-deg steady full field, (ii) a 1-deg cone-modulating local field, (iii) a 12-deg cone-modulating annulus, or 4) a 12-deg cone-modulating full field. The cone modulation was a 0.5-Hz temporal sinusoid along either L+M or L−M cone axis, and did not modulate rods. Results show that rod thresholds were elevated for the local and the annulus (lateral) modulating fields, but were reduced when both were simultaneously modulated (ie full-field condition).
[Supported by the Norwegian Research Council Grant 176541 V10.]

◆ **Symmetry influences colour perception: the transparent sheet model**
J Ninio (Laboratoire de Physique Statistique, Ecole Normale Supérieure, Paris, France; e-mail: jacques.ninio@lps.ens.fr)

Two photographs derived from a same negative but processed in different baths may present noticeable hue differences. However, when a natural or a computer generated picture is juxtaposed to a mirror-image visibly differing in hue, two-thirds of the observers hardly notice the difference along the symmetry axis. The effect works better with complex images. Grey level differences on the two sides of a symmetry axis are also perceptually reduced, but less strikingly. Recent neuropsychological studies (Pflugshaupt et al, 2007 *Neuropsychologia* **45** 2078 – 2091) suggest that when an image is examined, its mirror-image is also automatically represented in the brain. I propose that such an apparent dual encoding may be mediated by a single representation, which is accessed from two sides, like a picture printed on a transparent sheet. When colours are assigned to such a sheet, they apply to both the image and its mirror-image. Thus our phenomenon would differ from the classical neon and watercolour spreading effects, and might offer a clue about the brain's representation of shapes.

◆ **Effects of luminance contrast on chromatic induction**
A Kondo, H Yamamoto (Graduate School of Human and Environmental Studies, Kyoto University, Japan; e-mail: kondo@cv.jinkan.kyoto-u.ac.jp)

To examine the possibility that luminance contrast influences chromatic induction, a series of asymmetric colour matching was performed. Visual stimuli consisted of test patches and their immediate surround. The test colour alternated between red and green, while the surround colour alternated in opposite-phase or in-phase with the test chromatic modulation. Following the temporal 2AFC staircase procedure, the depth of the test chromatic modulation in the opposite-phase pair was adjusted to that in the in-phase pair. When the test and surround were isoluminant, subjects adjusted the test colors in the opposite-phase to be less saturated to achieve the perceptual match with those in the in-phase. The introduction of luminance contrast dramatically affected the degree of the induction effect. The induction effect decreased when the surround was darker, but increased or remained unchanged when the surround was lighter. These results provide clear evidence that luminance contrast contributes to the chromatic induction.

◆ **Chromatic distribution affects colour constancy**
M P Lucassen, A Gijsenij, T Gevers (Faculty of Science, University of Amsterdam, The Netherlands; e-mail: mlucassen@science.uva.nl)

What happens with our colour constancy performance when varying the chromatic distribution of a stimulus while keeping average chromaticity fixed? We synthesized images composed of about 900 colour patches varying in CIE L*a*b* values. Both the average chromaticity and the chromatic distribution were varied. The 2-D Gaussian distribution of a*b* values was either circular, or ellipsoid with the variance in a* 5 times that in b*, or vice versa. Four illuminants (equidistant from the neutral point) were used to simulate illumination of the colour patches by daylight variants. Using triad-comparison, observers judged the colour naturalness of the scenes under two illuminants (6 illuminant pairs possible) against the scenes under neutral reference illumination. They indicated which of the two scenes (illuminants) reproduced the colours of the reference scene most closely. Our results show that when the dominant axis in the chromatic distribution is parallel to the direction of the illuminant change, colour constancy is best. We conclude that colour constancy depends on the chromatic distribution of the scene.

◆ **The effect of luminance pseudo-ramps on simultaneous lightness contrast**
D Zavagno, O Daneyko¶ (Department of Psychology, University of Milano-Bicocca, Milan, Italy; ¶ Department of Psychology, University of Trieste, Italy; e-mail: daniele.zavagno@unimib.it)

Luminance pseudo-ramps (LPS) consist of sets of homogenous grey surfaces organized from the darkest to the brightest. An example is your typical neutral value Munsell scale used in lightness matching tasks, in which Munsell chips are linearly organized and equally spaced from 2.0 to 9.5 on a background. It has been shown that LPS can originate glare effects (Zavagno, 1999, *Perception* **28** 835 – 838). The present study combined simultaneous lightness contrast (SLC) with

LPS and Gelb illumination. The results, compared with those from another study that employed SLC with actual luminance ramps and Gelb illumination, show that LPS affects lightness just as actual luminance ramps do. These results challenge all current models on lightness perception, even those based on illumination–lightness scission, while suggesting a significant role for mechanisms related to illumination perception. However, the results also indicate that such mechanisms are still largely unknown, both in psychophysical and in neurophysiological terms. A basic question that arises from this study is: what constitutes a luminance ramp for the visual system?

◆ **Shadow and highlights are important to determine diffuseness and number of light sources in photographs of real objects**

S F te Pas, S C Pont¶ (Experimental Psychology [¶ Physics of Man], Helmholtz Institute, Utrecht University, The Netherlands; e-mail: s.tepas@uu.nl)

Human observers have been shown to use the direction of the light source to determine whether two objects are illuminated differently, but can they also use other lower-order aspects like diffuseness and number of light sources? We use a teapot, an orange, and a tennis ball from the ALOI database (Geusebroek et al, 2005 *International Journal of Computer Vision* **61** 103–112) to create stimuli either with a single light source that varies in diffuseness or with two light sources that vary in separation. Observers are presented with all three objects on every trial, and have to indicate which one is illuminated differently from the other two. Performance was above chance for most combinations. Moreover, results could be predicted fairly well by the average pixel differences between two photographs of the same object, suggesting that observers were able to extract information about diffuseness and number of light sources from the scenes, despite large differences in shape and material of the objects. A model using only shadow and highlight differences correlates highly with the behavioural data.

◆ **Bauhaus revisited: identifying form and colour preference using a gaze driven evolutionary algorithm**

T Holmes, J Zanker (Department of Psychology, Royal Holloway University of London, UK; e-mail: t.holmes@rhul.ac.uk)

The relationship between colour and form lies at the heart of aesthetic perception. Bauhaus artist Wassily Kandinsky studied this relationship empirically, using basic shapes and three primary colours and claimed a universal preference exists for yellow triangles, blue circles, and red squares. The reliability of the original experiment is unclear and subsequent attempts to replicate this finding have met with little success. Extending the evolutionary algorithm method first presented at ECVP 2007, we were able explore this multi dimensional feature space in a way which allows simultaneous convergence to multiple appealing feature combinations. Samples from a population of coloured shapes were presented on a screen and participants were instructed to locate their preferred colour/shape combination. Eye movements were tracked and the amount of time spent fixating on each shape was used to select subsequent items, until they converged to preferred combinations. Individual preferences vary considerably, however each participant exhibits consistent preferences for certain combinations of colour and form associations even when the space is increased to include secondary colours.

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◆ **Stochastic resonance cannot describe decreasing contrast detection threshold by noise**

T Takahashi, A Yagi (School of Psychology, Kwansei Gakuin University, Hyogo, Japan; e-mail: ToTakahashi@kwansei.ac.jp)

Internal/external noise generally impedes visual signal detection. However, Blackwell (1998 *Vision Research* **38** 267–280) showed that noise decreased contrast detection thresholds (CDT), and used the stochastic resonance (SR) model to account for the phenomenon. The SR model predicts that optimal noise stochastically enhances sub-threshold signal to exceed the threshold. According to the SR model, there is no noise effect when noise exceeds the threshold itself, because of decreasing S/N ratio, and the noise effect is independent of the spatial frequency of the signal. In the present study, we measured the CDT of noise, a Gabor patch (1.5–8 cycles deg^{-1}), and a Gabor patch with noise, as a function of noise contrast. As a result, optimal noise contrasts decreased the CDT twith the 1.5 cycles deg^{-1} Gabor patch with sub- and supra-threshold noise, while there was little decrease with the 8 cycles deg^{-1} patch. This result shows that the noise effect depends on the spatial frequency of the signal, and that the SR model cannot thoroughly describe the decrease in CDT.

◆ **The effect of object familiarity and changing illumination on colour categorization**
Y Ling, L Allen-Clarke¶, M Vurro, AC Hurlbert (Institute of Neuroscience [¶ School of Psychology], Newcastle University, UK; e-mail: yazhu.ling@ncl.ac.uk)
Colour constancy is typically quantified by matching or memory paradigms, using mondrian type stimuli. Here we investigate the effect of object familiarity on colour constancy using a colour categorization task. We employed a setup which allows us to adjust the apparent colours of natural 3-D objects. Observers had to categorize around 200 colours by selecting the appropriate colour name from a list of 8 (red, pink, violet, blue, green, yellow, orange, and neutral) under 4 illuminations, for 4 objects: generic dome, banana, apple, and carrot. The results show that colour category is influenced by both object familiarity and illumination. The yellow category is extended in size for the banana, compared with other objects. Under changes in illumination, categorization boundaries for some colours (eg neutral) remain relatively constant, but vary significantly for other colours (eg orange). Our results illustrate the limitations of mondrian stimuli and achromatic matching, and emphasise the importance of studying colour constancy for natural objects across the entire colour space.
[Supported by the EPSRC.]

EYE, HAND AND BODY MOVEMENTS

◆ **Visual feedback is not essential for children to make the perpendicular bias**
B De Bruyn, A Davis (Department of Psychology, University of Surrey, Guildford, UK; e-mail: b.de-bruyn@surrey.ac.uk)
The perpendicular bias refers to the finding that young children draw lines that protrude at an angle of 45° from the midpoint of an oblique baseline as more perpendicular. This tendency to copy angles of 45 degrees as being closer to 90 degrees can be seen in both spontaneous drawing and in the copying of abstract figures where the oblique baseline is predrawn. Here, we measured whether seeing the drawing hand, the drawn line and indeed the baseline drawn from affect the bias. This open-loop design precluded visual feedback and thus focused on pre-planned aspects only. We used standard figures (baseline 8, testline 4 cm, acute angle 45°) and asked 5- and 6-year-old children to copy the testline. Different orientations of the baseline and directions of the testline were tested. Comparing open loop and closed loop conditions, it was found that, whilst not having visual feedback decreases drawing precision, open loop testing does not affect the perpendicular bias.
[Supported by ESRC grant R238499 awarded to BDB and AD.]

◆ **Visual gaze behaviour of children and adult pedestrians at a signalized road crossing**
C D Egan, A Willis, H Ness, S Stradling (School of Health and Social Sciences, Napier University, Edinburgh, UK; e-mail: c.egan@napier.ac.uk)
Underdeveloped visual search strategies may be a contributing factor to children's involvement in pedestrian accidents. Although laboratory-based research suggests that the ability to detect targets in a cluttered scene may be less efficient in children compared with adults (Trick et al, 2003 *Memory & Cognition* **31** 1229 – 1237), no study to date has examined this using a real-world, roadside setting. The present study compared the visual gaze behaviour of 8-year-old children ($N = 5$) and adults ($N = 6$) during a real-world, road-crossing task, using an eye-tracker. Participants were asked to cross the road when they felt it was safe. Gaze fixation was analysed using frame-by-frame coding. In the 3 s prior to crossing, children fixated 8% of the time on traffic signs and signals, adults 30%. Children fixated more on traffic-irrelevant features such as buildings and trees than the adults. The children's attention to irrelevant features at the roadside concurs with previous laboratory-based studies and is a likely contributing factor to their involvement in pedestrian accidents.

◆ **When visual search takes a rest: searching the same display again after a delay**
C Körner, M Höfler, I D Gilchrist¶ (Department of Psychology, University of Graz, Austria; ¶ Department of Experimental Psychology, University of Bristol, UK; e-mail: christof.koerner@uni-graz.at)
Körner and Gilchrist (2007 *Psychonomic Bulletin & Review* **14** 846 – 851) found a memory recency effect in repeated visual search. When participants searched the same display twice for different targets they found the target in the second search faster when it had been fixated more recently in the first search. In this paradigm the second search started immediately after the end of the first one. In the presented experiment we introduced and varied a short delay between the first and the second search (0 ms, 400 ms, and 800 ms, respectively) in order to test if the recency effect can outlast the delay or if memory decays during such a period. Manual response time data as well as eye movement recordings suggest that the recency effect is robust and memory is

preserved during short retention periods. We discuss the implications of this finding for the properties of the memory system that supports this kind of visual search.
[Supported by the Austrian Science Foundation (FWF).]

◆ **Sources of variability in interceptive movements; is visual resolution a limiting factor?**
E Brenner, J B J Smeets (Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands; e-mail: e.brenner@fbw.vu.nl)
We asked people to hit a moving virtual disk through a virtual goal, and analysed the spatial and temporal variability in the way in which they did so. On the basis of both the amount of variability and the correlation between the variability in various movement parameters we estimated that performance is limited by standard deviations in timing and in positioning the hand of about 20 ms and 4 mm, respectively. Additional variability arises from individual movements being planned slightly differently, being adjusted during execution, or both. A comparison of the above-mentioned standard deviations with estimates of timing accuracy based on published studies in which subjects judged whether two flashes occur simultaneously, and with published estimates of the accuracy of visual judgements of position and velocity, suggests that a better accuracy is not really feasible. We propose that under natural conditions the perceptual resolution rather than motor noise limits performance in interception.

◆ **What can we learn from micro-saccades?**
F Hermens, R Walker, J M Zanker (Department of Psychology, Royal Holloway University of London, UK; e-mail: frouke.hermens@rhul.ac.uk)
During periods of fixation our eyes make frequent micro-saccades, which are believed to prevent fading of the retinal image and are thought to play a role in the perception of illusory motion in static Op Art patterns. More recently, it has been suggested that micro-saccades may be an indicator of covert attention, whereas an alternative view is that micro-saccades reflect motor preparation. To examine these two explanations, we asked participants to either make a delayed saccade towards a target ('pro-saccade') or away from it ('anti-saccade'). If micro-saccades reflect attention, we expect them to be initially directed towards the target for both conditions. However, if they reflect motor preparation, we expect micro-saccades to reverse away from the stimulus in anti-saccade trials. We did not find any directional effects either of the target location or the task, casting doubts on both interpretations of micro-saccades. Instead, we observed a stronger modulation of micro-saccade frequency for anti-saccades than for pro-saccades, suggesting that micro-saccades are linked to the suppression of automatic saccadic responses.
[Supported by the Leverhulme Trust F-07537-Z.]

◆ **Invisible colour cues and their influence on action**
I V Ivanov, A Werner (Centre for Ophthalmology, University of Tübingen, Germany; e-mail: iliya.ivanov@uni-tuebingen.de)
The fast processing of visual features is important for controlling motor actions. Sensorimotor interactions have therefore been proposed to be a property of the dorsal sensorimotor system and to be automatic. Our study aimed at the possible role of the ventral visual stream in sensorimotor interactions. We studied of the effect of subliminal colour in priming fast pointing hand movements. The colour primes were presented with an exposure time of 10 ms and were followed by a spatial mask, which rendered them invisible and at the same time cued the direction of the hand movements. Measuring the reaction times for the pointing we found evidence for priming of fast motor responses by subliminal colour cues. Importantly, the priming effect is not automatic; instead our findings indicate unsupervised perceptual learning of the relation between prime and masking cue, whereby the frequency of the presentation but not the relevance to the task seems to be crucial. The findings suggest a contribution of signals from the ventral stream to the control of action.

◆ **Driving smoother with the tangent point**
F I Kandil, M Lappe (Department of Psychology, University of Münster, Germany; e-mail: kandil@uni-muenster.de)
There are a number of strategies car drivers can employ to negotiate curves. The angle between the tangent point of the inner lane markings and the car's current heading direction is identical to the required steering angle. Alternatively, when drivers fixate points on their future paths, the curvature of optic flow vectors will inform them whether they oversteer or understeer. Nine subjects drove repeatedly on the four loops of a motorway junction for which street parameters were available, while eye-movements, parameters of the car and relations to the lane were recorded. In the first part, we observed which strategy drivers normally use, whereas in the second part, we instructed subjects to use exclusively either the tangent-point or the optic-flow strategy.

We replicated that subjects normally look at the tangent point whereas they do not use the second strategy of their own accord. Further, subjects drive more smoothly in terms of position on the lane and steering stability in the tangent-point condition.
[Supported by EC-Project Drivsco.]

◆ **Eye movements and recognition accuracy are affected by the presence of people in real-world scenes**
K Humphrey, G Underwood (School of Psychology, University of Nottingham, UK; e-mail: lpxkah@psychology.nottingham.ac.uk)

Does the presence of people in a natural scene affect the way we move our eyes? We investigated whether eye movements differed when participants correctly and incorrectly identified stimuli at recognition, and how this was affected by the presence of people. Eye movements were recorded from fifteen participants whilst they inspected photographs at encoding and during a recognition memory test. Half of the pictures contained people and half did not. The presence of people increased recognition accuracy and affected average fixation duration and average saccadic amplitude. Analyses of the order and pattern of fixations showed a high similarity between encoding and recognition in all conditions. Regions of interest (RoI) analyses showed that, on average, 58% of fixations on each 'people picture' fell inside the RoI and 45% of all the time spent on each 'people picture' was focused on the RoI. It is concluded that the presence of people does affect the way we move our eyes in natural scenes, and the results are discussed in relation to the 'Scanpath Theory'.

◆ **Precursory retinal image motion before small-amplitude saccades**
K Mergenthaler, R Engbert (Department of Psychology, University of Potsdam, Germany; e-mail: mergen@uni-potsdam.de)

During visual fixation on a stimulus, miniature eye movements are performed involuntarily and unconsciously. These fixational eye movements can be separated into fast microsaccades and slower components (drift, tremor). The control processes underlying fixational eye movements, especially the role of visual input, are not fully understood. In earlier work, we were able to show that a reduction in retinal image slip precedes microsaccades. To investigate the origin of this reduction, we compared motion before microsaccades in two conditions (fixations on stimulus and in darkness) with motion before small reactive saccades following displacements of the fixation spot. While in darkness participants were instructed to keep the eyes at the memorized fixation position, in the random displacement experiment they had to perform small (0.25 deg and 0.5 deg) reactive saccades to maintain fixation on the target stimulus. Interestingly, we found a similar reduction in retinal image slip before microsaccades independent of the experimental conditions. We conclude that our results are incompatible with direct visual control of microsaccades.

◆ **Differential effects of target onset and target uncertainty on saccade latency distributions in the gap and overlap tasks**
M Rolfs, F Vitu¶ (Laboratoire Psychologie de la Perception, Université Paris Descartes – CNRS, France; ¶ Laboratoire de Psychologie Cognitive, Université de Provence – CNRS, Marseille, France; e-mail: rolfs@uni-potsdam.de)

In the gap task, a fixation point disappears prior to the presentation of a target; in the overlap task, it remains visible. Comparing the two conditions provides an insight into the processes involved in saccade generation. In a previous study [Rolfs and Vitu, 2007 *Journal of Vision* **7**(10.7) 1 – 20], we showed that target onset (luminance increments at the target location) has a strong effect on saccade latencies in the overlap task, but not in the gap task if the target location is highly predictable. In a new experiment, controlling for potential confounds of stimulus configuration and target uncertainty, we replicated this finding, suggesting that saccade preparation is advanced in the gap task. In addition, we found that target onset differentially influences saccade-latency distributions in gap and overlap conditions. In the overlap condition, target onset reduces variability in response times, reducing the percentage of long-latency saccades; in the gap condition, the whole distribution is shifted towards shorter latencies. We discuss alternative models of oculomotor control to account for these findings.
[We thank Reinhold Kliegl for his support; this research was conducted in his laboratory.]

◆ **Reference frames for biological motion inversion effects**
N F Troje (Department of Psychology, Queen's University, Kingston, Canada; e-mail: troje@queensu.ca)

If biological motion point-light displays are presented upside down, performance on most tasks is strongly impaired. We have recently shown that this inversion effect has two entirely different and independent causes. One is due to the inversion of the familiar upright shape. The second

is related to a visual filter tuned to the gravity-constrained local motion of the feet of a human or animal in locomotion. Here, we are investigating whether the two inversion effects operate in retinal coordinates or in gravitational coordinates. We designed two different tasks isolating the structure-from-motion aspect of biological motion, on the one hand, and the mechanism tuned to local motion, on the other hand, and conducted experiments in which either the stimulus or the observer were turned upside down. The results clearly indicate that both inversion effects operate in retinal coordinates and are not affected by vestibular input. Apparently, a heuristic that gravity is aligned with retinal coordinates is replacing a reality check that would require visual-vestibular sensory integration.

◆ **Visual illusions: saccadic and manual responses reveal a similar time-course**
W van Zoest, A Hunt¶ (Department of Psychology, Ophthalmology and Visual Sciences, University of British Columbia, Vancouver, Canada; ¶ Vision Sciences Laboratory, Harvard University, Cambridge, USA; e-mail: wieske@psych.ubc.ca)

Although there is evidence to suggest visual illusions affect perceptual judgments more than actions, many studies have failed to detect task-dependent dissociations. In two experiments we attempt to resolve the contradiction by exploring the time-course of visual illusions on both actions and perceptual judgments. We used a modified Müller-Lyer illusion to probe changes in the effect of illusions on saccadic eye movements and perceptual judgments over time. The results showed that, regardless of whether a saccadic or manual response was made, the illusory bias was larger when responses were based on less information, that is, when saccadic latencies were short, or display duration was brief. The time-course of the effect was similar for both the saccadic and manual responses, suggesting that both modes may be driven by a shared visual representation. Changes in the strength of the illusion over time also highlight the importance of controlling for the latency of different response systems when evaluating possible dissociations between them.

MOTION PERCEPTION AND TEMPORAL ISSUES

◆ **Perception of intentionality in simple, straight motions of schematic shapes**
A Schlottmann, E Ray, S Congiu¶, A Bhutani (Division of Psychology and Language Sciences, University College London, UK; ¶ Cognitive Science, University of Siena, Italy; e-mail: a.schlottmann@ucl.ac.uk)

Discussions of the perceptual cues used for infants' ontological distinctions hold that self-motion appears intentional. If so, then this should also appear for adults. Ninety-one observers judged whether a square looked as if moving on purpose. Its straight-line motion was identical throughout; we varied whether another stationary/moving square or occluder appeared at/close to its origin and end points. A 6 origin × 6 end context factorial (Experiment 1) found smaller end than origin effects. Motion without context elicited the highest ratings, slightly higher than motion originating from contact/proximity to a stationary shape, or with hidden onset. Motion after collision with another shape was by far least purposeful. Eliminating the most/least purposeful origin contexts (Experiment 2) produced stronger end effects, but also strong individual difference: Some observers had a 'free will' view, that motion without external incentive was most purposive, others preferred external goals. Non-rigid, animal-like motion of target/goal also increased ratings (Experiment 3). Overall, adults have well-developed intuitions of intentionality even for simple motions, reflecting perceptual and cognitive factors.
[Supported by ESRC grant RES-000-23-0198.]

◆ **Plasticity unbound: distinct context-driven plasticity with judgments of visual speed**
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Studies of stimulus-driven attention, implicit learning, and memory often employ different/frequent stimuli (eg in repetition-priming, mismatch, and oddball tasks). The relative overall stimulus frequency is considered the primary modulatory variable for behavioural and brain responses. Using judgments of visual speed, we challenge this view showing that standard randomization of different/frequent stimuli confounds the effects of overall and outset stimulus occurrences. Participants judged sets of visual speeds comprising either frequent low or high speeds. Standard and biased randomization of stimuli for presentation made either frequent or infrequent speeds, respectively, to occur mainly at series outset. With standard randomization, speed judgments assumed their levels from the very beginning and did not change across the experiment. With biased randomization (ie on-overall infrequent speeds presented mainly at outset), however, the judgments exhibited a striking gradual change across the trials. Biased randomization uncovers

an unknown kind of judgment plasticity contingent on the opposite relationship of overall and outset stimulus occurrences. Overall- and outset-frequency processing is likely to engage distinct neural mechanisms.
[Supported by the Deutsche Forschungsgemeinschaft DFG grant No. SO 465-7 (to AS).]

◆ **Flicker-induced motion of stationary patterns**
A L Beer, M W Greenlee (Institut für Psychologie, Universität Regensburg, Germany; e-mail: anton.beer@psychologie.uni-regensburg.de)
Visual motion is usually elicited by luminance or feature-defined visual patterns varying in space and time. However, motion can be perceived even with stationary patterns containing elements of different luminance. Correlates for this type of illusory motion were found in direction-selective cells of macaque primary visual cortex (V1) and it was proposed that the motion percept results from luminance-defined latency differences of simple cell responses. We tested this notion and presented flickering stationary patterns containing dark and bright elements at different contrast levels. Our results showed that stationary patterns were consistently perceived as moving in a bright-to-dark direction. However, the percept of motion was most pronounced when dark and bright elements were of equal contrast rather than different contrast. Our findings suggest that illusory motion of flickering patterns may not be fully explained by differences in response latency of V1 cells. Alternative low-level mechanisms of illusory motion detectors are discussed.

◆ **An fMRI tests battery for visual motion processing**
D Bernhardt, M Raabe, M W Greenlee (Institute for Experimental Psychology, University of Regensburg, Germany; e-mail: daniela.bernhardt@gmx.net)
Recently, several tests batteries for the systematic assessment of deficits in visual motion processing have been developed (eg Vaina et al, 2002 *European Journal of Neurology* **9** 463 – 477). The common approach is to combine paradigms referring to a variety of aspects in motion processing to give a detailed description of the subjects' abilities. So far these batteries have not been adapted for functional imaging. We assembled an fMRI compatible motion tests battery including functional localiser and three experimental tasks: motion coherence detection (MC), recognition of biological motion (BM), and structure from motion (SFM). A validation of our design in healthy subjects shows expected (eg Sunaert et al, 1999 *Experimental Brain Research* **127** 355 – 370) and plausible task-related activation patterns (eg hMT+, inferior temporal lobe, superior temporal and intraparietal sulcus during BM; activity in the intraparietal sulcus, inferior and middle frontal gyrus, and posterior parietal cortex during the difficult MC condition). We are currently applying our battery for the assessment of patients with lesions in parietal brain areas.
[Supported by the German Federal BMBF project 01GW0653 (to all three authors).]

◆ **Blind saccades: accurate oculomotor responses to invisible motion stimuli under urgency conditions**
C De'sperati, G Agrusta, M Balderi, R G Grgic (Visuo-motor Functions Laboratory, Università Vita-Salute San Raffaele, Milan, Italy; e-mail: desperati.claudio@hsr.it)
Recently we revealed an early, transient dissociation between saccades and perceptual localization. Here we asked how well horizontal visual motion (random-dot kinetogram, coherence 0 – 60%) instructed the direction of saccades triggered by an imperative stimulus presented during motion integration (0.2 – 1.0 s after stimulus onset). Saccadic performance (% correct) and subjective visibility of motion direction (five-point absolute rating, re-calibrated to 50 – 100 scale) were measured. On average, saccadic threshold was lower than perceptual threshold. Saccadic performance was weakly correlated with stimulus visibility, and was better than chance even at null visibility. At 60% coherence, almost all trials were correct, and associated with full visibility; in contrast, at 15% and 30% coherences, correct trials (91% of total trials) were associated with poor visibility. Remarkably, this dissociation between performance and visibility decreased with time: at 30% coherence, the initial dissociation disappeared $\sim$1.5 s after motion onset: by that time, both performance and visibility were almost perfect. These findings suggest that saccades can access early visual motion signals during the integration time, before visual awareness is reached.

◆ **Neural architecture of cortical motion feature detection, figure – ground segregation and selective visual attention**
F Raudies, H Neumann (Institute of Neural Information Processing, University of Ulm, Germany; e-mail: florian.raudies@uni-ulm.de)
V1 neurons detect features and carry information about figure – ground segregation and shape related attention (Roelfsema et al, 2007 *Neuron* **56** 785 – 792). In relation to feature responses figural shape and attention modulation signals occur temporally delayed. We propose a novel architecture of cortical processing in model areas each described by stages of feeding input

processing, linking feedback, and shunting centre–surround normalization (Bayerl and Neumann, 2004 *Neural Computation* **16** 2041–2066). Brief motion of textured shapes and background is signaled by V1 neurons and MT integration cells. MT contrast cells enhance via modulating feedback V1 cells belonging to figural parts and establish shape representations in V2 and V4/IT. A (fixated) target is selected in working memory and a spatial attention signal modulates via feedback MT activities which in turn modulates corresponding V1 neurons. The different stages of recurrences cause different temporal delays of response amplification as observed in V1. The model unifies experimental findings about integrating localized feature detection with global configuration information and generates testable predictions varying feature parameters of moving shapes.
[Supported by EU-IST Cognitive Systems, project 027198, Decisions in Motion.]

◆ **Dynamic vision: linking perceptual performance to motor skills**
G Jendrusch, D Engel, W H Ehrenstein¶, P Platen (Department of Sports Medicine and Sports Nutrition, Ruhr-University Bochum, Germany; ¶ Leibniz Research Center for Working Environment and Human Factors, University Dortmund, Germany; e-mail: gernot.jendrusch@rub.de)

The high motion and action speeds of most sport activities demand an extraordinary capacity and precision of dynamic vision. We investigated whether perceptual performance might specifically relate to sports skills. A total of 187 young adult top athletes (German national or first league teams) participated: twenty-nine baseball players, fifty-six football players, sixty-seven hockey players, all male, and thirty-five female hockey players. Dynamic vision was assessed by a form-from-motion analogue to the Landolt test (Wist et al, 1998 *Journal of Neuroscience Methods* **80** 41–47). Mean dynamic visual performance was found to be lower in female than male hockey players (77.3, 2.34 SE vs 83.3, 1.60 SE; $p < 0.05$); among males, it was better in baseball than in football players (87.3, 2.41 SE vs 81.7, 1.74 SE; $p < 0.05$). Static visual acuity, however, did not differ among the four groups ($p > 0.10$). Our data suggest sex-related differences among top athletes together with genuine links between visual performance and motor skills that require further investigation.

◆ **Uncued prestimulus BOLD activity in hMT+ biases the perception of near-threshold coherent motion**
G Hesselmann, C A Kell¶, A Kleinschmidt (INSERM U562, CEA Neurospin, Gif/Yvette, France; ¶ Department of Neurology, University of Frankfurt, Germany; e-mail: g.hesselmann@gmail.com)

Recent evidence suggests that slow fluctuations (< 0.1 Hz) in ongoing fMRI BOLD activity impact on perception and behaviour. Here, we show that ongoing activity in hMT+ biases the perception of near-threshold coherent motion. In our experiment motion coherence thresholds were determined for each subject ($N = 12$) using a dynamic random dot display. During the experimental sessions brief events (355 ms) of subliminal (1% coherence), supraliminal (30% coherence) and periliminal (individual threshold) coherent motion were presented with long and variable inter-stimulus intervals between them (range 20–40s). On each trial subjects reported whether they had perceived a 'coherent' or 'random' motion stimulus. BOLD signal time courses were analysed separately for both percepts. In hMT+ and hV3A 'coherent' percepts yielded a larger stimulus-evoked response (at 6 s) than 'random' percepts. The immediate pre-stimulus baseline (at 0 s) showed larger activity for 'coherent' trials in right hMT+, but not in further motion-sensitive or attention-related regions. We conclude that ongoing activity in brain areas closely linked to a specific function such as motion integration can bias perceptual decisions.

◆ **Perception of animacy from a single moving object**
J Schultz, L Dopjans (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: johannes.schultz@tuebingen.mpg.de)

Humans attribute animacy to very simple objects displaying self-propelled or goal-directed motion. To test attribution of animacy parametrically using classical psychophysical techniques, we created animations consisting of a single dot that appeared either self-propelled (modelled on the movements of a fly) or moved by an external force (modelled on a leaf drifting in the wind). Both animations were built using the same movement equation and differed in speed and acceleration profiles, allowing parametric morphing from one 'extreme' animation to the other. Low-level stimulus properties (range of screen positions covered, speed, or acceleration) were not systematically affected by morphing. Twenty-six naive subjects were asked to rate the 'extreme' animations and 4 linearly-spaced intermediate morphs for animacy. Ratings from nineteen subjects as well as averages over all subjects could be modelled by a cumulative Gaussian, median PSE was in the middle of the morph range and median JND was 1.7 morph levels. These stimuli thus allow parametric testing of animacy perception from single objects with movements modelled on real animate entities.

◆ **Neural correlates of the continuous wagon wheel illusion: a functional MRI study**
L Reddy, F Remy, N Vayssiere, R Vanrullen (CerCo, CNRS – Université Toulouse 3, France; e-mail: leila.reddy@cerco.ups-tlse.fr)
After prolonged viewing of a continuous periodic motion stimulus at particular frequencies, observers experience fleeting impressions of reversed motion: the continuous Wagon Wheel Illusion (c-WWI). We proposed that this bistable effect reflects discrete attentional sampling; alternatively, it could be explained by intrinsic properties of low-level motion detectors. We investigated the neural correlates of the c-WWI using fMRI (3T). Subjects viewed a vertically bisected ring containing a radial grating rotating at 10 Hz, and continuously reported the perceived motion direction within each half of the ring. The two halves always rotated in opposite directions, allowing us to separately explore illusory reversals occurring within each hemifield. Comparing BOLD activity during illusory (c-WWI) or real perceptual periods revealed systematic differences in right parietal regions, but not in striate or extrastriate visual areas. This activation pattern did not depend on the side where the illusion occurred, and could not be accounted for by purely perceptual-switch-related activity—known to encompass parietal regions during other bistable effects. The results support the attentional account of c-WWI.

◆ **Neural correlates of memory in ambiguous perception measured with EEG**
M C de Jong, J W Brascamp, C Kemner¶, R van Ee (Helmholtz Institute, Department Physics of Man, Utrecht University, The Netherlands; ¶ Rudolf Magnus Institute of Neuroscience, Department Child and Adolescent Psychiatry, Utrecht, The Netherlands; also Department of Neurocognition, Maastricht University, The Netherlands; e-mail: m.c.dejong@uu.nl)
Ambiguous stimuli elicit changes in perception without any change in the stimulus itself. They thereby enable the study of perceptual processes in isolation from stimulus-driven mechanisms. Perceptual memory influences ambiguous perception: previously predominating percepts also tend to dominate during subsequent presentations (up to 1 min later). This cannot be explained as classical adaptation, which inhibits previously seen percepts. We presented an ambiguously rotating sphere repeatedly with intervening black periods and used EEG to study the neural correlates of perceptual memory. We compared event-related potentials in two conditions that differed only in 'long-term' perceptual history: the percepts seen multiple seconds before the current stimulus onset. The conditions did not differ in 'short-term' perceptual history (percepts seen < 3 s before the current stimulus onset) or the current percept. Perceptual memory clearly influenced activity on occipital electrodes from 120 ms after stimulus onset onwards. The timing and location of this effect suggest that perceptual memory affects processing in early visual cortex.

◆ **Neural model for the recognition of transitive actions**
M A Giese, F Fleischer¶, A Casile¶ (School of Psychology, Bangor University, UK; ¶ Hertie Institute for Clinical Brain Research, Tübingen, Germany; e-mail: martin.giese@tuebingen.mpg.de)
The visual recognition of goal-directed movements is crucial for imitation and possibly the understanding of actions. We present a neurophysiologically-inspired model for the recognition of goal-directed hand movements. The model exploits neural principles that have been used before to account for object and action recognition: (i) hierarchical neural architecture extracting form and motion features; (ii) optimization of mid-level features by learning; (iii) realization of temporal sequence selectivity by recurrent neural circuits. Beyond these classical principles, the model proposes novel physiologically plausible mechanisms for the integration of information about effector shape, motion, goal object, and affordance. We demonstrate that the model is powerful enough to recognize hand actions from real video sequences and reproduces characteristic properties of real cortical neurons involved in action recognition. We conclude that: (i) goal-directed actions can be recognized by view-based mechanisms without a simulation of the actions in 3-D, (ii) well-established neural principles of object and motion recognition are sufficient to account for the visual recognition of goal-directed transitive actions.
[Supported by DFG, EC FP6 project COBOL, and Hermann & Lilly Schilling Foundation.]

◆ **Noise-dependent interhemispheric integration of motion**
N Zokaei, B Bahrami¶, V Walsh¶, G Rees¶ (Department of Psychology [¶ Institute of Cognitive Neuroscience], University College London, UK; e-mail: nzokaei@gmail.com)
Human neuroimaging and monkey electrophysiological studies show that retinotopic visual cortex responses to contralateral stimulation can be modulated by ipsilateral stimuli. We tested the behavioural significance of these interhemispheric interactions in perception of direction of vertical motion, and show that processes affecting sensitivity and bias are dissociable. In Experiment 1, observers discriminated the direction of vertical motion of a random-dot pattern (RDP) at

threshold while another vertically moving distractor RDP of variable coherence was displayed in the opposite hemifield. Congruency enhanced accuracy when target and distractor were similar in noise but impaired performance when distractor RDP was fully coherent. In Experiment 2, a two-interval forced choice design was employed. Sensitivity (d') was impaired by the noisy incongruent, but not the coherent, distractor suggesting that the reverse congruency effect observed for coherent distractors in Experiment 1 resulted from changes in decision bias. Together, these results suggest a noise-dependent mechanism for interhemispheric integration of information in the human brain that modulates motion processing at perceptual and decision levels.

◆ **Influence of the field of view on speed estimation during visual translations**
P Pretto, J P Bresciani, M Vidal¶, H H Bülthoff (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; ¶ LPPA – CNRS / Collège de France, Paris, France;
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During translations along the antero-posterior axis, the angular velocity of the visual flow on the retina varies with the retinal eccentricity of the stimulus. We tested how the perceived translation speed is affected by the portion of the retina that is stimulated. Twelve seated subjects were presented with visual translations at constant speed through a volume of random dots. The perceived speed was compared between different field-of-view (FOV) conditions, masks of different sizes being used to occlude either central or peripheral areas of the FOV (230*125 degrees when non-occluded). With central FOVs smaller than 40 degrees (ie, peripheral vision occluded), the visual speed was systematically underestimated, the bias being inversely proportional to the size of the FOV. In contrast, when the central region was occluded and visual flow only presented peripherally, the speed was systematically overestimated. This overestimation was observed even when only 10 degrees of central FOV were occluded. Our results suggest that correct perception of visual speed requires at least 40 degrees of central FOV.

◆ **Temporal dynamics of motion-induced-blindness**
R Goutcher (Department of Psychology, University of Stirling, UK;
e-mail: ross.goutcher@stir.ac.uk)

Motion-induced-blindness (MIB) occurs when a moving pattern induces the perceptual suppression of a physically present stimulus (Bonneh et al, 2001 *Nature* **411** 798 – 801). Previous studies of MIB have concentrated on factors affecting the extent of suppression. As a consequence, little is known about the basic temporal dynamics of the phenomenon. We address this deficit here. Observers were presented with a rotating blue grid (rotating at 16.7 rpm; presented for 90 s), which induced the perceptual suppression of three yellow target dots. Observers reported dot disappearance by holding down one of three keys. We find that the probability of suppression for any single dot is relatively constant over the presentation duration, but that the stability of suppression (ie the probability of continued suppression) varies with time. We also analyse the independence of dot disappearance over time, and show how factors affecting the extent of suppression affect its temporal dynamics. We compare our results to those of studies examining the dynamics of other forms of perceptual suppression.
[Supported by RCUK Fellowship EP-E500722-1.]

◆ **The role of (other or self-) reference in the perception of expanding biological motion**
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Previous research has suggested that exocentric and egocentric perceptions are associated with different performances in various tasks. However it is unclear if the use of self-reference would differently affect the perception of expanding biological and rigid motion? Experiment 1 consisted in an exocentric velocity judgement between simultaneous expanding patterns—two rigid, two biological, or one of each. Results revealed more correct responses and lower reaction times for rigid (less complex) stimuli. Experiment 2 used the same stimuli in a self-based collision estimation. The observer had to judge whether an object moving towards his/her direction would pass him/her before or after a sound marker. Here, biological pattern elicited more accurate collision estimations. A high bias, speed overestimation, was verified in the presence of rigid objects. Reaction times did not differ between conditions. In an exocentric task the complexity of the motion seems to be the crucial factor. However in an egocentric task with higher potential for action, biological patterns elicited better responses, even when patterns were more complex.
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◆ **Motion-induced blindness: a consequence of overzealous motion deblurring?**
T S A Wallis, D H Arnold (School of Psychology, University of Queensland, Brisbane, Australia; e-mail: t.wallis@psy.uq.edu.au)

In motion-induced blindness (MIB), static targets are stochastically suppressed from awareness when presented near moving elements. In motion deblurring, the visibility of moving form is enhanced by suppressing residual streaks at the trailing edges of movement. The possible relationship between MIB and deblurring was investigated in three experiments. Static peripheral targets were surrounded by rectangular arrays of randomly positioned dots, manipulated to generate different types of motion. Observers reported more suppression at the trailing edges of movement than at the leading edges (Experiment 1) and more suppression when motion trajectories crossed target locations (Experiment 2). It was also found, by manipulating motion-signal luminance contrast, that MIB only occurs when motion-defined form can be clearly discerned. Both motion-defined form and MIB fail at equiluminance. Overall, MIB was stronger in conditions ideal for motion deblurring. MIB might therefore be caused by an overzealous motion deblurring mechanism, which mistakenly suppresses static peripheral targets that are near motion signals in order to preserve the clarity of moving form.
[Supported by an Australian Research Council discovery project grant and fellowship (to DHA).]

◆ **Temporal conditions for pure phi in two-element and multiple-element apparent motion displays**
V Ekroll, L Trampenau, T R Scherzer (Institut für Psychologie, Universität Kiel, Germany; e-mail: vekroll@psychologie.uni-kiel.de)

In recent experiments [Ekroll et al, in press *Journal of Vision* **8**(4.31) 1 – 22] with two-element apparent motion stimuli it was found that pure phi (also known as shadow motion or omega motion) depends on three temporal variables (stimulus onset asynchrony, temporal duty cycle and local interstimulus interval). Violations of either of these constraints lead to specific competing motion and non-motion percepts. Here, we report the results from experiments investigating how these findings generalise to multiple-element stimuli like those used by Steinman et al (2000 *Vision Research* **40** 2257 – 2264). Using displays with eight instead of just two stimulus elements, a similar pattern of results was found. In particular, the same three variables constrain the occurrence of pure phi but the critical thresholds in terms of stimulus onset asynchrony and local interstimulus interval vary systematically.
[Supported by Grant EK 72-1-1 from the Deutsche Forschungsgemeinschaft (to VE).]]

OBJECTS, FACES AND SHAPES

◆ **Face recognition from caricatures**
A I F Mendes, S S Fukusima (Department of Psychology, FFCLRP, University of São Paulo, Brazil; e-mail: anairene@usp.br)

To investigate face recognition, caricatures and anti-caricatures were generated respectively by exaggerating and reducing differences on faces from averaged (prototypical) faces of samples from the Brazilian population. In one experiment, these differences were manipulated holistically and in another, isolated or specific combinations of features were manipulated in order to understand the role of holistic and analytical processes in face recognition. In both experiments, subjects rated how similar each caricature and anti-caricatures was to the original face. Results suggested that the effectiveness of caricatures for face recognition depends on how distinctive or non-distinctive a face is in relation to the prototypical faces. Furthermore the facial recognition process is predominantly holistic but the manipulation of distinctive facial elements reduces the similarity judgment more than the manipulation of non-distinctive features.
[Supported by CAPES and CNPq.]

◆ **Faces of each gender are coded in reference to gender-matched prototypes: evidence from masking**
A Zadbood, Z Basseda¶, M Vaziri Pashkam§ (Shahid Beheshti University of Medical Sciences, Tehran, Iran; ¶ Interdisciplinary Neuroscience Research Program, Medical Sciences, University of Tehran, Iran; § Vision Sciences Laboratory, Harvard University, Cambridge, USA; e-mail: azadbood@gmail.com)

Previous research has provided valuable evidence in favour of the prototype-based face-space model of face recognition, which implies that our brains encode faces in reference to a prototypical face. The nature of the prototype face is still controversial. In this study, we used backward masking paradigm to evaluate the role of different gender prototype faces in face recognition. Identification of male and female target faces were assessed under different masking conditions: an average male face mask, an average female face mask, and an average of both male and female faces mask (general average face mask). Results showed that each gender average face mask disrupted the identification of faces of that gender more than the general average face mask.

It can be concluded that average faces of each gender might play a special role in the recognition of faces from that gender, and this suggests that faces of each gender are coded in reference to gender-matched prototypes, rather than an androgynous general prototype face.

◆ **Size constancy mechanism and spatial illusions in an anuran**
V A Bastakov (Institute for Information Transmission Problems, Russian Academy of Sciences, Moscow, Russia; e-mail: bastakov@iitp.ru)

For proper spatial orientation, animals utilize information about the physical parameters of the external objects. The aim of this work is to discuss what is known about constancy mechanisms of size and distance perception in frogs and toads and to compare these mechanisms with corresponding human mechanisms. The parameters affecting size estimation of moving objects has been investigated in these species. The stimuli were moving coloured spheres. The varying parameters were colour, size, velocity, and background texture. Some properties of the constancy mechanisms has been revealed by means of studies of spatial illusions. In the absence of structural background, prey-catching or escape responses of frogs and toads to the stimuli moving around on fixed distances were triggered depending on the perceived size of the object and perceived distance. Inappropriate reactions, ie escape of a prey-size object and trying to catch a very large one were evidently due to wrong estimation of the distance to the moving object. Functionally, such behaviour corresponded to human spatial visual illusions.
[Supported by Program of Branch of Biological Sciences Russian Academy o Sciences 2008.]

◆ **Modelling face adaptation aftereffects**
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Human perception of faces shows systematic aftereffects as a result of adaptation to specific faces (Leopold et al, 2001 *Nature Neuroscience* **4** 89 – 94), but it is not clear what mechanisms underlie these effects. We show that face aftereffects can arise from Hebbian learning of connections in a LISSOM self-organising map model of visual cortex (Miikkulainen et al, 2005 *Computational Maps in the Visual Cortex* (New York: Springer)). The model is trained and tested on faces from a generative model of a multi-dimensional face space (Hancock, 2000 *Behavior Research Methods, Instruments and Computers* **32** 327 – 333). Adaptation in the model shifts perception along a trajectory passing through the mean face. The perception of a target face on this trajectory is facilitated after adaptation to the target face's anti-face, but impaired after adaptation to other anti-faces. The model results suggest that high-level aftereffects can be explained through the same mechanisms previously used for low-level effects like tilt aftereffects (Miikkulainen et al, 2005 *Computational Maps in the Visual Cortex* (New York: Springer), but in circuits selective for faces.

◆ **If not in the eye, then in the visual short-term memory of the beholder**
S Davies (Department of Psychology, Liverpool Hope University, UK; e-mail: daviess@hope.ac.uk)

Visual representations are a product of a perceptual building-up and visual short-term memory (VSTM). The relative contributions of the two, however, are poorly understood. We report two experiments on perceptual completion aimed at exploring the nature of visual microgenesis and stored visual representations. In a matching task we used as primes either partly occluded geometric figures or shapes truncated and separated by a gap from an occluder. Targets were either whole or truncated unoccluded shapes. Experiment 1, with a 500-ms prime, showed that matching performance was governed by completion-derived representations rather than optically identical ones. In comparison, Experiment 2 arrested perceptual processing by masking the prime shapes at 100 ms, but the same pattern of interaction between primes and target shapes emerged. These imply that halting a perceptual input does not stop the process of perceptual completion. The results demonstrate a clear dissociation between the two facets of visual processing and indicate that VSTM does not rely wholly on the output of perceptual processing, but actively constructs an object-based representation.

◆ **Perception of emotional expression of faces is affected by the vertical placement of inner facial features**
D Todorovic (Department of Psychology, University of Belgrade, Serbia; e-mail: dtodorov@f.bg.ac.yu)

Informal observations indicated that in simple schematic faces the vertical placement of inner facial features (the constellation of eyes, nose, and mouth as a whole) within the head outline affected emotional expression: placements of inner features towards the top made faces look happier, and placements towards the bottom made them look sadder. These surprising effects of

feature placement were clearly confirmed in Experiment 1, in which eighty-three subjects rated emotional expressions of schematic faces which differed in feature placement, mouth curvature (which also had an effect), and gaze direction (which had no effect). In Experiment 2, analogous facial feature manipulations were performed on realistic computer-simulated faces, again confirming the feature placement effect. Such effects may be due to an association of emotional expression with head slant. In Experiment 3, computer-simulated faces were presented in three orientations (frontal, slanted backwards, slanted forwards), resulting in similar projected placements of facial features as in Experiments 1 and 2. The outcomes were only in partial agreement with the head slant hypothesis.

◆ **Chicks' preferences for different types of symmetry**

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Spontaneous preferences for pecking at symmetrical or asymmetrical stimuli were tested in newly-hatched visually-naive domestic chicks, on a task originally employed by Clara and coll. 2007. Six stimuli (3 symmetrical and 3 asymmetrical) of identical area and perimeter and differing only in the degree of symmetry were employed. Preferences for different kinds of symmetry (bilateral symmetry, 2-axis-symmetry, mirror symmetry) were scored. Pairs of same-sex chicks kept in total darkness for 24 hrs after hatching underwent a first test on their second day of life and a retest 24 hrs later, after experiencing standard rearing conditions. A preference for symmetrical patterns was found in naïve chicks, no preference was there at retest. Moreover, chicks showed a significant preference for the bilateral-symmetry over the other types of symmetry. The possibility that naïve chicks' bias for symmetrical objects is limited to edible items was ruled out by testing chicks' preferences for approaching much larger symmetrical or asymmetrical objects.

◆ **Visual memory: the effects of time, fixations, and presentation mode**

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We examined the influence of viewing time, blocked vs interleaved presentation and fixations on performance in a visual memory task. Participants viewed a display containing eight photographs of natural objects arranged on an invisible circle. The stimuli were presented either for 1000 ms, 3000 ms, or 7000 ms, or until 3, 7, or 10 object fixations had been made. For both modes, we used a blocked and an interleaved design. Memory for one object was tested after each trial. Performance increased with longer viewing times. The effect was more pronounced in the blocked condition. Even though the interleaved design minimized the predictability of the viewing length, it did not decrease performance but instead attenuated differences in performance for the various viewing lengths. Fixating an object helped in remembering it better in the trials with a length of 1000 ms or equivalent to three fixations but had no effect at longer times. Taken together, we found only a limited beneficial effect of fixating objects and a modest improvement after prolonged viewing time.

◆ **Asymmetrical length perception in Fick illusion**

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Left/right asymmetry of geometrical shape perception was examined using vertical/horizontal illusion, known as Fick illusion. The degrees of the illusory perception were compared between when the vertical line was at the left end of the horizontal line and when the vertical line was at the right end of the horizontal line. The total illusory perception, on a grand average, showed no difference between the two conditions. However, we classified the nineteen subjects into several groups by their performance; ones who perceived the vertical line in the left-end condition longer than in the right-end condition (type A, 47% of the subjects), another ones whose perception was longer in the right-end condition than in the left-end (type B, 26%), and the others. Then, we found that type A observers showed stronger length illusion in the left-end condition than the right-end condition, while no significant difference were found between the two conditions in the type B observers. The result implies the population composition of left/right asymmetrical perception.

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◆ **How natural are natural images?**
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The global amplitude spectrum allows for surprisingly accurate classification of natural scenes, particularly animal vs non-animal. However, humans evidently do not utilize this in classification tasks. In a new approach, we represent the images of the Corel Stock Photo library (CSPL) by means of frequency, orientation, and location. Achieving 78% classification accuracy, we discovered an apparently photographically-induced artifact in the animal images of the CSPL: the consistent use of depth of field causes upper image regions to be out of focus, while the image centre is always well focused. This affects the distribution of high-frequency energy within an image, explaining why simple classifiers can reach relatively high classification accuracy. This does not correlate to human performance. Comparing the CSPL to the Tübingen natural image database (TNID), we found the TNID to be generally more difficult for human and algorithmic classification, yet also affected by the photographic artifact. These results show a strong effect in a popular image database, greatly affecting algorithmic classification while barely affecting human performance.

◆ **Finding an angry face from a crowd: an investigation of anger superiority effect using schematic faces**
K Takabatake, H Yamada¶ (Graduate School of Literature and Social Sciences, Department of Psychology, Nihon University, Tokyo, Japan; ¶ College of Humanities and Science, Nihon University, Tokyo, Japan; e-mail: kahoru_face@yahoo.co.jp)

Anger superiority effect, or the face-in-the-crowd effect, has been of interest to investigators seeking for evidence of human's sensitivity towards potential threat. Many studies investigating this phenomenon use schematic facial expressions, and the results have been contradictory: in some studies anger superiority effect were found, while other studies suggested that no threat-specific attention exists. The ecological relevance of the schematic expressions used in past studies has been an issue. The main purpose of this study was to investigate whether anger superiority effect would be observed using the schematic expressions of Yamada (1993 *Applied Cognitive Psychology* **7** 257 – 270), which faithfully portray real facial expressions. Thirty participants judged whether the presented crowd of faces was composed of single facial expressions (all-anger, all-happiness), or included one discrepant expression (find-anger, find-happiness). Results showed a clear anger superiority effect, with efficient search shown only for find-anger trials. This experiment proves that, on using ecologically relevant stimuli, anger superiority effect will be seen using schematic expressions. Further investigation will be conducted using expressions of fear and anger.

◆ **Contrast-invariant visual object recognition from active sensation**
M Jüttner, E Osman¶, I Rentschler¶ (Department of Psychology, School of Life & Health Sciences, Aston University, UK; ¶ Institute for Medical Psychology, University of Munich, Germany; e-mail: m.juttner@aston.ac.uk)

Reversal of contrast polarity severely disrupts visual recognition of human faces. However, for non-face objects the impact of contrast reversal on recognition is less clear and may depend on learned representations of object categories (Jüttner et al, 2004, Visual Cognition 11, 921-945). Using a paradigm of cross-modal priming and learning (Jüttner et al, 2006 *Behavioural Brain Research* **175** 420 – 424) we explored, for a set of unfamiliar, three-dimensional objects, how prior knowledge obtained visually or haptically during priming affects the ability to recognize the objects from novel (unlearned) views in a subsequent generalization test. We observed an increase of generalisation performance in priming conditions that involved active visual or haptic sensation relative to the unprimed control condition. Crucially, contrast reversal of the test views had no effect on spatial generalisation in the former two conditions, whereas it significantly impeded performance in the latter. These results suggest that invariances to viewpoint and contrast polarity have a common representational basis. Such invariances are learning-dependant and facilitated by active sensation.

◆ **An examination of the neural markers of face perception using magnetoencephalography**
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Face perception is a vital aspect of normal social functioning that is underpinned by specialised cognitive and neural mechanisms. A magnetoencephalography (MEG) component has been identified that is sensitive to perception of faces, termed the M170. It has been demonstrated this component is attenuated when a face is presented repeatedly, a measure of specificity.

Intriguingly, however, the M170 is not involved in configural processing, despite considerable evidence that such processing is involved in face perception. We therefore tested the hypothesis that another specific neural component correlates with configural face processing. In two experiments with the same participants we (i) localised the components involved in face perception and (ii) examined the correlation of these components with configural face perception. The localiser involved the presentation of faces, houses, objects and scrambled pictures. The configural processing experiment involved the presentation of repeated or non-repeated upright or inverted faces. An early component was discovered in the anterior portion of the temporal lobe prior to the M170 that reflects configural face perception.
[Supported by NHMRC.]

◆ **Suprathreshold discriminations of naturalistic images at fixation and in the periphery**
M To, J Kho, T Troscianko¶, D Tolhurst (Department of Physiology, Development and Neuroscience, University of Cambridge, UK; ¶ Department of Experimental Psychology, University of Bristol, UK; e-mail: mpst2@cam.ac.uk)

We have investigated whether suprathreshold natural-image discrimination tasks in peripheral vision can be explained using similar V1 models to those used for foveal vision. Observers viewed pairs of coloured naturalistic images and rated perceived difference in appearance, foveally and at 16 and 31 degrees eccentricity. 180 image pairs from 4 family sets (cat, balloon, books, fruits) were presented at each location. Images differed along one or two dimensions: colour, blur, size, and posture/shape. Ratings were modelled with visual difference predictors comprising multiple orientation and frequency selective Gabor fields, interacting nonlinearly. Peripheral models were identical to the foveal model (To et al, 2007 *Perception* **36** Supplement, 157) except for different luminance and isoluminant grating contrast sensitivities appropriate to eccentricity (obtained from Mullen and Kingdom, 2002 *Visual Neuroscience* **19** 209). Although similar correlation coefficients (0.68 – 0.70) were obtained between observers' ratings and model predictions at all locations, peripheral ratings were markedly scaled down compared to the models, implying that peripheral and foveal vision of natural images differ more than by any underlying grating sensitivity.
[Supported by EPSRC and Dstl (UK).]

◆ **Object substitution masking induced by illusory masks: evidence for higher object-level locus of interference**
N Hirose, N Osaka (Department of Psychology, Graduate School of Letters, Kyoto University, Japan; e-mail: nobuyuki.hirose@gmail.com)

Object substitution masking, in which a briefly presented target can be rendered invisible by a lingering mask that does not even touch it, is thought to occur at the object-level of processing. However, it remains unclear whether object-level interference alone produces substitution masking because previous studies only manipulated the presence or absence of a physical masking stimulus after the removal of the target, leaving the possibility of some image-level interference contributing to the total masking. To assess object-level interference, we used an illusory-contour figure as an object mask, adjacent to the possible target locations, which was created by rotating four previewed pacmen inducers to face inward to form a subjective square region. The illusory object persisting beyond the target offset reduced the visibility of the target only when presented in its immediate vicinity. This masking effect could not be attributed to the local directional changes, symmetry, or perceptual closure of the inducers near the target. These results provide strong evidence for a high-level locus of interference in object substitution masking.
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◆ **Priming of visual object processing : effect of prime duration and task**
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Two experiments aimed at investigating which are the relevant information (high spatial frequencies or low spatial frequencies) for object visual processing using a priming procedure. The target was an object photo and four types of primes were used (a control random phase, a low-pass, a band-pass, or a non-filtered prime of the target). Prime duration varied (30 ms vs 70 ms) and two tasks were used: global form discrimination (horizontal/vertical) in Experiment 1 and a semantic categorization (man-made/natural) in Experiment 2. Results showed a significant priming effect of the non-filtered prime relative to control prime and a smaller significant priming effect for low-pass and band-pass primes that did not differ among them. Type of prime did not interact with prime duration and was identical in the two experiments. Hence, both the global form and the details of the object seem to be relevant visual primitives for processing in the very first stage of processing, whatever the task.

◆ **Face recognition at short presentation times in congenital prosopagnosia**
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The face recognition deficit in prosopagnosia ('face-blindness') has been linked to a lack of holistic processing and the reliance on compensatory featural processing. Here, we emphasise temporal aspects and propose that prosopagnosics' performance depends critically on sufficient stimulus presentation times. In three face recognition experiments we investigated performance differences between thirteen subjects with congenital prosopagnosia and twenty-two age-matched controls. First, we compared reaction times under unlimited viewing and presentation times required for 80% accuracy in an old/new recognition task. Reaction and presentation times were correlated across individuals, and both were longer for prosopagnosics. In the second and third experiments, we tested recognition performance for limited presentation times (50 to 750 ms) either during the learning or the testing phase. In both experiments performance differences between controls and prosopagnosics were largely established within the first 50 ms. Subsequent differences in information gain are compatible with different gaze behaviour in congenital prosopagnosia (Schwarzer et al, 2007 *Psychological Research* **71** 583 – 590). Our results indicate early processing differences and time-consuming compensation strategies in prosopagnosic face recognition.

◆ **Face familiarity affects memory recall dependency on encoding and presentation times**
S Nasr, T Roostaee¶ (School of Cognitive Sciences, IPM, Tehran, Iran; ¶ Tehran School of Medical Sciences, Tehran, Iran; e-mail: sh_nasr@ipm.ir)
Image memory is shown to accumulate over time. However the dependency of this phenomenon on encoding time and stimulus familiarity is still a matter of debate. Using a parameterized face space and backward masking procedure, we instructed fourteen subjects to participate in identity and emotion recall tasks in two different conditions: (i) variable encoding time (12 – 324 ms) with constant presentation time (12 ms) and, (ii) variable but equal encoding and presentation times (12 – 324 ms). We found that subjects' performance significantly improved with increased encoding time ($p < 0.001$). This effect was significantly enhanced when we simultaneously increased the presentation time ($p < 0.001$). Increasing stimulus familiarity significantly improved the subjects' face recall performance ($p < 0.001$), however their performances still remained sensitive to the encoding time ($p < 0.001$). In contrast and despite being below saturation level, subjects' recall performance became insensitive to presentation time ($p > 0.05$). On the basis of these results we suggest that increasing face familiarity decreases presentation time dependency of face recall while its dependency on encoding time remains intact.

◆ **Cognitive modulation of the oblique effect**
T Borra, I Hooge, F A J Verstraten (Experimental Psychology, Helmholtz Institute, Utrecht University; e-mail: t.borra@uu.nl)
In two experiments we investigated whether the oblique effect (a lower sensitivity for oblique object orientations) can be cognitively modulated. In Experiment 1 observers were asked to match the orientation of a test stimulus to a reference stimulus (0° to 45°, with 5° increments). Both the reference and test stimulus were two dots implying a line. In Experiment 2 the reference stimulus was replaced by four dots implying a square. Furthermore, observers were asked to regard the two-dot test stimulus as one side of a square, and match it to one side of the reference square. If the oblique effect can be cognitively modulated, then we expect higher matching performance for the 45° orientation, since a 45° square orientation contains horizontal/vertical diagonals. Results for Experiment 1 show the standard oblique effect: lower matching performance for oblique reference orientations. However, for Experiment 2 an increase in matching performance is found for the 45° reference orientation. We conclude that the oblique effect can be cognitively modulated.

◆ **Body inversion effect in capuchin monkeys (*Cebus apella*)**
T Matsuno, K Fujita (Department of Psychology, Kyoto University, Japan; e-mail: toyomi.matsuno@bun.kyoto-u.ac.jp)
Recent progress in the studies of object perception revealed that body forms are configurally processed in the human visual system, showing the body inversion effect (eg, Reed et al, 2003 *Psychological Science* **14** 302 – 308). In this behavioural study, we investigated the visual discrimination of body postures in capuchin monkeys. Monkeys showed inversion effects in perceiving human body forms: the discriminations of the upright human body postures were well-performed compared with those of the inverted forms, even when the body postures are human-specific and not in the postural repertoires of monkeys. Control experiments that used body parts,

scrambled forms, and robot-like body stimuli revealed that the human-like appearance of full body was the prerequisite for the configural processing of body forms. These results provide the first evidence of the configural processing of body forms in non-human primates.
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◆ **Costs and benefits of image averaging for human face matching**
X van Montfort, R Jenkins (Department of Psychology, University of Glasgow, UK; e-mail: Xandra@psy.gla.ac.uk)

We are able to recognize familiar faces across a wide range of images, however with unfamiliar faces performance is strikingly poor. Image averaging has recently been proposed as a model for face familiarity (Burton et al, 2005 *Cognitive Psychology* **51** 256 – 284). The technique involves merging several photos of one person into a single image, and has been shown to improve automatic face recognition (Jenkins and Burton, 2008 *Science* **319** 435). We tested whether image averaging can also improve human face matching. Participants viewed either two photos, or a photo and an average, and indicated whether these showed the same person or different people. For familiar faces performance was good, and unaffected by averaging (Experiment 1). For unfamiliar faces averaging increased accuracy on same trials, but decreased accuracy on different trials (Experiment 2). Experiment 3 revealed the same patterns in a real-world experiment using identity cards. We conclude that for unfamiliar faces, image averaging helps positive identification but hinders correct rejection.

SEGMENTATION AND GROUPING

◆ **Distractor influence on the right angle perception**
A Bielevičius, A Bulatov, A Bertulis, E Loginovich (University of Medicine, Kaunas, Lithuania; e-mail: arubiel@vision.kmu.lt)

On the monitor, three light spots formed imaginary sides of a 90° angle. Inner or outer distracting stripes were flanking each stimulus spot at the same distances: two stripes were placed at the end-spots of the sides in parallel with them; the third stripe at the apex-spot was orthogonal to the angle bisection. The spot diameter and stripe width were 1.5 min of arc; luminance, 75 cd m^{-2}; the length of the stripes and that of the stimulus sides were 2.5, 5, or 7.5 min of arc and 30, 60, or 90 min of arc, respectively. Subjects readjusted the right angle by manipulating the end-spot positions tangentially. The judgment errors as functions of the stripe-to-spot distance varying within a ± 25 min of arc interval showed near symmetrical curves with two parts comprising positive and negative values and corresponding maxima. The maxima positions changed proportionally with the length of the stimulus sides. Considering the lateral interaction processes in the visual pathways and the centroid bias conception (Morgan et al, 1990 *Vision Research* **30** 1793 – 1810), an appropriate mathematical description of the experimental data is proposed.

◆ **Discrimination between spiral Glass patterns early in human visual cortex**
D J Mannion, J S Mcdonald, C W G Clifford (School of Psychology, The University of Sydney, Australia; e-mail: damienm@psych.usyd.edu.au)

We used fMRI to test for the presence of cortical representations capable of discriminating complex spatial form. Subjects ($N = 5$) viewed alternating blocks of clockwise and anticlockwise spiral Glass patterns. The stimuli were constructed such that local orientation information provided only a weak cue to the global structure. We trained multivariate pattern classifiers to discriminate clockwise from anticlockwise blocks on the basis of the distribution of activity within each of several functionally defined visual areas. Classifier performance was evaluated for each area by a leave-one-out train and test procedure repeated over 10 runs. We found classifier accuracy to be significantly above chance as early as V1 and V2. The distribution of activity within these areas may thus be sufficient to recover the structure of Glass patterns, consistent with a role as input to the global pooling mechanisms implicated in numerous psychophysical studies.
[Supported by grants from the Australian Research Council and The University of Sydney (to CC).]

◆ **Spatial structure affects temporal discrimination**
F Bauer, S Cheadle¶, A Parton§, H J Müller, Y Bonneh#, M Usher¶ (Department of Psychology, Ludwig Maximilian University Munich, Germany; ¶ School of Psychology, Birkbeck, University of London, UK; § Centre for Cognition and Neuroimaging, Brunel University, Uxbridge, UK; # University of Haifa, Israel; e-mail: fbauer@lmu.de)

The process by which the brain groups elements belonging to one object, whilst segregating them from other scene elements is called visual binding. According to the binding-by-synchrony (BBS) hypothesis, detectors that respond to elements of a single object fire in synchrony, while

detectors that respond to elements of different objects do not. The existing data about the role of BBS in the visual integration process is inconclusive. In this study, observers had to judge the synchrony of two flickering targets embedded in a static contour. We found that a smooth contour, as compared to a jagged one, impedes judgments of temporal synchrony, whilst facilitating non-temporal judgments of target contrast. The data suggest that the visual system implements a mechanism that synchronizes response onsets to object parts and attenuates or cancels their latency differences. The results are consistent with a simple computational model that implements synchronization of responses via lateral interactions, enabling the visual system to pick up objects by synchrony among a temporally diverse background.

◆ **Low-level interference in positional encoding: crowding falls into line**
J A Greenwood, P J Bex¶, S C Dakin (UCL Institute of Ophthalmology, University College London, UK; ¶ Schepens Eye Research Institute, Harvard Medical School, Boston, USA; e-mail: john.greenwood@ucl.ac.uk)

Visual crowding is a significant, yet poorly understood, impairment in object identification imposed by surrounding objects. Subjectively, a key feature of crowding is that the position of object features within targets and flanks become 'scrambled'. We examined this phenomenon using peripherally presented cross-like stimuli, where observers judged whether the horizontal component was positioned above or below the midpoint of the vertical component. Flanking the left and right sides of the target with crosses increased position thresholds without shifting the subjective midpoint. By contrast, flanks with horizontal lines positioned away from the midpoint both elevated thresholds and shifted psychometric functions in a direction consistent with the horizontal line-offset. This bias persisted with subthreshold line offsets, demonstrating that awareness of flank structure was not required. We finally used a method of adjustment to probe subjects' percept of the target. Together, these results provide direct evidence for low-level positional processes contributing to crowding, with the observed patterns of bias, precision and subjective report allowing comparison between predictions from averaging and 'flank substitution' models.
[Supported by the Wellcome Trust.]

◆ **Comparing orientation-specific adaptation and pattern classification analyses in human V1 using high-field fMRI**
P Sapountzis, D Schluppeck, R W Bowtell¶, J W Peirce (School of Psychology, University of Nottingam, UK; ¶ School of Physics and Astronomy, University of Nottingam, UK; e-mail: lpxps@psychology.nottingham.ac.uk)

Recent fMRI studies have demonstrated new methods to study orientation selectivity in human V1 (eg Haynes and Rees, 2005 *Nature Neuroscience* **8** 686 – 691; Larsson et al, 2006 *Journal of Neurophysiology* **95** 862 – 881). These utilised either prolonged adaptation paradigms averaging signals over a region of interest (ROI) or multivariate, pattern-classification analyses taking into account the pattern of activity within the ROI. Given that both approaches aim to quantify neuronal selectivity on a sub-voxel scale, it is of interest to study whether these techniques have similar neural substrates. Specifically we sought to determine whether voxels showing substantial orientation-specific adaptation also drive performance in pattern classification analyses. We acquired high-resolution fMRI data at 7T (Philips Achieva; $1 \times 1 \times 1.5$ mm^3 voxels). (i) A linear pattern-classifier successfully discriminated voxel-wise responses to grating stimuli presented at one of two orientations. (ii) Significant orientation-selective adaptation was also observed, across the same voxels. (iii) We found little relationship between the methods; voxels showing strong selective adaptation were not those principally responsible for driving the pattern classification analyses.

◆ **Orientation bias is predicted by pre-stimulus EEG alpha activity**
A R Nikolaev, S Gepshtein¶, C van Leeuwen§ (RIKEN Brain Science Institute, Wako-shi, Japan; also Institute of Higher Nervous Activity, Moscow, Russia; ¶ RIKEN Brain Science Institute, Wako-shi, Japan; also Salk Institute for Biological Studies, La Jolla, USA; § RIKEN Brain Science Institute, Wako-shi, Japan; e-mail: nikolaev@brain.riken.jp)

Human observers normally prefer some orientations of visual stimuli over other orientations. We studied how this orientation bias is represented in the electrical brain activity. Observers did a grouping task in multistable dot lattices (Kubovy, 1994 *Psychonomic Bulletin & Review* **1** 182 – 190). The dots were seen to spontaneously group into strips, according to their proximity, such that one of several orientations was perceived at a time. Other factors being equal, most observers preferred vertical groupings to groupings along other orientations. We examined how scalp EEG during 1 s before stimulus presentation was related to the orientation bias. We found that the alpha activity of pre-stimulus EEG predicted the perceptual bias: the lower the alpha power the larger the bias. This relationship was most prominent in those trials where the reported

grouping was inconsistent with the proximity principle. The results suggest that perceived grouping is determined in a competition between stimulus factors that support certain orientation and the intrinsic orientation bias that originates in the ongoing cortical activity.

◆ **Audiovisual temporal order judgments in a three-is-a-crowd stimulus**
G B Remijn, H Kojima, H Ito¶ (Department of Psychology, Kanazawa University, Japan; ¶ Faculty of Design, Kyushu University, Japan; e-mail: remijn@staff.kanazawa-u.ac.jp)

In this study we further examined whether the just noticeable difference (JND) between a sound and a flash (17 ms each) was influenced by the presentation of an additional sound or flash presented 250 ms either before or after the target sound-flash pair. In these three-is-a-crowd stimuli, the constituents of the target pair thus could either group with each other (crossmodal simultaneous grouping) or one of them could group with the additional sound or flash (unimodal sequential grouping). We found that the mean JND for the target pair decreased significantly, as compared to the JND obtained for the pair presented in isolation, when the additional sound or flash lead the target pair. A decrease in jdn was not found, however, when the additional sound or flash followed the target pair. The results could suggest that unimodal sequential grouping constrained crossmodal grouping and facilitated temporal discrimination between the constituents of the target pair. Alternative explanations and some procedural difficulties are discussed.
[Supported by the COE programs of Kanazawa University and Kyushu University, Japan.]

ORAL PRESENTATIONS

MOTION

◆ **Global rotation from multiple Gabor arrays**
A Rider, A Johnston (Department of Psychology, University College London, UK; e-mail: a.rider@ucl.ac.uk)

Local randomly oriented 1-D motion elements appear to translate rigidly if their speeds are consistent with a global 2-D motion [Nishida et al, 2006 *Journal of Vision* **6**(6) 1084a]. This requires motion signals from several Gabors to be combined either locally or globally. We investigated whether motion integration extends beyond global translation to global rotation arrays for which the local expected velocity varies with position and the global mean expected velocity is zero. Arrays of randomly oriented Gabors drifted with speeds consistent with a global rotation. Subjects compared the perceived rotation speed with a comparison pattern made up of unambiguous moving plaid patches. They reported which appeared to rotate faster. We found the Gabor array cohered to give a perception of rigid rotation and perceived rotation speed was veridical even though the average local speed of the Gabor elements was considerable slower than that of the plaid array. Local motions combine to produce a perception of global rotation. A simple global pooling algorithm cannot account for these results.

◆ **Priors in interceptive timing: sometimes reliability is not enough**
J López-Moliner (Facultat de Psicologia, Universitat de Barcelona, Spain; e-mail: j.lopezmoliner@ub.edu)

Assuming a known size helps interpret optic flow that would otherwise be ambiguous and extract useful temporal information for interceptive timing [López-Moliner et al, 2007 *Journal of Vision* **7**(13.11) 1 – 8]. Therefore size and velocity, whose ratio determine optic flow monocularly, might evolve to a prior when either is extracted from a narrow distribution across trials. Subjects were shown simulated balls under monocular and binocular conditions. In some sessions the size was drawn from a narrow distribution and velocity from a wide distribution. In other sessions it was the other way around. Results from monocular sessions show that subjects developed a prior for size but not for velocity. This was so even when the optic flow was consistent with velocity being drawn from a narrow distribution. For binocular presentations, mean size was also assumed regardless of its deviation but with more weight given to the actual size (likelihood). These results raise some doubts about the assumption that a cue is weighted solely on the basis of its reliability.

◆ **Anti-correlations in motion, stereopsis and orientation detection**
M J Lankheet (Functional Neurobiology, Utrecht University & Helmholtz Institute, The Netherlands; e-mail: m.j.m.lankheet@uu.nl)

Motion, binocular correlation, and orientation in random-dot patterns require very similar correlation processes. Anti-correlations, however, have different effects in the different domains. In motion they cause a reversal of perceived direction but in stereopsis and orientation (Glass patterns) they generally do not evoke a percept. In this study we show that in all three domains anti-correlations cause similar low-level inhibitions. The evidence is based on nulling experiments and the presence of aftereffects. In all three domains adding an anti-correlated pattern effectively

cancels the percept for regular correlations, and anti-correlations lead to clear aftereffects, despite the fact that the adapting stimulus is not perceived. Different perceptual effects of anti-correlations therefore result from differences in the way that inhibitions are taken into account in generating percepts. Motion is inherently opponent, treating inhibitions in one direction similar to excitations in the opposite direction. In stereopsis and orientation detection inhibitions by themselves do not evoke a percept, presumably due to the absence of opponent interactions.

◆ **Static motion aftereffect depends on relative depth**
H Ashida, H Shirakawa¶ (Graduate School of Letters [¶ Faculty of Letters,], Kyoto University, Japan; e-mail: ashida@bun.kyoto-u.ac.jp)

Visual motion processing is contingent on binocular disparity (eg Verstraten et al, 1994 *Perception* **23** 1181 – 1188). Sohn and Seiffert [2006 *Journal of Vision* **6**(2.3) 119 – 131] further demonstrated that motion aftereffect (MAE) arising from two opposing motions in different depths depends on depth order rather than absolute disparity. However, since they tested dynamic MAEs, it remains possible that the link might be at a relatively high level. Here we show that even static MAEs depend on relative depth, in a similar experiment but using completely static test stimuli. Opposite adapting motions were presented in front and back surfaces, and one of the two test surfaces matched one of the adapting surfaces in depth. Participants reported the duration and direction of MAE in one surface in each trial. MAE was mostly observed in the direction predicted by the depth order rather than the absolute disparity. The result suggests that relative depth information is available at an earlier stage, or static MAE occurs at a later stage, than it is commonly thought.
[Supported by JSPS Grant-in-aid for Scientific Research A18203036.]

◆ **Alternating 'jagged' motions give anomalous perceived directions and aftereffects of motion**
S Anstis (Department of Psychology, University of California at San Diego, USA; e-mail: sanstis@ucsd.edu)

A random-dot field jumped alternately through 10 mm downwards and 1 mm to the right ('jagged motion'). Result: The perceived direction of motion depended critically on the viewing distance. From close up (large display), the 0.2° horizontal jumps predominated over the longer 2° verticals and the dots seemed to move to the right. From twice the distance (small display), the 1° vertical jumps predominated over the shorter 0.1° horizontals and the dots seemed to move downwards. Yet both displays gave a motion aftereffect (MAE) to the left, not upwards. Rotation results were similar. A Botticelli picture rotated alternately 5° clockwise (CW) and 0.5° counterclockwise (CCW), and was perceived as rotating CW. But when it stopped, a clockwise MAE was seen, in the same direction as the perceived adapting motion. In these displays, the medium and large jumps drove the perceived direction of movement but the small jumps drove the motion aftereffect. Conclusion: Adaptable visual pathways prefer jumps of 0.2° –1° (equivalent velocities: 2.5° – 15° s^{-1}).
[Supported by a grant from UCSD Senate.]

OBJECTS AND SHAPES

◆ **Perceptual learning and the critical period for visual development**
J A Movshon, L Kiorpes (Center for Neural Science, New York University, USA; e-mail: movshon@nyu.edu)

Classical studies established a critical period for visual development by measuring ocular dominance plasticity. This critical period was initially thought to correspond to the period of maturation of spatial vision and of V1 neuron responses. Recent work in both humans and monkeys has shown that the maturation of visual function continues for a much longer time for more complex visual functions and higher visual cortical areas. Meanwhile, studies of perceptual learning in adults have increasingly suggested that the locus of learning lies in these higher cortical areas, and that learning is most extensive for complex visual tasks. As suggested by Levi (2005 *Devepmental Psychobiology* **46** 222 – 232), and based on behavioural and neurophysiological studies of development in macaque monkeys, we propose that visual maturation and perceptual learning reflect the same underlying processes. The apparent distinction between them arises from a cascade of developmental periods, ending early in life in lower visual areas, continuing longer in higher ones, and extending throughout life in yet higher ones.

◆ **The organisation of the foveal confluence in human revealed by high resolution fMRI**
M M Schira, C W Tyler¶, B Spehar (School of Psychology, University of New South Wales, Sydney, Australia; ¶ The Smith-Kettlewell Research Institute, San Francisco, USA; e-mail: mschira@unsw.edu.au)

Decades of research have resulted in a detailed understanding of the retinotopic layout of early visual areas V1 and V2, but a less detailed understanding of V3 and V4. The central ends of

these retinotopic maps join together and form the foveal confluence. Using electrophysiology or cytoarchitecture mapping the precise organisation of visual areas in this foveal confluence has proven difficult. Ironically, therefore the most important region of the visual field maps has remained 'terra incognita'. We used fMRI with $1.2 \times 1.2 \times 1.2$ mm functional resolution to resolve the foveal confluence in human subjects. Our results show that the two halves of V3 are connected. Accordingly, in the fovea, V3 forms a band of 5 to 10 mm width (varying across subjects) surrounding the foveal band of V2. In contrast to current models of primate visual cortex, V4 does not border V2. We also show that roughly half of the representation of the central 0.3 degree cannot be attributed to V1 – V3, but belongs to uncategorised visual areas.

◆ **Objects, big and small: evidence for canonical visual size in object representation**
T Konkle, A Oliva (Brain and Cognitive Sciences, MIT, Cambridge, USA; e-mail: tkonkle@mit.edu)

Real-world objects typically have a fixed physical size and can be viewed from a range of distances, thus they can subtend a range of angles in the visual field. Given this range, is there a visual size that is preferred? Akin to studies on canonical viewpoint, we present a series of studies supporting the existence of a canonical visual size for objects, using subjective norming, short-term memory, and long-term memory paradigms. The data show that the canonical visual size is (i) the anchor for memory of the object's visual size, (ii) related to the known physical size of the object in the world, dissociated from the information content in the stimulus, and (iii) depends on the frame of space around the object, both on the screen and in real-world viewing settings. These results suggest that knowledge about the physical size of objects in the world influences the visual size at which objects are preferentially viewed and optimally remembered.
[Supported by NSF (IIS 0705677).]

◆ **Seeing objects in the dark: evidence for a robust internal representation of external objects in the world**
T Carlson, G Alvarez¶, D Wu, F A J Verstraten§ (Vision Science Laboratory, Harvard University, Cambridge, USA; ¶ Department of Brain and Cognitive Sciences, MIT, Cambridge, USA; § Helmholtz Institute, Universiteit Utrecht, The Netherlands; e-mail: tom@wjh.harvard.edu)

Davies (1973) previously showed volitional movements of appendages (eg the hand) causes an induced positive afterimage of that appendage to fade or disappear. This phenomenon has been attributed to an internal conflict between the location of the appendage seen in the afterimage and proprioceptive feedback. The present study tested an alternative hypothesis, which is that the fading is a consequence of a conflict between visual information present in the afterimage and a broader internal representation of the world. We conducted a series of experiments in which subjects interacted with external objects visible in the afterimage. Our experiments found that external objects also faded when subjects displaced their location (ie dropped the object onto the floor). Importantly, if the fading were solely a consequence of proprioception, these external objects would not be subject to this fading phenomenon. We therefore conclude that the brain maintains an active representation of both body position and, at a minimum, a small set of objects directly under the observer's control.

◆ **Invariant decoding of object categories from V1 and LOC across different colours, sizes, and speeds**
Y Chen, J D Haynes¶ (Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany; ¶ Bernstein Center for Computational Neuroscience Berlin, Germany; also Charité, Universitätsmedizin, Berlin, Germany; e-mail: ychen@cbs.mpg.de)

Categorical representations of objects in visual cortex have been intensively investigated using fMRI in humans. However it remains unclear to which degree specific brain regions encode objects invariant of their defining features. We approached the problem using 3-D rendering of objects rotating along a randomly changing axis. Multivariate techniques were used to decode objects from fMRI signals. We investigated to which extent changes of size and rotation speed of objects affected the accuracy with which they could be decoded. The degree of generalization of classifiers across different conditions was also assessed by training the classifier on one scale or rotation speed and testing it on the other. While decoding accuracy for objects in V1 was above chance for all speeds except for a control condition where decoding was attempted across multiple static 3-D renderings, object selectivity in LOC showed much higher generalization than in V1. Our results support the notion that object representations in temporal cortex can be decoded independently of their precise spatial representation in retinotopic regions.

SYNAESTHESIA

◆ **Visualizing synaesthesia: attention, perception, and crossmodal plasticity**
M J Proulx (Institute of Experimental Psychology II, Heinrich Heine University Düsseldorf, Germany; e-mail: Michael.Proulx@uni-duesseldorf.de)

This symposium provides a cross-cutting snapshot of synaesthesia research, with a focus on its neural origins, its impact on visual attention, and its implications for the development and plasticity of crossmodal processing in normal cognition. The overview talk will provide a basic introduction of research on synaesthesia and crossmodal perception, with the aim of connecting the various research themes within a common framework. A particular focus will be paid to the implications that synaesthesia and crossmodal perception have for visual perception, and for possible visual aids for the blind. The four talks will focus on aspects of synaesthesia research described above, providing an excellent basis for a discussion of particular intersecting areas of research on crossmodal perception and vision.

[Supported by the Volkswagen-Stiftung.]

◆ **Posthypnotic suggestion induces synaesthetic crossmodal sensation in the absence of abnormal neuronal connections**
R Cohen Kadosh, A Henik¶, A Catena§, V Walsh, L J Fuentes# (Institute of Cognitive Neuroscience & Department of Psychology, University College London, UK; ¶ Department of Psychology, Ben-Gurion University of the Negev, Be'er Sheva, Israel; § Department of Psychology, University of Granada, Spain; # Department of Psychology, University of Murcia, Spain; e-mail: r.cohenkadosh@ucl.ac.uk)

Abnormal crossmodal interactions can occur following brain damage, or in participants with additional experiences, such as synaesthetes, who otherwise can be considered neurologically normal. Grapheme-colour synaesthetes, for example, will experience certain achromatic graphemes in specific colours. A better understanding of the causes of synaesthesia and, in turn, of the causes of the abnormal crossmodal interactions is fundamental for our understanding of crossmodal connectivity and inter-aerial interactions in the normal brain, as well as other phenomena such as perceptual awareness, feature binding, and automaticity. The question of whether the kinds of abnormal crossmodal interactions seen in synaesthesia or following brain damage occur due to hyperconnectivity between or within brain areas or whether they are a result of lack in inhibition is highly contested. We will show that under posthypnotic suggestion non-synaesthetes can be induced to have synaesthetic experiences. Due to the short time-frame of the experiments, it is unlikely that new cortical connections were established, leading to the conclusion that synaesthesia can result from disinhibition between brain areas.

◆ **The impact of synesthesia on visual attention**
D Smilek, J S A Carriere, M J Dixon (Department of Psychology, University of Waterloo, Canada; e-mail: dsmilek@uwaterloo.ca)

We describe two lines of research that explore the impact of synaesthesia on visual attention. The first line focuses on individuals with time-space synaesthesia, a condition in which units of time, such as years and months, are experienced as occupying specific spatial locations. Using a variant of the standard cuing paradigm, with month names as centrally presented cues, we demonstrate that for time-space synaesthetes, time units can reflexively direct spatial attention. The second line of research focuses on how attention is influenced by grapheme-colour synaesthesia. We investigated the ramifications of grapheme colour congruency on attention by monitoring eye movements as individuals either freely viewed displays or searched for a target in displays of coloured graphemes. The results of both tasks showed that synaesthetic colours influenced eye movements. Taken together the findings suggest that synaesthesia can have a substantial impact on visual attention. The findings are discussed in the context of a growing body of research showing that synaesthetic experiences are not epiphenomenal but can have a substantial impact on cognition.

◆ **Localizing synaesthesia using fMRI**
T M van Leeuwen, K M Petersson¶, O Langner§, M Rijpkema, P Hagoort (F. C. Donders Centre for Cognitive Neuroimaging [§ Behavioral Science Institute], Radboud University Nijmegen, The Netherlands; ¶ Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands; e-mail: tessa.vanleeuwen@fcdonders.ru.nl)

People with grapheme-colour synaesthesia experience colour for letters and/or numbers; how is this colour experience mediated in the brain, without external colour input? Two theories propose different neural mechanisms of synaesthesia. The cross-wiring theory hypothesises synaesthesia is due to excess anatomical connectivity in the inferior temporal cortex, while the disinhibited feedback theory proposes increased feedback from multimodal parietal regions as the mechanism.

The goal of our fMRI study was to distinguish between these theories. First, we localised colour areas, grapheme areas and the effect of synaesthesia in a separate experiment, yielding regions of interest (ROIs) for nineteen synaesthetic subjects. Next, we performed a priming experiment to identify repetition suppression effects for synaesthesia in the ROIs. For synaesthetes, a synaesthetically induced colour should lead to a reduced BOLD response for a subsequently presented identical colour, in areas involved in colour experience. In matched controls, this effect should not occur. Taking into account individual differences between synaesthetes, we investigate the involvement of inferior temporal cortex and parietal regions in synaesthetic colour experience.

◆ **Interaction between cortical areas: lessons from synaesthesia**

C Blakemore (University of Oxford, Oxford, UK; e-mail: colin.blakemore@ndm.ox.ac.uk)

Normal perception depends on integration of information from different sensory systems, and there are many examples of enhancement or modification of perception in one sensory modality as a result of spatially and temporally correlated signals from other senses. Synaesthesia has been interpreted as an aberrant form of sensory interaction, dependent on inappropriate connections between cortical areas, perhaps established genetically (since synaesthesia is often familial). However, the particular induced sensations in synaesthesia, and the exact form of the inducing stimulus, are individually determined. The inducing stimulus often depends on learned concepts, such as graphemes or days of the week, suggesting that the underlying connectivity is not simply pre-specified genetically. Synaesthetic visual sensations can persist for decades in blind individuals, which implies that they do not depend on some sort of continuing associative learning. But synaesthesia in the blind also provides evidence that the particular aberrant associations are modifiable, at least in the first few years of life. This talk will review the development and plasticity of cortico–cortical connectivity and will consider other ways in which information might pass between cortical areas.

CROWDING

◆ **Crowding**

F W Cornelissen, D G Pelli¶ (Laboratory for Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, The Netherlands; ¶ Psychology and Neural Science, New York University, USA; e-mail: f.w.cornelissen@rug.nl)

In the periphery, a visual object that is easily recognized when shown in isolation is hard to identify when surrounded by other objects. This phenomenon is now commonly known as 'crowding'. Diverse studies of crowding come together to reveal one universal story, which we call the 'Bouma law': to be identified, simple objects must be separated by at least the observer's critical spacing. Recent work confirms Bouma's claim (Bouma, 1970 *Nature* **226** 177–178) that crowding limits the rates of reading and visual search. While the phenomenon of crowding has been well described, theoretical understanding of it is still tentative. For instance, it has been suggested that crowding may be feature integration for object recognition, or compulsory averaging for texture perception. This symposium honours the pioneering work of Herman Bouma on crowding. In it, recent theoretical and experimental work supporting and challenging the generality of the Bouma Law will be presented. The first three talks support the Bouma law, and the next three challenge it.

[Symposium supported by the Dutch Society for Biophysics and Biomedical Technology.]

◆ **In retrospect: adverse interactions in parafoveal letter recognition**

H E Bouma (Emeritus Professor, Technische Universiteit Eindhoven, The Netherlands; e-mail: heebouma@xs4all.nl)

Following my dissertation on light reactions of the human pupil (1965), I developed an interest in visual reading processes. For decades, this had not been an active research field. I investigated how far in the parafovea single letters can be recognized. The outcome was 16 letters from fixation, determined by acuity limitations. However, in text letters come in groups and the functional visual field is reduced by a factor of four for embedded letters. As saccade size averages 8 letters, this outcome made sense. Thus, in reading, adverse interactions, rather than visual acuity, restricts parafoveal recognition. Later, we bridged the gap between letter and word recognition. Next, I gradually increased the centre-to-centre spacing of the letters. Performance went up gradually, but only at a spacing of half the eccentricity did performance for embedded letters match that for single letters. The adverse interactions were also stronger toward the fovea than away from it (Bouma, 1970 *Nature* **226** 177–178). Our explorations continued in word recognition (including dyslexia) and visual search.

◆ **The uncrowded window and the Bouma law**
D G Pelli, K A Tillman (Department of Psychology and Neural Science, New York University, USA; e-mail: denis.pelli@nyu.edu)
It is now emerging that vision is usually limited not by object size, but by spacing. The visual system recognizes an object by detecting and then combining its features. When objects are closer together than the critical spacing, the visual system combines features from them all, producing a jumbled percept. We review the explosion of studies of this 'crowding' phenomenon—in grating discrimination, letter and face recognition, visual search, and reading—to reveal a universal principle: the 'Bouma law'. Critical spacing is equal for all objects. Furthermore, critical spacing at the cortex is independent of object position, and critical spacing at the visual field is proportional to object distance from fixation. The region where object spacing exceeds critical spacing is the uncrowded window. Observers cannot recognize objects that are outside this window. The uncrowded window limits how quickly people can read text and find an object in clutter.
[Supported by NIH grant R01-EY04432.]

◆ **Crowding explained by population coding**
R van den Berg, J B T M Roerdink, F W Cornelissen¶ (Institute for Mathematics and Computing Science & School of Behavioral and Cognitive Neuroscience, University of Groningen, The Netherlands; ¶ Laboratory for Experimental Ophthalmology & BCN NeuroImaging Center, University Medical Center Groningen, University of Groningen, The Netherlands; e-mail: r.van.den.berg@rug.nl)
Although the behavioural aspects of crowding have been studied for nearly a century, theoretical understanding of its neural basis and function has remained limited. One of the current issues is the question whether crowding is a top-down attentional phenomenon or a hard-wired bottom–up phenomenon. While supporting evidence exists for both theories, a fully comprehensive explanation of crowding is still lacking. Here, we demonstrate how a model based on principles of population coding can be derived from what is often considered the defining property of crowding, namely a critical region that scales with eccentricity according to Bouma's law. Interestingly, an emergent feature of this model is that it also explains when compulsory averaging in crowded orientation signals occurs, thus solving an apparent contradiction in the literature, where both the presence and absence of this effect has been reported. We present psychophysical data that both support these predictions and rule out purely attentional theories of crowding. Overall, our results suggest that crowding can be well-explained by a hard-wired feature integration mechanism.

◆ **Breaking the bound: weakly masking a target greatly expands the range of crowding interaction**
T J Vickery, W M Shim¶, R Chakravarthi§, YV Jiang#, R Luedeman (Department of Psychology, Harvard University, Cambridge, USA; ¶ Department of Brain and Cognitive Sciences, MIT, Cambridge, USA; § Department of Psychology, New York University, USA; # Department of Psychology, University of Minnesota, USA; e-mail: tim.vickery@gmail.com)
We found that the range of crowding, normally approximately half of target eccentricity, is dramatically enhanced by weak masks surrounding or trailing a target. Observers identified peripheral targets, either unflanked or flanked by distractors appearing at target–distractor distances up to 70% of the target's eccentricity. Targets were not masked or weakly masked by either a surrounding contour or backwards pattern mask. With no flankers, performance was near ceiling, with only a small effect of adding the mask. Flankers at a target–distractor distance of 50–70% of the target's eccentricity did not produce crowding of unmasked targets, but dramatically impaired target identification when the target was weakly masked. Effects of crowding and masking were super-additive, and thus inexplicable by their simple combination. Like standard crowding, this effect scaled with target-flanker similarity and was most affected by the outermost flanker. Critically, 'weakening' the target by reducing its contrast did not have this dramatic effect. Weakly masking a target reveals 'supercrowding', suggesting that peripheral feature integration occurs over wider expanses than previously thought.

◆ **Crowding and multifocal attention: splitting attention increases the size of the isolation field**
G A Alvarez, S L Franconeri¶ (Department of Brain and Cognitive Sciences, MIT, Cambridge, USA; ¶ Department of Psychology, Northwestern University, Evanston, USA; e-mail: alvarez@mit.edu)
Crowding refers to the difficultly of reporting the identity of a target item surrounded by distracting items. Most studies on crowding examine the ability to isolate and report the identity of a single target item, but in many tasks we must monitor and independently report the identities

of multiple targets. How is crowding affected when attention is split into multiple, independent foci? To address this question, we measured the size of the 'isolation field', which is the region over which the visual system integrates information. The smallest isolation field at a given location is measured as the minimum separation between the target and distractors at which there is no crowding (the 'critical spacing'). In several tasks, we find that the critical spacing increases as the number of targets increases, suggesting that splitting attention increases the size of the isolation field. This effect could have implications for understanding the nature of feature integration within and across multiple foci of attention.

◆ **Crowding is modulated by global stimulus configuration**
T P Saarela, B Sayim, G Westheimer¶, M H Herzog (Laboratory of Psychophysics, EPFL, Lausanne, Switzerland; ¶ Department of Molecular and Cell Biology, University of California at Berkeley, USA; e-mail: toni.saarela@epfl.ch)

In crowding, neighbouring elements impair the perception of a target. Crowding is often considered a consequence of spatial pooling of visual information. We investigated the role of configural effects in crowding by manipulating the global stimulus configuration while keeping constant the orientation, spatial frequency, and spatial phase of the elements making up the stimuli. We measured contrast and orientation discrimination thresholds for a peripheral Gabor target that was flanked on both sides by seven Gabor patches. When the target and the flanking Gabors were of equal length, discrimination performance was strongly impaired. However, when changing the stimulus configuration by (i) making the flanks either shorter or longer than the target or (ii) constructing each flank from two or three small Gabors, the impairment was largely reduced, even abolished. These results challenge simple pooling accounts of crowding. We suggest crowding is weak or absent whenever the target and flanks do not form a coherent texture, even when their 'low-level' properties are matched. A target that stands out avoids crowding.
[Supported by the Swiss National Science Foundation (SNF).]

Erratum

The abstract below was accidentally omitted from the Wednesday posters session. It should have appeared in second position under the heading "Motion perception and temporal issues" (page 110).

◆ **Motor and perception-based prediction**
A Sciutti, F Nori, G Metta¶, T Pozzo§, G Sandini (Istituto Italiano di Tecnologia, Genoa, Italy; ¶ Dipartimento di Informatica Sistemistica e Telematica, University of Genoa, Italy; § INSERM U887, Motricité Plasticité, France; e-mail: alessandra.sciutti@iit.it)

In this study we investigated whether prediction is differently realized when it is aimed at 'driving a motor act' and when instead its purpose is 'perceptual-only'. In particular we focused on how dynamical information of target motion is used depending on prediction goal. In a first experiment a ball disappeared behind an occlusion after following parabolic paths. To analyze the 'driving a motor act' condition we asked subjects to move their arm to intercept the ball. In a second experiment we investigated the 'perceptual-only' condition by repeating a similar task but requiring only a perceptual evaluation. Subjects had to select (in 2AFC protocol) where the ball would have arrived after the occlusion. Performances in both experiments were measured in two conditions: (i) ball driven by a constant force field and (ii) by a variable force field. Results showed that while ball dynamics stability facilitates interception, it does not affect perceptual assessment. The dynamic visual information seems therefore to be processed differently when its purpose is a motor act versus a perceptual one.

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