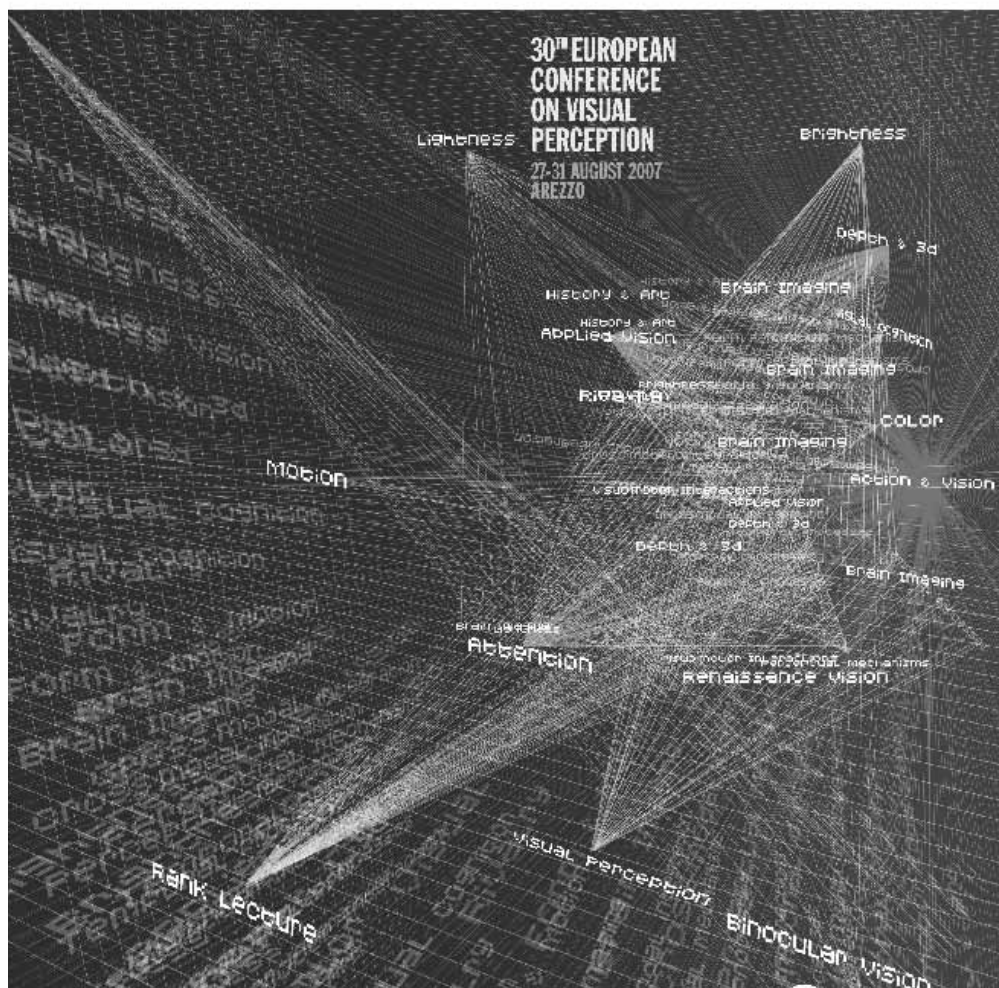


PERCEPTION

VOLUME 36 SUPPLEMENT



30TH ECVP
AREZZO 27-31 AUGUST 07

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Thirtieth European Conference on Visual Perception

Arezzo, Italy

27 – 31 August 2007

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Monday/Tuesday

ECVP '07 Abstracts

MONDAY

THE PERCEPTION LECTURE

◆ **The intersection of visual science and art in Renaissance Italy**

C W Tyler (Smith-Kettlewell Research Institute, San Francisco, USA; e-mail: cwt@ski.org)

An extraordinary confluence of art and science was instigated in the Marches region by the Grand Duke Federigo of Montefeltro early in the Renaissance. Educated in the humanistic school of philosophy, his court of Urbino patronized many of the greatest practitioners of the age in the newly scientific arts of geometric analysis for both painting and architecture. The Duke's famous study contained a portrait gallery of influential philosophers and an array of 'trompe l'oeuil' inlaid panels in vivid perspective. Some of the collaborators in the intellectual community of Urbino were the artists Paolo Uccello, Leonardo da Vinci, Botticelli, Perugino, Pisanello, the young Raphael, his father Giovanni Santi, Justus of Ghent, Fra Carnevale and the iconic artist/mathematician, Piero della Francesca. The artistic confluence included architects Leon Battista Alberti, Donato Bramante, Francesco di Giorgio Martini and Luciano Laurana. Inspired by the recent translation of Greek classical texts by Marsilio Ficino, a keynote book of this philosophy was *Divina Proportione* by mathematician Luca Pacioli. With illustrations of the Platonic Solids by Leonardo, this ambitious work expounded the power of mathematics in art and science. This theme is extended in Piero della Francesca's last painting, the Montefeltro Altarpiece, in which the purity of the Virgin is epitomized by the perfect forms of an egg suspended from a scallop shell, with the Duke himself paying homage. From a mathematic viewpoint, these artistic intellects were sophisticated exponents of the defining visual tool of the period, linear perspective, which formed the analytic framework for the new explorations of the perceptual qualities of their architecture and the wall decorations of their urban environment. The catholic interests of Duke Federigo thus inspired a unique convergence of philosophical, artistic and scientific thought that was a key influence on the Renaissance as a whole.

TUESDAY

ORAL PRESENTATIONS

GROUPING AND INTEGRATION PROCESSES

◆ **Locus of spatial attention determines inward – outward anisotropy in crowding**

Y A Petrov (Northeastern University, Boston, USA; e-mail: y.petrov@neu.edu)

In crowding studies, it is well-known that an outward mask is much more disruptive than an inward mask. Here I show that the locus of attention strongly affects this inward–outward anisotropy, inducing it in some conditions, removing or reversing it in others. In a 2AFC paradigm, subjects identified whether a high-contrast Gabor, slanted left 45°, was presented on the left or right of fixation. When a fixed eccentricity (8°) was used, the outward plaid mask produced stronger crowding than the inward mask. When 7°, 8°, and 9° eccentricities were interleaved within the same run, diffusing attention, the inward and outward masks produced the same amount of crowding for all three eccentricities. When target identification was contingent on a foveal cue, biasing attention inward, the inward mask produced stronger crowding. A separate contrast-detection experiment for an isolated target demonstrated that attention is generally mislocalized outward of the target, which may explain the commonly observed anisotropy in crowding. Spatial attention is intimately involved in the mechanism of crowding.

[Supported by National Institute of Health Grant RO1EY01728 and by the Smith-Kettlewell Eye Research Institute.]

◆ **Crowding: An interplay of grouping and segmentation**

T Livne, D Sagi (Department of Neurobiology, Weizmann Institute of Science, Rehovot, Israel; e-mail: Tomer.Livne@weizmann.ac.il)

A smooth arrangement of co-circular Gabors around a target caused considerably less crowding than pseudo-random arrangements [Livne and Sagi, 2007 *Journal of Vision* 7(2):4 1–12]. Here, we show, using 2AFC orientation-discrimination task, that it is the separation of flankers and target into distinct groups of elements that reduces crowding, rather than simply their collinearity.

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In the experiment, a two-flankers stimulus served as a baseline with other stimuli containing additional Gabors that formed different spatial and orientation relationships between stimulus elements (10 configurations, 100 ms duration, 2.5° eccentricity). We found that strong crowding by two flankers (0.52 log units) is not affected by adding two pairs of collinear or co-oriented Gabors in proximity to each of the flankers from the pair; however, crowding is much reduced if each of these flankers becomes a part of a group which does not include the target (0.15–0.3 log units). A segmentation model, one that assumes competitive grouping between stimulus elements following the Gestalt laws of proximity and (orientation) similarity, was able to approximate these results.

◆ **Suppressive and facilitatory effects of context on contour integration**

S C Dakin, N Baruch ¶ (UCL Institute of Ophthalmology, University College London, London, UK; ¶ St George's Medical School, London, UK; e-mail: s.dakin@ucl.ac.uk)

We adapted a psychophysical contour-detection paradigm (Field et al, 1993 *Vision Research* 33 173–193) to examine the role that a contour's surround has on its detectability. Specifically, we manipulated the relative orientation of distractor elements compared to their nearest contour element (weighted by contour–distractor distance) to generate surround conditions ranging from near-parallel to near-perpendicular. To prevent the surround acting as a cue (as it would for detection) observers judged (2AFC) which configuration the contour was in (from two 'S'-like possibilities). To factor out any contribution of local orientation 'pop-out' between contour elements and distractors, we compared performance with contours composed of either contour-parallel elements ('snakes') or contour-perpendicular elements ('ladders'). The ratio of snake to ladder thresholds gives the 'value added' by the surround to contour integration, over and above normal orientation pop-out. We report that near-perpendicular and near-parallel surrounds substantially improve and interfere with contour detection, respectively. These findings are consistent with facilitatory-surround and inhibitory-surround effects observed in V1 and with the orientation statistics of natural scenes.

[Funded by The Wellcome Trust.]

◆ **Visual crowding distinguishes features, parts, and objects**

D Pelli, K A Tillman (Department of Psychology and Neural Science, New York University, New York, USA; e-mail: denis.pelli@nyu.edu)

Object recognition requires feature detection and feature integration. In crowding, feature detection succeeds, but feature integration fails. This happens when the scene is cluttered and the visual system integrates features over an inappropriately large region, jumbling the features of the object with extraneous nearby features. The critical spacing for crowding is equal for all stimuli susceptible to crowding. Critical spacing increases in proportion to eccentricity in the visual field, but corresponds to a constant 14 mm interval at V1 [Motter and Simoni, 2007 *Journal of Vision* 7(2):6, 1–15]. Measuring critical spacing provides diagnostic tests for features, parts, and objects. (i) One-feature tasks, eg vertical vs horizontal, are immune to crowding. (ii) Recognizing objects with only one part, like a letter, requires only one feature integration. Thus, one-part objects can be crowded by surrounding clutter, but do not crowd themselves. (iii) Multi-part objects, like words and faces, require a feature integration for each part. Thus, a multi-part object crowds itself. In sum, crowding exposes the steps of object recognition, and critical spacing seems to be a fundamental parameter of human vision.

[Supported by grant NIH R01-EY04432.]

◆ **Texture-surround suppression of contour shape coding**

F A A Kingdom, N Prins ¶ (Department of Ophthalmology, McGill Vision Research, Montreal, Canada; ¶ University of Mississippi, Oxford, USA; e-mail: fred.kingdom@mcgill.ca)

Iso-orientation surround suppression (IOSS) is the phenomenon in which the detection of a line is suppressed by similarly oriented surrounding lines. IOSS has been demonstrated in monkey neurons and by demonstrations of lines becoming 'lost' when embedded in gratings. Recently we showed that the shape-frequency aftereffect, or SFAE (in which the perceived shape-frequency of a sinusoidal contour is altered by adaptation to a contour of different shape-frequency), is reduced when the adaptation contour is surrounded by parallel contours. Here we investigate the orientation tuning of the surround inhibition. We found that, when the surround contours were made from Gabors that were oriented parallel to the adaptation contour, the SFAE was reduced by about a factor of 2. However, when the surround Gabors were oriented orthogonally to the adaptation contour, the SFAE was only minimally affected. These findings reveal that

contour-shape coding is susceptible to IOSS, and that IOSS neurons in V1 likely feed their signals into shape-coding neurons in higher visual areas.

[Supported by a Natural Sciences and Engineering Research Council of Canada (NSERC) grant # OGP01217130 given to FK.]

◆ **Low task interference reveals ready grouping of distant motion flows**

Y Festman, J Braun (Institute of Biology, Otto-von-Guericke Universität, Magdeburg, Germany; e-mail: yariv.festman@nat.uni-magdeburg.de)

Recent theories of attentional selection emphasize the role of grouping processes in forming object-based representations. One important consequence is that grouping processes may eliminate or reduce interference in dual-task situations. Here we use task interference as a quantitative measure of grouping between distant motion flows. Two fields of moving dots were presented simultaneously to the left and right of fixation (diameter 2.5 deg, eccentricity 4°, coherence 10%–25%). Four types of motion flows were used (vertical, horizontal, circular, or radial). In a dual-task situation, observers identified motion direction independently for each motion field (eg left upward or downward, right expansion or contraction). In single-task situations, observers identified motion direction of one field and ignored the other. Task interference decreased systematically with increased grouping between left and right motion flows (estimated independently with a computational model). Surprisingly different flows resulted in significant grouping: rotation and translation, two counter-rotations, expansion and contraction, among others. Thus, grouping processes readily link distant motion flows on either side of fixation.

EYE MOVEMENTS

◆ **Contributions of fixational eye movements to pattern vision**

M Rucci, R Iovin, M Poletti, F Santini (Department of Cognitive and Neural Systems, Boston University, Boston, USA; e-mail: rucci@cns.bu.edu)

The function of fixational eye movements during natural viewing has long been debated. Retinal stabilization experiments have selectively focused on prolonged fixation, a condition that alters fixational instability. Here, we investigate the effect of eliminating retinal image motion during natural intersaccadic fixation. In a forced-choice discrimination task, subjects reported whether a noisy grating was tilted by 45° clockwise or counterclockwise. Stimuli were displayed for 1 s after a saccade to a randomly cued location. Retinal stabilization impaired discrimination of high-frequency gratings but had no impact on discrimination of low-frequency gratings. This effect originated from the temporal modulations of luminance introduced by fixational eye movements, as demonstrated by experiments with controlled retinal image motion. Discrimination was impaired when these input modulations did not convey information about the grating's orientation but was instead normal when retinal image motion resulted in maximal information. These results suggest that fixational eye movements contribute to the processing of spatial detail, as originally proposed by Hering in 1899.

[Supported by NIH-EY015732.]

◆ **Perceptual continuity across saccadic eye movements: The role of predicting remapping of visual features**

D Melcher, (Center for Mind/Brain Studies and Department of Cognitive Science, University of Trento, Rovereto, Italy; e-mail: david.melcher@form.unitn.it)

The use of saccadic eye movements to fixate objects in a scene raises the question of why perception seems to be stable and continuous. One possible explanation is remapping of receptive fields around the time of saccades. Consistent with this hypothesis, visual form processing was altered by the intention to make a saccade at both the current fixation position and the location of the saccadic target. When observers prepared to follow a displacement of the stimulus, tilt adaptation was transferred from current fixation to the future gaze position. In addition, a pre-saccadic transfer of adaptation was found before observers moved their eyes towards a stationary adapting stimulus in peripheral vision. Further experiments show that this 'remapping'—the transfer of adaptation—is not limited to a single object and can be dissociated from shifts of attention.

◆ **A retinal compensation mechanism for fixation instability as revealed by the peripheral drift illusion**

A L Beer, A Heckel, J Winkler, M Greenlee (Institut für experimentelle Psychologie, Universität Regensburg, Regensburg, Germany; e-mail: anton.beer@psychologie.uni-regensburg.de)

In the peripheral drift illusion, static patterns containing four elements of different luminance appear to move. The illusion depends on the contrast of the elements and the extent of fixation instability (eye micro-movements). However, these factors alone cannot account for the persistent

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and distinct nature of the illusion. We proposed a retinal (as opposed to an extra-retinal) compensation mechanism for fixation instability. According to this notion, the strength of the illusion in the periphery depends on the pattern presented at fixation. The results of a behavioural experiment showed that illusory motion was perceived strongest when the pattern at fixation was the reversal of the peripheral pattern, weakest when the fixation pattern was the same as in the periphery, and intermediate with a neutral pattern. Preliminary fMRI data indicated that activity at peripheral representations of V1 is similarly modulated by the fixation pattern. The modulation of the peripheral drift illusion by the central pattern suggests a retinal compensation mechanism for fixation instability that feeds back to early visual cortex.

[Supported by the Excellence Network Bavaria (ENB) and (FP6 Cognitive System, Project “Decisions in Motion”).]

◆ **Spatial predictability decreases the impact of target onset in the gap task**

M Rolfs, F Vitu ¶ (Department of Cognitive Psychology, University of Potsdam, Potsdam (OT Golm), Germany; ¶ UMR 6146, CNRS, Université de Provence, Marseille, France; e-mail: rolfs@uni-potsdam.de)

The gap effect is a robust phenomenon showing that saccade latency is reduced when the fixation stimulus is removed shortly before a saccade target appears compared to when the fixation stimulus remains present. To test the assumption that the gap effect benefits from advanced motor preparation (Pare and Munoz, 1996 *Journal of Neurophysiology* 79 3060–3076), we manipulated both the onset of the saccade target and the uncertainty of target location. The signal to launch a saccade (ie a peripheral offset at the location opposite the saccade target) was accompanied or not by a luminance increment at the target location; the number of potential target locations in a trial varied between 2, 4, and 8. Target onset reduced saccade latency in all conditions, but the effect scaled as target uncertainty became lower in gap trials, while the gap effect was found to be greatest under low spatial uncertainty. These findings confirm that advanced motor preparation is involved in the gap effect, at least under optimal spatial-predictability conditions.

[Support: We greatly thank Reinhold Kliegl for his help and encouragements, and for letting us use his eye-movement laboratory.]

◆ **Can we see image motion during pursuit eye movement?**

T C A Freeman, J Sumnall, R Snowden (Department of Psychology, Cardiff University, Cardiff, Wales, UK; e-mail: freemant@cardiff.ac.uk)

To extract objective velocity during pursuit, image motion must be mapped onto other coordinate systems. Can image motion be accessed independently of these mappings? To investigate, we examined whether varying pursuit speed in a speed-discrimination task affected performance. Discrimination thresholds for image motion were compared in two conditions: homogeneous pursuit, where each trial combined two intervals with a common pursuit speed (4, 4; 8, 8; 12, 12 deg s⁻¹); heterogeneous pursuit, where intra-interval pursuit varied (4, 8; 4, 12; 8, 12). Separate thresholds were obtained for image motion in ‘same’ or ‘different’ directions from pursuit. Eye-movement recordings were used to estimate actual image speed in each interval and psychometric functions constructed by means of a histogram analysis. We found no difference between pursuit conditions and only one observer showed any effect of direction. Removing relative motion between pursuit target and stimuli did not alter the results. Furthermore, trial-by-trial decisions during heterogeneous pursuit were a better function of image speed than screen speed. Observers seem able to access image motion independently of the mapping process.

[Supported by the Wellcome Trust.]

◆ **Changes in contrast sensitivity of area V4 neurons during saccadic eye movements**

X Han, S Xian ¶, T Moore (Department of Neurobiology, Stanford University, Stanford, USA; ¶ Cornell University, Ithaca, USA; e-mail: xuehan1@gmail.com)

We determined the contrast sensitivity of V4 neurons at varying intervals prior to the onset of saccadic eye movements in monkeys performing a behavioral task adapted from studies of saccadic suppression in human observers. We measured luminance and chromatic contrast thresholds using briefly flashed stimuli presented within a V4 neuron’s receptive field (RF) prior to saccades directed at targets distant from the RF. Chromatic stimuli were presented at equiluminance and varied either in L–M or S cone contrast. We found that luminance contrast sensitivity was dramatically reduced before saccades for most V4 neurons. Chromatic contrast sensitivity was much less reduced, with many neurons showing enhancement, particularly for S stimuli. Our results suggest that the saccadic suppression of contrast sensitivity reported in human observers can be accounted for, at least in part, by an active perisaccadic suppression of contrast sensitivity in extrastriate visual cortex. These results are also consistent with evidence of an active influence of saccade-related signals on the gain of visual responses in cortex.

Supported by HHWF (to XH), NIH Grant EY14924 and Pew Charitable Trust (to TM).

SPATIAL VISION◆ **Precise discrimination of stimulus position in visual object and motion regions of the human brain**

D Whitney, N Spotswood, E Louie (Center for Mind and Brain, University of California at Davis, Davis, USA; e-mail: dwhitney@ucdavis.edu)

Although precise retinotopic maps have been found in early visual areas, it is thought that these maps either do not exist or are spatially coarse in object-selective regions (eg, LOC, FFA, PPA) and motion-selective regions (MT+) of the visual cortex. Using a novel fMRI technique, we tested and quantified the precision of position coding in these regions. Within separate FFA, PPA, LOC, and MT+ ROIs, we cross-correlated patterns of activity produced by flickering Gabors (no net motion) located at one of five eccentricities ranging from ~ 9 to 11 deg. Within the PPA ROI, Gabors that were closely positioned produced highly correlated patterns of activation. As the separation between the Gabors increased, the patterns of activity decorrelated, indicating that PPA was able to reliably discriminate shifts in Gabor position of less than 2 deg. The LOC and MT+ ROIs were also able to discriminate Gabors shifted by less than 2 deg. The results suggest that object- and motion-selective regions of the visual cortex are able to code precise information about object position.

[Supported by NIH, USA.]

◆ **Quickly modifying a trajectory in response to a change in target orientation**

E Brenner, J Smeets (Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; e-mail: e.brenner@fbw.vu.nl)

During goal-directed movements it takes just over 100 ms to start adjusting the position of the hand to a sudden change in target position or the orientation of the hand to a sudden change in target orientation. We here examine a less direct relationship: that between target orientation and hand trajectory. We previously argued that a tendency to approach surfaces orthogonally is critical for many goal-directed movements. We therefore used a simple interception task with elongated targets to examine whether the hand's path is quickly adjusted when the target's orientation changes. For abrupt 45° changes in target orientation, subjects took just over 100 ms to start adjusting the path to achieve a more orthogonal approach. Such adjustments were guided by the new orientation, rather than the rotation itself, because responses to (apparent) leftward and rightward 90° rotations, which resulted in identical target orientations but could be distinguished because our targets were asymmetrically patterned, were identical. These adjustments could even be responsible for the fast responses to target orientation in grasping.

◆ **Area summation is linear but the contrast transducer is nonlinear: Models of summation and uncertainty and evidence from the psychometric function**

R J Summers, T Meese (School of Life and Health Sciences, Aston University, Birmingham, UK; e-mail: R.J.Summers@aston.ac.uk)

Area summation has not been assessed against contemporary models involving probability summation and uncertainty for 2IFC. Here we did this for 2.5 cycles deg^{-1} vertical gratings with diameters of 1–32 cycles. The different areas were (i) blocked (framed by a quad of fixation-points) and (ii) interleaved. We found steep summation curves over the first 8 cycles and slightly greater sensitivity (~ 1.5 dB) for the blocked condition. Neither area nor blocking affected the slope of the psychometric function ($\beta \sim 3.5$). We derived predictions for summation of (stochastic) noisy mechanisms using the framework of Tyler and Chen (2000 *Vision Research* **40** 3121–3144) for blocked and interleaved strategies. The contrast transducer was either linear or nonlinear ($C^{2.4}$), and area summation was either linear or a MAX operation over an attention-window that never exceeded the largest stimulus (1024 mechanisms) or included a further 1024 irrelevant mechanisms. Of these 8 canonical models, only the nonlinear transducer with linear summation described the form of the data. The MAX rule with additional noise came second. The other models failed badly.

[Supported by The Wellcome Trust.]

◆ **Area summation of contrast extends over the entire dipper function**

T S Meese, R Summers (School of Life and Health Sciences, Aston University, Birmingham, UK; e-mail: t.s.meese@aston.ac.uk)

The world's textures extend over space, suggesting a need for spatial integration. But most models fall shy of this because there is no advantage of grating area above threshold, and the advantage at threshold is attributed to probability summation. Both of these beliefs are challenged here. Results at threshold are consistent with linear summation of contrast following retinal inhomogeneity, spatial filtering, nonlinear transduction, and additive Gaussian noise. The suprathreshold loss of the area advantage in previous studies is due to a concomitant increase

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in suppression from the pedestal. To overcome this, a novel stimulus class is designed where: (a) the observer operates on a constant retinal area, (b) the target area is controlled within this summation field, and (c) the pedestal size is fixed. With this paradigm, substantial summation (~ 6 dB) is seen over the entire dipper function. All this is modelled with one free parameter, implying suprathreshold summation of contrast over at least seven grating cycles. Attentional summation (Tyler and Chen, 2000 *Vision Research* **40** 3121–3144) cannot account for the results. [Supported by grants from the Wellcome Trust and the Engineering and Physical Sciences Research Council.]

◆ **Non-oriented filters are better than oriented filters for skewness detection**

L Sharan, E H Adelson, I Motoyoshi ¶, S Nishida ¶ (Department of Brain and Cognitive Sciences & Computer Science and Artificial Intelligence Lab, MIT, Cambridge, USA; ¶ NTT Communication Science Laboratories, Atsugi, Japan; e-mail: l_sharan@mit.edu)

A material that has mesostructure, such as stucco, looks darker and glossier when the skewness of the luminance histogram is higher. Skewness is a useful cue, and humans seem to use it. We have proposed a simple computational model for estimating skewness with neurons, in which the ON and OFF output streams of filters are each run through a nonlinearity, followed by pooling and differencing (Motoyoshi et al, 2007 *Nature* **447** 206–209). We now show computationally that non-oriented (center–surround) filters have advantages over oriented (Gabor-like) filters in this task. We used the skewness of filter outputs (ie sub-band histograms) to classify images as having positive or negative luminance skewness, and estimated d' . Non-oriented filters typically outperform oriented filters by factors ranging from 2 to 10; this is true both for natural images and for random noise. We also find no psychophysical evidence for orientation selectivity in the skewness aftereffect (Motoyoshi et al, 2007 *Nature* loco cit). Thus, non-oriented filters seem to dominate skewness computations.

[Supported by NTT CS Labs, NSF.]

◆ **Redundancy reduction processes revealed by suppressive centre – surround interactions**

J R Cass, P J Bex ¶, S Dakin (Institute of Ophthalmology, University College London, London, UK; ¶ Schepens Eye Institute, Harvard University, Boston, USA; e-mail: j.cass@ucl.ac.uk)

The perceived contrast of small achromatic patterns is generally found to depend upon the orientation and spatial-frequency content of the immediate surround. Such contextual interactions are usually suppressive, particularly when centre and surround have similar spatial characteristics (Chubb et al, 1989 *Proceedings of the National Academy of Sciences of the USA* **86** 9631–9635; MacDonald and Tadmor, 2006 *Vision Research* **46** 3098–3104). We investigated the nature of surround suppression by systematically varying the relative orientation or fractal dimension of the centre and surround. We report that (spatially narrow-band) surround suppression is greatest when centre and surround are closely matched in orientation (decreasing monotonically out to differences of 45°). For spatially broad-band stimuli, peak suppression depended critically on the surround having a greater exponent (relatively over-representing high spatial frequencies) than the centre, regardless of the absolute fractal dimension of the centre ($a = -1.5, -0.9, \text{ and } -0.5$). Combined, these results imply that visual system uses surround suppression to reduce redundancy within a visual scene, but employs distinct rules depending on whether differences arise from changes in local orientation or fractal dimension.

[Supported by The Wellcome Trust.]

TEXTURES, CONTOURS AND SHAPES

◆ **The speckled hen: A perceptual scale for number**

D C Burr, J Ross ¶ (Department of Psychology, Università di Firenze, Florence, Italy; ¶ University of Western Australia, Crawley, Australia; e-mail: dave@in.cnr.it)

Recent neurophysiological evidence has confirmed a 1971 suggestion of Atkinson and Campbell that there exist in primate parietal cortex neurons that respond selectively to numerosity. We have investigated the number sense in humans with psychophysical techniques. Using the method of single stimuli and two-alternative forced-choice, we confirm that Weber's law applies over a very wide range of base numbers, yielding Weber fractions around 25% (leading to perfect performance at $n = 4$). Varying the shape and size of elements to be judged did not affect accuracy or precision, showing that numerosity judgments are not based on texture. Adaptation to more or less numerous fields affected greatly apparent numerosity of a subsequent test, up to threefold. Linearizing techniques suggest that perceived numerosity follows a logarithmic scale. These results show that, like luminance, contrast and shape, numerosity can be considered a perceptual attribute, which can be profoundly affected by adaptation and context.

◆ **A straightforward account of texture perception across the visual field**

D R Keeble, C Vakrou, D J Whitaker, B T Barrett (Department of Optometry, University of Bradford, Bradford, UK; e-mail: D.R.T.Keeble@Bradford.ac.uk)

The spatial processing of most visual tasks is homogenous across the visual field apart from a change in scale. We investigated the eccentricity-dependent variation in scale for a texture segmentation task in an attempt to account for the many reported observations of central performance drop (Yeshurun and Carasco, 1998 *Nature* **396** 72–75). We measured performance for detection in a 2IFC task of a small patch of oblique lines within a larger background of lines tilted obliquely in the opposite direction. Stimuli at all eccentricities were simply magnified versions of each other—a method of spatial scaling. We obtained estimates of the magnification required to equate performance in central and peripheral vision. Performance across all eccentricities could be accounted for simply by a change of scale with different exposure durations, each revealing a unique, critical stimulus size. In other words, there is no qualitative difference in texture perception across the visual field, and we found no evidence for inferior performance at the fovea compared to more peripheral locations.

◆ **Grasping points along the contour of outline drawings of everyday objects**

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In previous research we investigated the role of curvature singularities along the contour for identification and segmentation of outlines derived from line drawings of everyday objects. Here we examined whether they also influence the more behaviourally relevant task of grasping. Plastic shapes (12 mm thick and max. 70 mm long), consisting of smoothed outlines of 30 objects (10 animals, 10 artefacts, and 10 unidentifiable shapes), were presented in three orientations (0°, 120°, and 240°). Twelve participants had to move their hand from the right side of the table to the target shape, grasp it with thumb and index finger, lift it, and put it on the left side of the table. The contact points of the fingers on the shape (measured with Optotrak) were determined more strongly by properties that determine how good they are as grasping points (stable grip, grasp axis going through centre of gravity) than by their perceptual salience as such (curvature singularities). Intersubject consistency was highest for identifiable shapes in upright orientations.

◆ **From cortical anisotropy to failures of 3-D shape constancy**

Q Zaidi, E Cohen (College of Optometry, State University of New York, New York, USA; e-mail: qz@sunyopt.edu)

The ability to perceive the shape of a rigid object as constant across viewing angles has been considered essential to perceiving objects in the visual world accurately. We show that the perceived depths of 3-D shapes defined by monocular texture cues vary as the image rotates. In paired comparisons of static stimuli, perceived curvature magnitude is greater at vertical than oblique orientations (0.738, SE = 0.020). A similar oblique bias is found for isolated 2-D obtuse angles (0.853, SE = 0.004). Using projective geometry to link angle magnitude to the orientation flows that convey 3-D shape from texture, we show quantitatively that the 2-D bias predicts the 3-D bias. We added anisotropies in numbers and tuning-widths of orientation-tuned cortical cells, and the distribution of oriented-energy in natural scenes, to an optimal stimulus decoding model for 2-D angles. The model revealed that the narrower tuning of cells for horizontal orientations and cross-orientation inhibition explain the orientation-dependent angle distortion and hence the 3-D shape distortion.

[Supported by NEI grants EY13312 and EY07556 to QZ.]

◆ **Families of models for the Gabor path paradigm**

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It is possible to perceive a contour formed from adjacent Gabor patches within a random field if the orientation difference from one target Gabor to the next is less than 40° (Field et al, 1993 *Vision Research* **33** 173–193). We have studied computationally and psychophysically the separate contributions of these two types of relation: spatial and orientation. We present four different families of model, all of which produce similar variations in performance to human data: (i) adjacency by Delaunay triangulation to specify spatial connectivity in combination with curvature measurement; (ii) fixed distance connectivity model; (iii) spatial connectivity based on the spatial overlap of responses from filters of different orientations; (iv) association field models which specify both spatial and orientation relations. All models behave similarly to humans, despite some (i, ii, iii) not having any specific selectivity for orientation relations. We conclude

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that the fundamental visual step in the Gabor path task is the spatial relation rather than the orientation judgment.

◆ **How and why we perceive sets: What does modeling tell us?**

R Rosenholtz, G Alvarez (Department of Brain & Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, USA; e-mail: rruth@mit.edu)

The visual system accurately estimates simple set statistics, such as average size, given only brief displays. Is the accuracy surprising, given feature estimates for individual items? Are all items in a display used, or just a subset? Do we compute set statistics simply to judge the sample mean in a display? Or to make decisions about whether different image regions come from different processes, as suggested by work in visual search and texture segmentation (outlier items pop out, and significantly different regions segment)? We show that performance is qualitatively different than expected from a model in which the visual system computes the average of all display items. It is well modeled by simple averaging models that sample only a subset of the display and/or otherwise capture the uncertainty in population mean when presented with more variable samples. We demonstrate that modeling is critical for understanding set perception. To aid predictions and experimental design, and to further explore set perception, we make modeling code available at <http://dspace.mit.edu/handle/1721.1/7508>.

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ATTENTION AND AWARENESS

◆ **How surface-based attentional shrouds regulate scanning eye movements and view-invariant object category learning**

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How does the brain avoid classifying parts of different objects together, as attention and eye movements interact during scene scanning? The ARTSCAN model predicts that an object's surface representation molds a form-fitting 'shroud' of spatial attention (Tyler and Kontsevich, 1995 *Perception* **24** 127–153). Surface representations compete to form shrouds. The winner persists while an object is scanned, thereby sustaining a view-invariant object representation that multiple learned, view-specific representations are linked to. The shroud tends to restrict foveations to salient attended object features. Object attention regulates learning of view-specific object categories. Shroud collapse triggers a reset signal that inhibits the active view-invariant category in the 'what' stream. A new shroud then forms in the 'where' stream, the focus of attention shifts, and eye movements scan a new object. The model clarifies the temporal dynamics of classic attention shift effects (engage, move, disengage), fits human reaction time data, and learns with 98.1% accuracy and a 430 compression factor a letter database whose tokens vary in size, position, and orientation. [Supported by NGA, NSF, ONR.]

◆ **In-stream temporal facilitation of test-stimulus perception with repetitive TMS to visual cortex: attentional effects are enhanced**

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In a temporal-order judgment task, a test stimulus presented within a stream of invariant objects appears to be perceived earlier than its simultaneous replica that is presented in isolation (Bachmann and Pöder, 2001 *Vision Research* **41** 1103–1106). Here we show that 10-Hz biphasic rTMS of about 15% thumb-twitch threshold intensity, applied to the pericalcarine occipital area enhances in-stream facilitation when between-test SOAs range from –67 ms to +67 ms and when stationary crowding stimuli are flanking one of the test locations. Facilitation reminiscent of prior entry for the flanked location is increased by rTMS when in-stream test-stimuli are presented simultaneously with, or later than, the isolated test-stimuli. The rTMS effect is generalised showing no significant difference between contra- and ipsilateral occipital application. The results indicate (i) occipital activation speeding up visual processing at the simple-features-related processing level and (ii) involuntary spatial attention to the locus presupposing more difficult discriminations being facilitated by rTMS. In-stream temporal facilitation can originate from early cortical stages of processing.

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◆ **Visual cortex mirrors stimulus variations that remain unconscious**

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We presented different signals to the two eyes by means of dichoptic presentation, by separating the ray paths to the two eyes. Using fMRI, we investigated at which point the inputs of both eyes are fused in a way not to allow upstream areas to detect suitably chosen differences between the two eyes. To this end, we compared the response to a change in illuminant of a Mondrian-like stimulus that occurred in parallel in both eyes (in-phase) with that to a change in opposite directions in the two eyes (counter-phase). The in-phase case produced a change in perceived colour of the Mondrian, whereas the counter-phase case subjectively was virtually identical to a stationary illuminant. Visual cortical areas such as V4 and MT+ strongly responded to the variation of illuminant in both the in-phase and counter-phase case, while upstream medio-parietal and medio-frontal areas responded only to the in-phase, also subjectively changing stimulus, while not to the counter-phase case, mirroring the latter's conscious perception as a stationary stimulus.

◆ **The effect of attentional blink on change detection in the auditory system: Does our ear blink?**

K Haroush, S Hochstein, L Y Deouell (Hebrew University, Jerusalem, Israel; e-mail: kharoush@gmail.com)

Following the successful detection of a visual target within a rapid sequence of stimuli, a second target may be missed, a phenomenon named 'attentional blink' (AB). An extensive debate addresses the question whether the blink is modality specific or supramodal. A main problem with previous studies was the use of dual-task paradigms, the effect of which could not be separated from the blink effect. In the current study we overcame this obstacle by recording event related potentials (ERPs) to an unattended deviant stimulus within an auditory stream, while participants were engaged in a visual AB paradigm as their only behavioral task. The mismatch negativity (MMN) ERP is the difference between the response to auditory standards and deviants, and is signature of involuntary change detection. We found that when conditional identification of the second visual target fails (at lag 3), the MMN significantly increases, suggesting allocation of resources to the auditory modality at the same time as the visual system blinks.

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◆ **The nature of capacity limits in multiple object tracking**

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Multiple object tracking (MOT) experiments typically report a capacity limit of 3–5 objects, similar to that observed in visual short-term memory (VSTM). As with VSTM, we can ask whether the limit is a fixed number of structures or a limited, but divisible resource. We approached this question using a novel direction probe version of MOT. Observers indicated whether a probe arrow pointed clockwise or counterclockwise relative to the item's trajectory. We varied the angle between probe and trajectory to obtain a psychometric function. Experiment 1 demonstrated that observers have coarse information about target direction. Experiment 2 showed that little or no directional information was encoded for distractors. Experiment 3 illustrated that directional resolution decreases as more targets are tracked. This was not simply an effect of difficulty, as shown in experiment 4, where increasing velocity decreased performance on a 2AFC target/distractor discrimination task, but not directional resolution. Finally, in experiment 5 we found evidence that tracking capacity is defined by a fixed number of structures, rather than a continuously divisible resource.

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◆ **Visual interactions across the surface of consciousness**

D Sagi, Y Bonne (Department of Neurobiology, Weizmann Institute of Science, Rehovot, Israel; e-mail: Dov.Sagi@Weizmann.ac.il)

Motion-induced-blindness (MIB) was used to examine accessible properties of high-contrast visual objects which are not consciously available. Stimuli consisted of a static Gabor target embedded in a rotating grid. Under such conditions, the target perceptually disappears within a few seconds. Following observers' report of disappearance, a high-contrast Gabor cue was presented. The cue effect on the reappearance of the target within the limited trial time was examined. Surprisingly, results showed very low reappearance rates when cues were remote from the target or when orthogonal to it, even when proximal. High reappearance rates were observed with cues proximal and similar to the target. Plaid targets reappeared with component cues and plaid cues; however, plaid cues were not very effective with component targets. The results show that subconscious

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objects preserve their location and component-orientation, demonstrating that visual processes sensitive to proximity and feature-similarity operate across the boundary of consciousness. By controlling the duration of target presentation we found that reactivating the target may take 200–400 ms, depending on the depth of suppression.

DEVELOPMENT AND PLASTICITY

◆ **Rapid reorganization in the adult human visual system**

D D Dilks, C Baker¶, Y Liu, N Kanwisher (McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, USA; ¶ National Institutes of Health, Bethesda, USA; e-mail: dilks@mit.edu)

In adult animals, regions of primary visual cortex deprived of normal input begin responding to stimuli that normally activate adjacent cortex only. However, it is unknown how quickly this cortical reorganization can happen, and some studies have failed to find it at all, spawning considerable controversy. We investigated the existence and speed of reorganization in the adult human visual system, using a novel perceptual test. We predicted that, if a deprived region of cortex begins responding to stimuli that previously activated adjacent cortex only, then those stimuli will be perceptually elongated towards the visual space represented by the deprived region. To produce temporary cortical deprivation, we patched one eye, thereby cutting off bottom–up input to cortex corresponding to the blind spot of the unpatched eye. After only 10 min of deprivation, rectangles adjacent to the blind spot appeared to be elongated towards it. These findings suggest that cortical reorganization can occur very rapidly in the adult human visual system, and implicate unmasking of horizontal connections as the underlying mechanism.

◆ **Four- to seven-month-old infants respond to the corridor illusion**

A Yonas, C Granrud¶ (Department of Child Development, University of Minnesota, Minneapolis, USA; ¶ University of Northern Colorado, Greeley, USA; e-mail: yonas@umn.edu)

We investigated the perception of object size from pictorial cues by infants aged 3–7 months. After habituation, infants viewed two test displays, presented side by side. In each display, the image of an object moved continuously against a background. For adults, linear perspective creates the impression of objects approaching and receding. In our constant-size display, the object's image size decreased as it appeared to move away and increased as it appeared to move closer. In our varying-size display, the object's image became larger as it receded and smaller as it approached. The 4–7-month-old infants looked longer at the varying-size display. This was not due to retinal image size, because the same image sizes were present in both displays. Only the relationship between image sizes and pictorial distance cues varied between the displays. These results suggest that, by 4 months, infants can perceive object size, and achieve some degree of size constancy, based on pictorial cues. Younger infants showed no significant looking preference.

◆ **Integration of information between senses develops late in humans**

M Gori, M M Del Viva¶, G Sandini¶, L Beccani¶, D Burr¶ (IIT Italian Institute of Technology, Genoa, Italy; ¶ University of Florence, Florence, Italy; e-mail: monica.gori@unige.it)

Recent studies suggest that information from different senses is integrated in a statistically optimal fashion. But when does this capacity develop? We asked young (5–10-year-old) children to judge the width of real plastic blocks using vision, touch, or both (congruent or in conflict), comparing width of variable test blocks to constant probes, to produce bias-free psychometric curves from which perceived subjective equality (PSE) and threshold were calculated. Adults combined visual and haptic information optimally, as previously demonstrated with virtual reality methods. However, PSEs for 5–6-year-old children followed the haptic signal, even though haptic acuity was worse than visual (loser-take-all). Similarly, bimodal thresholds followed haptic thresholds: not only was there no bimodal advantage, bimodal were worse than visual thresholds. By 8 years of age, there were clear signs of integration of both PSEs and thresholds, becoming near optimal by 10 years of age. These results show that integration of information between senses develops late in humans, possibly reflecting a need for one sense to calibrate the other during development.

◆ **What does MT contribute to the development of sensitivity to visual motion?**

L Kiorpes, M J Hawken, J A Movshon, A Kohn, N C Rust (Center for Neural Science, New York University, New York, USA; e-mail: lynne@cns.nyu.edu)

Sensitivity to visual motion develops over a long, slow time course. We sought to understand the neural limitations on this process. Neurons in adult monkey MT/V5 are selective for motion direction. We previously reported that many basic response properties of MT neurons are mature at 1 week while others matured postnatally. To extend this study, and make a direct

comparison between performance of neurons and animals, we examined the relationship between coherence sensitivity of infant MT cells and that of infant monkeys. For MT cells, we measured coherence thresholds for RDK stimuli optimized for speed and direction in 1 week, 4 weeks, 16 weeks, and adult animals. We compared neuronal performance to that of developing monkeys tested with the same stimuli optimized for best performance. Changes in behavioral threshold with age parallel neuronal threshold change up to 16 weeks. Thereafter, neuronal sensitivity asymptotes while behavioral performance continues to improve. These results suggest that MT neurons set a lower bound on performance in infants, but thereafter downstream areas permit further improvement to adult levels.

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◆ **High-density VERPs to global form and motion in adults and infants**

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Sensitivity to global form and global motion are presumed indicators of ventral- and dorsal-stream processing, respectively. We have studied the development of the two streams with high-density (128 channel) VERPs, to explore topographic differences in the responses to global form and motion. The form stimulus had dots arranged in short concentric arcs giving a static global circular pattern. The motion stimulus dots moved along similar arcs, producing global rotation. These patterns alternated at 2 Hz with randomly arranged dot trajectories with no global structure. Adults showed posterior responses to form and motion with significantly different topographies. Of thirty 3–5-month-olds, 60% showed motion responses, while only 20% showed a form response. In infants showing responses to both, there was, as in adults, a significant difference in the topography. Global form and motion responses have distinct scalp distributions, implying distinct neural sources, in both adults and infants. The high-density multichannel method opens the possibility of tracking developmental changes, and the effects of perinatal risk factors, in the relationship between these sources.

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◆ **Comparison of direction-reversal (DR-) and orientation-reversal (OR-) VEPs shows early dorsal vulnerability in healthy premature infants**

J Atkinson, D Birtles¶, J Wattam-Bell, A Wilkinson¶, O Braddick¶ (Visual Development Unit, Department of Psychology, University College London, London, UK; ¶University of Oxford, Oxford, UK; e-mail: j.atkinson@ucl.ac.uk)

Previously we have found measures of visual cortical function, including OR-VEPs, to correlate with the extent of perinatal brain damage in very premature infants and predict later visuo-cognitive outcome. Here we find, in healthy premature infants, normal development of orientation responses but delayed directional motion responses. DR- and OR-VEPs were measured at 2–4 months corrected age in seventeen prematurely born infants (< 33 weeks gestation, normal cerebral ultrasound), and twenty-six term-born controls. For 8 Hz OR, VEP signal:noise ratio (S:N) showed flat regression with age, and no difference between the groups. In contrast, 2 Hz DR S:N increased linearly with age, and was significantly lower for the prematures, implying approximately 4 weeks delay in development of the directional response. We conclude that motion processing provides a sensitive indicator of deleterious effects of preterm birth, possibly reflecting subtle white-matter anomalies, not detectable by ultrasound. We discuss this in relation to dorsal stream vulnerability, indicated by impaired global motion sensitivity relative to form in many neurodevelopmental disorders, eg autism, hemiplegia, fragile-X.

SYMPOSIA & TUTORIAL SESSIONS

FEATURES, OBJECTS AND CATEGORIES: MAPPING THE MAPS IN IT CORTEX

[Supported by Medical Research Council grant G0601007.]

◆ **Inferotemporal cortex and visual object recognition**

K Tanaka (RIKEN Brain Science Institute, Riken, Japan; e-mail: keiji@postman.riken.jp)

The visual object recognition in the primate is a flexible process, tolerating changes in images due to changes in illumination, viewing angle, and object pose. Moreover, we behave with novel objects on the basis of previous experience of visually similar objects. The generalization or categorization is an essential feature of visual object recognition. The inferotemporal (IT) cortex is thought to be essential for visual object recognition. We found that most IT cells responded to only moderately complex features, which were not complex enough to identify particular objects

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that exist in nature. However, when we examined responses of a large number of IT cells to a large set of natural object images, we found that objects belonging to the same object category tended to evoke similar response patterns over the cell population. The response patterns became more different as the categories of the objects became more distant. Thus, response patterns distributed over a cell population in IT cortex represent object categories and their hierarchical structure.

◆ **A specialized system for detecting and measuring faces in the macaque temporal lobe**

D Tsao (Institute for Brain Research, University of Bremen, Bremen, Germany;
e-mail: doris@nmr.mgh.harvard.edu)

The ability to rapidly detect and recognize faces is critical to the survival of primates. A wealth of evidence from psychophysics, neurology, and electrophysiology suggests specialized mechanisms in the primate brain for processing faces. At the same time, face recognition shares the same general challenges as all object recognition, namely the detection of an abstract class followed by individual identification invariant to a myriad of possible changes in appearance. These two properties make face recognition an attractive model system for studying the neural mechanisms of object recognition. I briefly discuss fMRI evidence for the existence of a specialized system of face-selective regions in the macaque monkey, and then describe in detail the properties of single cells within the different nodes of this system: (i) In each face patch, what is the selectivity of cells to faces as compared to other objects? (ii) What is the selectivity to different faces (transformed in view angle, identity, gaze direction, expression, size, or position)?

◆ **The role of visual features in object-selective IT maps, in humans and monkeys**

R Tootell (Harvard University Medical School, Charlestown, USA;
e-mail: tootell@nmr.mgh.harvard.edu)

Current evidence suggests that multiple, specific regions of IT cortex selectively process facial images. This face-processing network appears generally equivalent (presumably homologous) in humans and monkeys. In occipital/temporal cortex, there are three general face patches in macaques, corresponding to OFA, FFA, and an anterior temporal region in humans. In addition, a parietal region (intraparietal sulcus) and a frontal region (anterior to FEF) are also selectively activated by faces, in both humans and monkeys. A surprising number of these face-selective regions are retinotopically differentiable, in both humans and macaques. Even high-contrast features within a given object (eg a nose or mouth in different visual-field positions) will produce different maps of activity in retinotopic cortex. Such retinotopic, feature-based differences could easily be mistaken for object-selective activity, since it is impossible to visibly change object shape without also altering its lower-level visual features. To begin parsing these effects, fMRI was used in combination with systematic variations in 3-D morphs, ranging from a head, through intermediate shapes, to a house.

◆ **Critical elements in human object perception**

R Malach (Department of Neurobiology, Weizmann Institute of Science, Rehovot, Israel;
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What are the critical neuronal activity patterns needed for eliciting an object percept? This deceptively simple question is actually extremely difficult to decipher. Here I address this question using fMRI data obtained from healthy subjects and electrical recordings in clinical patients. I focus on two spatio-temporal dimensions of neuronal activity in high-order ventral stream visual areas of the human cortex. At the temporal dimension, I show results from backward-masking experiments in which object images were presented briefly, followed by a disruptive visual stimulus. Results from such experiments reveal that a minimal ignition time leads to a unique profile of electrical activity as well as fMRI activation, and both are tightly linked to the emergence of an object percept. At the spatial dimension, I describe recent results indicating an antagonistic relationship between activity in human sensory areas and an intrinsic self-related cortical network. The relevance of these findings to neuronal models of human object perception is discussed.

◆ **How is ventral temporal cortex organized? Clues from the study of 'tools'**

A Martin (Laboratory of Brain and Cognition, National Institute of Mental Health, Bethesda, USA; e-mail: alexmartin@mail.nih.gov)

Functional brain imaging has established that ventral temporal cortex is involved in processing and storing information about object form, whereas other critical object properties, such as how an object moves or is manipulated, are processed and stored elsewhere. It has also been established that ventral temporal cortex is not a homogeneous processing system, but rather has a seemingly category-related organization. The principles driving this organization, however, remain largely unknown. I discuss recent evidence using an adaptation paradigm to explore the neural substrate for tools (manipulable objects with a direct relationship between form and

manipulation/function), versus other manipulable objects with a non-systematic relationship between form and manipulation/function (eg book, wallet), non-manipulable objects (anchor, desk), and animals. The findings suggest that inputs from dorsal-stream regions representing motor-relevant properties drive ventral stream neural specificity for 'tools'. More generally, these data suggest that one basic organizing principle giving rise to 'category-specificity' in the ventral stream may involve similarity metrics computed over information represented elsewhere in the brain.

FROM MOTOR PRODUCTION TO VISUAL ACTION AND PERCEPTION

◆ **Mirror neurons and the cognitive properties of the motor system**

L Fogassi (Department of Neuroscience, University of Parma, Parma, Italy; e-mail: fogassi@unipr.it)

The neurophysiological studies of the last two decades have provided evidence that the motor cortex is not simply involved in movement programming and execution, but plays a main role in coding the goal of motor acts. In fact, premotor cortex contains many categories of motor neurons, each coding a specific goal. The presence of dedicated anatomical circuits linking each premotor area with a specific area of the posterior parietal cortex allows motor representations to be matched with several types of sensory inputs. An example of this matching mechanism is represented by mirror neurons, found in both ventral premotor and inferior parietal cortex of the monkey, that respond during action observation and action execution. It has been hypothesized that the mirror-neuron matching system, that has been largely described also in humans, underpins action understanding. Recent data indicate that mirror neurons may also have an important role in understanding action intention. This evidence suggests that the organization of the motor system constitutes the basis for the emergence of cognitive functions.

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◆ **Muscle synergies as building blocks for motor production**

A d'Avella (Department of Neuromotor Physiology, IRCCS Fondazione Santa Lucia, Rome, Italy; e-mail: a.davella@hsantalucia.it)

Generating the appropriate muscle pattern for a given goal-directed movement is complex because of the many degrees of freedom of the motor system and its nonlinear dynamic behavior. A prevailing idea in motor control is that muscle pattern selection depends on the existence of internal models of the musculoskeletal system and the physical world. However, how these models are organized in the neural circuitry is still an open question. A long-standing hypothesis is that the mapping of goals into motor commands is simplified by combining a limited number of building blocks. Recent observations of structural regularities in the muscle patterns used by different species in a variety of behaviors support this hypothesis. For example, the muscle patterns for reaching movements in different directions and with different speeds can be reconstructed by the combinations of a few time-varying muscle synergies, coordinated activations of groups of muscles with specific time-varying profiles. Such spatiotemporal invariants in the motor output might not only simplify motor production but also underlie action–perception coupling.

◆ **Fitt's law in action perception**

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Fitt's law is one of the best established principles in cognitive neuroscience. It captures how speed and accuracy trade off in both performed and imagined movements. Does this law also hold when we perceive the actions of others? Participants were shown displays of a person moving her arm between two identical targets. Target width, movement speed, and the distance between targets were varied. Participants reported whether the person could move at the observed speed without missing the targets. The movement times that were perceived as being just possible were exactly as predicted by Fitt's law ($r^2 = 0.96$). A subsequent experiment demonstrated the same relationship for the perception of a robot arm ($r^2 = 0.93$). Thus Fitt's law, a motor principle, also holds in imagery and in the perception of biological and non-biological agents.

◆ **Geometric approaches to the study of action – perception coupling**

T Flash (Department of Computer Science and Applied Mathematics, Weizmann Institute of Science, Rehovot, Israel; e-mail: tamar.flash@weizmann.ac.il)

Earlier studies suggest that similar organizing principles and constraints underlie both motion perception and production. These constraints are reflected in the kinematic and temporal properties of 2-D human drawing movements and in the local coupling between path curvature and movement speed. These constraints are also reflected in the subjective judgment human subjects make concerning the speed and form of visual motion. The underlying geometry of internal

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representations is thought to be a key to our understanding of the similarities between motion perception and production. Based on empirical observations of 2-D motion production a mathematical framework has been developed which is based on differential geometry and group theory for the kinematic analysis of 2-D movements and for the definition of possible motion primitives, ie elementary building blocks from which more complicated movements are constructed. It is shown that a natural geometric description of continuous 2-D trajectories is based on equi-affine and not Euclidean metrics. This approach is then extended to the analysis and modeling of 3-D motion production and perception.

◆ **Perception and action planning: Strong interactions**

W Prinz (Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany; e-mail: prinz@cbs.mpg.de)

An overview is presented of some work from our lab on strong couplings between action perception and action production. The Ideomotor Principle claims that action planning should modulate action perception and that, conversely, action perception should modulate action planning, too. I discuss examples of such strong interaction from three kinds of paradigms: bimanual coordination, task sharing, and action simulation. Results from these studies shed new light on the cognitive underpinnings of action control.

TUTORIAL SESSION

◆ **What's new in Psychtoolbox-3?**

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Psychophysics Toolbox version 3 is a collaboratively developed free set of MATLAB (and GNU/Octave) functions for vision research. It is available for Apple Mac OS X, Microsoft Windows, and GNU/Linux. It makes it easy to synthesize and show accurately controlled visual stimuli and interact with the observer in a general-purpose programming environment. It has about two thousand active users, an active forum (about 4 messages/day), and is highly cited (more than 400 papers) (see <http://psychtoolbox.org>). Psychtoolbox-3, although maintaining a large degree of backward compatibility with its predecessor Psychtoolbox-2, implements a new drawing model based on OpenGL, a new high-precision sound output system, and many other improvements. This presentation introduces the new OpenGL concepts and how to take advantage of the new stimulus presentation model. New features simplify development of code for stimulus presentation and response collection. Many of the new features are demonstrated during the presentation and there are opportunities for questions.

POSTER SESSION

AGING

Ageing effect at various levels of visual information processing—VEPs testing

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In 133 healthy volunteers aged 19–83 years (38 ± 17 years) we examined reactions of the primary visual cortex to pattern-reversal stimuli, responses of extrastriate areas to motion-onset, and P300 wave in visual cognitive task (recognition of digits and letters). The most distinct change of visual evoked potentials (VEPs) was a prolongation of P300 latency representing highly significant delay of cognitive processes toward elderly (2 ms/1 year of age, $r = 0.71$). Decreased cognitive functions due to ageing are signalled also by reduction of P300 amplitude ($r = -0.48$). Motion processing (activity of the magnocellular system/dorsal stream) seems to be more influenced by ageing (irrespective of gender) compared to the parvocellular system/ventral stream function according to age-related changes in latencies of the motion-onset VEPs (increase of 0.5 ms/1 year) and of the pattern-reversal VEPs (0.3 ms/year increase). More detailed information can be found on our web page: <http://www.lfhk.cuni.cz/elf>.

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◆ **Suprathreshold contrast perception in young and old drivers**

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The limits of vision are often measured with tests on acuity or the contrast-sensitivity function (CSF). However, most everyday visual tasks are concerned with stimuli that are well above the detection limits (suprathreshold). Therefore, it may be more informative for the performance of certain everyday tasks to measure differences in suprathreshold contrast. We therefore compared suprathreshold contrast perception in younger and older drivers matched for visual acuity and attention. In the first experiment, a standard procedure for measuring the CSF was used. In experiment 2, participants had to match the contrast of two different Gabor patches (2AFC classical staircase procedure): a 'standard' [contrast 50%, spatial frequency (SF) 5 cycles deg⁻¹, or contrast 100% SF 0.5 cycle deg⁻¹] with a 'variable' (SF: 0.5; 1; 2; 5; or 8 cycles deg⁻¹). As expected, detection measured by the CSF was worse for the older group. However, a consistent pattern of differences between the young and old group also emerged for the suprathreshold contrast-matching task. The implications of this finding for driving are considered.

◆ **Body width estimation is affected by the experience of walking through an aperture**

M S Tada, K Suzuki[¶] (Department of Clinical Psychology, Kansai University of Welfare Science, Kashiwara, Japan; [¶]Taisei Gakuin University, Sakai, Japan; e-mail: tada@fuksi-kagk-u.ac.jp)

We explored the effect on body width estimation by the experience of walking through an aperture. Participants (in three age groups: young, middle-aged, old) judged the ability to pass through an aperture without physical contact (using an adjustment procedure). They made three types of judgments: before actually passing through, immediately after having actually passed through, and after a delay of two months. (i) Before actually passing through, the body width estimation was greater than the body width in all age groups. (ii) Immediately after actually passing, the body width estimation became equal to the body width. (iii) However, two months later, the body width estimations of the younger and the middle-aged adults were significantly smaller than the actual body width. In contrast, the body width of the older adults was equal to the body width. These results suggest that body width estimation is affected by the experience of walking through an aperture. However, the strength of the effect differed with age and time interval.

◆ **Age-related changes of attentional control: Effects of task-irrelevant onset and the number of stimuli**

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Previous studies indicate that it is more difficult for older adults to inhibit irrelevant information than for young adults. In this study, age-related changes in attentional control were examined by using a visual search task. Eight older and eight younger adults participated. Participants were asked to search for a target while ignoring a task-irrelevant onset distractor and an additional distractor. Sensitivity to detect the target (d') and reaction times were measured. The former indicates an early stage, the latter indicates whole stages in visual information processing. The results showed that (i) there was no age-related difference in the late stage affected by onset distractor, (ii) an increase in the number of distractors reduced d' among older adults, and (iii) presentation of the onset distractor had a derogatory effect on reaction times among older adults. These findings suggest that decline in attentional control among older adults is concerned with the presence of an onset distractor and an increase in the number of stimuli.

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◆ **Psychophysics of retinal straylight**

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The psychophysical technique of compensation comparison, embedded in the C-Quant instrument for clinical assessment of retinal straylight is demonstrated. Retinal straylight is the cause of complaints such as glare hindrance and contrast loss. It results from disturbances in the optical media. Its assessment helps to decide on surgery of (early) cataract, or to evaluate corneal or vitreal problems. Retinal straylight is assessed in a functional way, ie as sensed by the retina. Added value in comparison to visual acuity was assessed in 2400 active drivers of the European GLARE study. Repeatability of the obtained straylight value was tested for 17 naive subjects and several groups of patients. Absolute measurement precision of the C-Quant was tested with a scattering sample with known straylight value in front of the eyes of the 17 naive subjects. Many individuals were found to suffer from increased straylight that is undetected in visual acuity. In 6% of cases with decimal visual acuity > 0.5 straylight was increased more than fourfold compared to normal.

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ART AND VISION◆ **The colour of the best illumination for appreciation of art paintings is bluish-white**

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The visual effects of light sources on art paintings are important aspects that should be considered by museum curators. The aim of this work was to determine the correlated colour temperature (CCT) of daylight illumination preferred by observers when appreciating art paintings. Hyper-spectral images of eleven oil paintings were collected at the museum and the appearance of the paintings under D-illuminants with CCT from 25 000 K to 3600 K was computed. In a psychophysical experiment using precise CRT reproductions of the paintings, observers had to adjust the colour temperature of the illuminant such that it produced the best visual impression. Two groups of observers were tested: forty university students and forty museum visitors; the students were tested in the laboratory and the others in the museum. The average CCT selected in museum environment was 6755 K and in the laboratory was 6173 K suggesting that observers prefer a much more bluish-white light than that normally used in museums.

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◆ **The microgenesis of style and content in art perception**

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Although empirical aesthetics has a long tradition in experimental psychology, only few studies (eg Bachmann and Vipper, 1983 *Archiv für Psychologie* **135** 149–161) have dealt with the underlying processes of art perception and their relation. According to the microgenetic approach (Flavell and Draguns, 1957 *Psychological Bulletin* **54** 197–217), final percepts are the outcome of a complex interplay and succession of several perceptual sub-processes. In a series of experiments, we followed this approach to analyse the time-course of art perception, focusing on two aspects that are central to representational art: style and content. Participants gave similarity ratings for masked pairs of pictures that were crossed in style (same/different) and content (same/different). Presentation times were varied systematically within and between persons. While effects of content on similarity ratings could already be traced at 10 ms, effects of style developed later and were more time-dependent. The results suggest that in art perception style follows content.

◆ **Anisotropy of aesthetic evaluation in simple-color-arrangement patterns**

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Anisotropy of aesthetic evaluation in color arrangement seems to significantly influence visual arts especially in the case of abstract arts with simple composition, the more so the simpler they are. In order to find out more, we analyzed the impression of simple Mondrian-like color arrangement pattern with red, yellow, and blue. We made 18 square patterns composed of four small color squares of the same size. Two of the small squares on the diagonal are white and another two of them are filled with different two colors selected from red, yellow, and blue. Subjects were asked to judge naturalness, brightness, and preference under the simultaneous presentation of two square patterns with different color arrangement side-by-side on the screen. The results show that there is some anisotropy in the impression of color arrangement patterns even when two patterns are mirror images of each other, although reversal of left and right generally is not so essential for us in comparison to reversal of up and down.

◆ **The King with the Swollen Head: Reflections on Diego Velázquez' *Las Meninas***

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When Diego Velázquez painted his crowning work *Las Meninas* (1656) he solved the dilemma of how to glorify his royal benefactor while simultaneously heralding the monarchy's imminent downfall and presaging the emerging era of intellectual enlightenment. He accomplished this by embedding his critical message within a benign narrative designed to appeal to a self-possessed monarch, without rousing the suspicions of potential adversaries. The critical narrative is subtly suggested in references to classical fables of hubris, in paintings barely visible in the background. However, the impact of Velázquez' commentary becomes only fully apparent in the manner in which he manipulates the viewer's perception, through the use of perspective, mirror optics, and implied direction-of-gaze, to ambiguate the viewer's position in front of the painting, thus evoking the fate of Narcissus for a self-possessed king. This presentation elaborates on the perceptual aspects of Velázquez' masterpiece with a combination of empirical evidence and theoretical argument.

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◆ **When style matters. Art-specific adaptation effects**

C C Carbon, H Leder, T Ditye (Faculty of Psychology, University of Vienna, Vienna, Austria; e-mail: claus-christian.carbon@univie.ac.at)

The effect of the observation of a unique style of painting on the aesthetic appreciation of various other painting styles was investigated. In the first part of the experiment (T1) participants were asked to rate their liking of a number of portraits by various artists of a variety of different historical epochs on a seven-point Likert scale. Each portrait was presented in 11 different versions, which differed in the amount of compression or extension in height (cf Carbon et al, *Memory & Cognition* in press). This block was followed by an adaptation phase in which paintings of the artist Amedeo Modigliani were used. Modigliani used an idiosyncratic style of manneristic face elongation. In a succeeding test phase (T2) participants again had to rate the liking of the paintings that had been presented earlier in T1. Results revealed systematic changes in aesthetic appreciation of those exemplars that were structurally rather similar in style to Modigliani's (the extended versions). Thus, even aesthetic appreciation of art paintings seems to adapt to previous encounters of artistic exemplars.

◆ **From exposure to evaluation: Dynamic changes in appreciation of innovative designs**

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Innovativeness is defined as the "originality by virtue of introducing new ideas" (Carbon and Leder, 2005 *Applied Cognitive Psychology* **19** 587). Innovative designs often disrupt common visual habits. Rejected at first sight, innovative designs gain appreciation through experiencing them over time. Nonetheless, they preserve their innovativeness over a relatively long period of time. Using the repeated evaluation technique (RET) (Carbon and Leder, 2005 *Cognitive Psychology* **19** 587–601), the attractiveness of highly innovative designs increased by intensive elaboration, whereas that of not very innovative designs decreased over time. In contrast, no such dissociations between not very and highly innovative designs were discovered on examination with a classical mere exposure design. Thus, the RET seems to be a more valuable method for investigating dynamically changing psychological constructs such as the appreciation of innovative product designs. [Supported by the Austrian Science Fund (FWF, P18910).]

◆ **Preferred location of the centre of projection in picture viewing**

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When the viewer is located at a picture's centre of projection (CoP), the retinal image is identical to the image generated by the original scene. Thus, one expects the viewer to prefer pictures in which the CoP and eye locations are the same. We investigated this by varying the CoP distance relative to the viewer. Observers indicated the CoP distance at which spheres looked most spherical when presented on flat and spherical display surfaces. Somewhat surprisingly, the preferred CoP location depended on the estimated local slant of the display surface. When the observer viewed monocularly through a pinhole and thus could not determine the surface slant, the preferred CoP location was near the eye. When the observer viewed binocularly and so could accurately determine surface slant, the preferred CoP location was the one that minimized the local distortion in the projected image, where spheres project as circles. Thus, pictures may look distorted because of a poor choice of CoP location even when the observer is at the CoP. [Supported by NIH ROI-EY012851.]

◆ **Contributions of boredom to liking judgments over time**

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Attractiveness judgments in everyday life change dynamically over time. To account for this, Carbon and Leder (2005 *Applied Cognitive Psychology* **19** 587–601) introduced the repeated evaluations technique (RET). Through RET, numerous exposures to and evaluations of stimuli are simulated and subsequent changes of liking judgments are measured using a pre–post test design. Using the RET procedure, Carbon and Leder showed that highly innovative designs were judged unattractive at first sight by participants. However, after engagement with these stimuli during the RET phase, the stimuli were appreciated more. In contrast, liking judgments for not very innovative designs decreased over time. These opposing effects may be due to boredom. Not very innovative designs are familiar and massive exposure to them leads to boredom, which in turn reduces liking. Highly innovative designs on the other hand challenge common visual habits and remain more interesting over time. The present study analyzes the interplay between boredom and dynamically changing liking judgments. [Supported by the Austrian Science Fund FWF Project P18910.]

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◆ **Framing the frame: Goodness-of-fit for probe shapes within a rectangular frame**

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The structure of a rectangular frame strongly influences the perceived goodness-of-fit of small probe shapes positioned within it. In several experiments, the centre of a rectangular frame was consistently rated as the best position for a single, small, circular dot, followed by positions along the horizontal and vertical symmetry axes. With a second dot in the frame, ratings changed dramatically, but observers still gave higher ratings to positions that rendered the configuration symmetrical with respect to the centre or to the symmetry axes. Dot proximity and collinearity along axes parallel to the frame sides also increased ratings. When the dots differed in size, observers seemed to give higher ratings to positions that achieved balance of their visual weights. Changing the probe shapes to triangles produced strong orientational effects, especially along the axes of symmetry, and directional effects when they pointed into the frame and/or toward the right. The results are discussed as relevant to the empirical study of aesthetic response to images within rectangular frames.

◆ **The aesthetic experience of 'contour binding'**

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To find the diagnostic spatial-frequency information in different painting styles (cubism, impressionism, and realism), we have compared d' in distinguishing the subject of the painting from noise with normal (N), high-pass (HF), and low-pass filtered (LF) images at long (150 ms) and short (30 ms) exposures. For cubist-style images, d' increases with HF compared with N and LF images but decreases with LF compared with N images, indicating that channels with high spatial resolution solve the binding problem. For impressionistic images, d' was reduced by both LF and HF, indicating that both channels play a role in solving the binding problem through collator units that group the response of channels tuned to the same orientation. The difference between realism, which shows higher sensitivity for LF at short durations and cubism in which the binding problem is solved by HF channels, has a corresponding difference in the aesthetic judgment, suggesting that it is available during early processing of an image and could influence high-level categorization.

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◆ **Aesthetic experience of abstract forms: Effects of external and internal constraints**

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The external and internal constraints of aesthetic experience of abstract forms were investigated. In the preliminary factor analytic study the aesthetic experience was defined by three descriptors: fascinating, irresistible, and unique. External constraints were defined by 4 bipolar stimulus features: asymmetry–symmetry, compactness–dispersion, simplicity–complexity, and ovalness–sharpness. The set of 16 forms was generated by combining these features. Internal constraints were defined by dimensions of subjective judgments of paintings and drawings extracted in previous study: regularity (scales: precise, clear, regular), arousal (unusual, imaginative, impressing), attraction (beautiful, pleasant, healthy), evaluation (clever, balanced, interesting), and serenity (unimposing, tender, serene). Thirty-four subjects judged 16 forms on the 3 unipolar seven-step scales of aesthetic experience and 12 bipolar seven-step scales of subjective dimensions. The results indicate significant effects of complexity and dispersion on aesthetic experience: complex forms have higher values than the simple ones, and dispersed forms have higher values than the compact ones. Regression analysis revealed the significant relationship of aesthetic experience with the dimension arousal.

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◆ **An effect of changes in posture in a motion-picture shot on the perceptual grouping with serially presented motion-picture shots**

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When a number of motion-picture shots are continuously presented, perceptual grouping is observed in the series of motion-pictures (Suzuki and Osada, 2004 *Perception* **33** Supplement, 80). It has been suggested that the discontinuity of the motion of objects in an individual shot facilitates the continuity between motion-picture shots. In addition, because discontinuous motion applies to the interruption of object motion, it is possible that the motion of objects will be determined by the difference between the posture of objects and the position of objects in

the motion-picture shots. In this study, we examined whether the position of objects and frames, or the change in object posture facilitated continuity between motion-picture shots. The motion-picture shots of walking, which were made with motion capture system that moved horizontally with rotation was divided into several motion-picture shots. These motion-picture shots were continuously presented at random, and we analyzed the conditions which facilitated perceptual grouping of motion-picture shots. As a result, we showed that the position of objects and frame facilitates the continuity between motion-picture shots, regardless of changes in posture.

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◆ **Beyond the golden section and normative aesthetics: Why do individuals differ so much in their preferences for rectangles?**

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Gustav Theodor Fechner, who founded psychophysics, also carried out the first experiments on experimental aesthetics, examining the question of preferences for the golden section rectangle. Subsequent studies have concentrated almost entirely on asking whether there are population preferences for the golden section, while ignoring very large individual differences in preference, which nearly swamp population preferences. Here we describe a more efficient way for measuring individual rectangle preferences, using an incomplete paired comparison design and logistic regression, that also assesses within-task reliability. *Q*-mode factor analysis of forty subjects identified three major factors, consisting of preferences for squares, a canonical rectangle at about the golden section, and vertical relative to horizontal rectangles. Differences in preference showed no relation to differences in the horizontal-vertical illusion or veridical perception of object proportions, or to a range of personality measures, although there was a small correlation with interest in the visual arts and experience of drawing and painting. Individual differences in rectangle aesthetics are reliable and large, but frustratingly remain without obvious explanation.

◆ **The way we look at art**

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Art theory suggests that works of art will be examined differently depending upon their status and expertise of the viewer. Here we present two experiments using saccadic eye movements to examine these issues. In experiment 1, the subjects of abstract pieces of art were changed: they were described as landscape, portrait, or untitled. We found that people's saccades were of greater amplitude and shorter fixation durations in the first half of their inspection time but that there was no effect of description. In a second experiment, the status of the work was changed: the work could be an original, a photographic reproduction, or on a computer screen. These works were viewed by art experts and non-experts. We found the same results as in experiment 1, ie shorter amplitudes and fixation durations for initial inspection; however, there was no effect on saccades of the status of the pieces or the level of expertise of the viewer. We discuss the results in terms of general scene viewing and art theory.

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◆ **The role of reference system in aesthetic evaluation**

K Mitsui, K Shiina, K Odaka (Graduate School of Information & Media Studies, University of Tsukuba, Tsukuba, Japan; e-mail: mitsui@slis.tsukuba.ac.jp)

We examined whether the relative orientation of a symmetrical dot pattern and framework influenced aesthetic evaluation. Participants were asked to rate aesthetic evaluation of each pattern on a 7-point scale. The results showed that: (i) in an upright and a diamond framework (0° and 45°), aesthetic evaluation was highest when a symmetrical pattern was presented vertically (bilateral symmetry) and aesthetic evaluation was somewhat higher when a symmetrical pattern was presented at 45° ; (ii) on the other hand, in an oriented framework (22.5°), aesthetic evaluation was high when a symmetrical pattern was presented at the same orientation (22.5°). The result showed that aesthetic evaluation was influenced by the bilateral symmetry and frame-pattern relationship. The present study demonstrates that aesthetic evaluation depends on the relationship between the object and the framework.

◆ **What eye movements reveal about aesthetic judgments of Mondrians**

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Observers prefer paintings by Mondrian in their original orientation compared to when rotated (Latto et al, 2000 *Perception* **29** 981–987). We tested whether eye movements provide any insight into this aesthetic bias by presenting 8 Mondrian paintings in either their original or seven rotated

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positions to ten observers for 20 s each while recording eye movement duration and saccade length. During a 5 s ISI observers used a 1–7 Likert scale to report how (dis)pleasing they found each image. In 9 cases, fixation durations increased linearly, where pleasing images fixation duration increased more than non-pleasing images. Moreover, saccade distances oscillated over the viewing interval, with the pleasing image having larger saccade distance oscillations than the non-pleasing image fit. Both these findings agree with earlier work by Nodine, Lochear, and colleague; and suggest that the more pleasing an abstract painting is, the greater the diverse/specific types of image exploration become.

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◆ **Korean photographers and affective impressions of portrait photography**

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To examine the spectrum of affective impressions evoked by portrait photography, photographic portraits of celebrities taken by well-known Korean photographers were used as stimuli. Participants observed the selected photographs and reported their feelings in adjective terms. Gloomy, peaceful, sad, and sexy were critical, compared with the results of an earlier study (Shin et al, 2004 *Aura* 11 72–79). Participants then evaluated the selected portrait photographs on a 7-point scale based on three affective dimensions: positive–negative, dynamic–static, and light–heavy (Park et al, 2004 *Korean Journal of the Science of Emotion & Sensibility* 7 41–49). Most of the celebrity portraits were slanted toward negative, static, and heavy feelings, with static feeling being the strongest among them. Presentation embodied in traditional portraits, such as frontality, could be inferred a factor. Based on these results, portrait photographers were categorized according to the affective impressions of the viewers.

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◆ **Simplicity and likelihood principle in perception of architectural space**

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The projection of each object in the environment corresponds to an infinite number of more or less deformed shapes, among which the simplest and most likely is typically chosen. As opposed to wide variety of forms in nature, most urban spaces are filled with right angles, parallel straight lines, and other simple and well-known forms. This fact may influence the flexibility of our perception of the urban environment. We tend to see what we expect to see and fail to notice less conventional solutions. We are not aware of numerous architects' adjustments of the design of buildings and other compositions being applied in order to achieve an observer's pleasant impression, raise the overall experience, and occasionally reveal further meanings perceived in the buildings. The role of the simplicity and likelihood principles is explained, taking as examples the architectural manipulations (eg perspective distortion, figure–ground organization, direction of lighting and shadows).

◆ **Spatial memory bias effects in viewing preferred stimuli**

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Emotional stimuli capture the viewers' attention and enhance the perception of early vision, eg contrast sensitivity (Phelps et al, 2006 *Psychological Science* 17 292–299). We investigated whether higher-order visual processes such as location memory in the peripheral field can be affected by the magnitude of preference for emotional stimuli (paintings). First, the participants ($N = 16$) were required to manipulate a mouse and point to the remembered location of the target that appeared for 200 ms in the periphery, following the painting stimuli presented at a fixation point (SOA = 50 ms or 250 ms) After completing this task, the participants judged the preference of all pictures presented on a five-point scale (from strongly dislike to strongly prefer). Results showed that the location memory of the targets was significantly biased towards the fovea when the highly preferred or neutral paintings were presented, while the bias decreased for the dislikable paintings. These findings indicate that the preference for visual stimuli potentially modulates the location memory for peripheral objects.

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◆ **The perceptual organization in a series of motion-picture shots**

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Suzuki and Osada (2005 *Perception* **34** Supplement, 139) studied the perceptual organization of serially presented motion-picture shots. We investigated the Gestalt factor in the series of motion-picture shots measuring the continuity of actor's movement and the impression of actor's separate identity in the motion-picture sequence. We used natural motion-picture shots in which a walking actor moved across the screen. Four types of screen width were used. There were five types of duration. We presented twenty motion-picture shots randomly with each of them presented ten times. Our results suggested that the event perceived by observer changed with the ratio of screen width per durations. A series of shots in which observers could perceive continuity was perceptually organized as one single continuous event. On the other hand, a series of shots in which observers perceived discontinuity were perceptually organized as several segregated events. We concluded that the perceptual grouping was the outcome of incomplete motion of an actor almost fully occluded by screen edge.

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◆ **Visual stimulus familiarity and generalization effects: An experimental examination of mediating factors**

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The relationship between familiarization to a visual stimulus and its subsequent aesthetic evaluation is complex. Previous studies have demonstrated that many factors, such as the characteristics of the stimulus, can influence this relationship (Bornstein, 1989 *Psychological Bulletin* **106** 265–289). We investigated the dynamic interplay between familiarization to stimuli and their aesthetic judgments as mediated by factors known to bias judgments in a positive direction. Particular emphasis was placed on the generalization effects of such factors to similar or different stimuli that were subsequently viewed. The results are presented and discussed within the context of general perception and recent approaches to psychological aesthetics (Biederman and Vessel, 2006 *American Scientist* **94** 249–255; Jacobsen and Hofel, 2003 *Cognitive and Affective Behavioral Neuroscience* **3** 289–299).

◆ **Motion blur in the Op artist's palette**

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Motion blur illusions constitute a striking component in the complex range of perceptual effects associated with actively viewed black and white line images [von Helmholtz, 1856 *Handbuch der Physiologischen Optik* (Leipzig: Voss); Wade, 1978 *Perception* **7** 21–46]. Motion blur is partly attributed to receptor delays during visual registration of swift changes in image contrast (Barbur, 1980 *Perception* **9** 303–316), and has been successfully modeled through temporal averaging of image signals (Gosselin and Lamontagne, 1997 *Perception* **26** 847–855). Here, it is shown that second-order feedback improves simulation of the illusion, and a novel, yet general, concise explanation of the particular geometry of motion blur illusions is proposed. On applying the model to simulate the fluctuating perceptual structure of Fall, a representative Op art painting by Bridget Riley, reveals that the artist's use of the illusion supports distinct compositional layers comprised of dynamic contrast loci, and a stable, multi-scale scaffold. It is suggested that this structuring is an intentional aspect underlying the visual attraction of this art work.

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CHANGE DETECTION

◆ **People have the power even when the mind is busy. Priority differences among socially relevant and irrelevant targets in a change-detection task**

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The priority afforded to social information has been demonstrated in several perceptual tasks, from change detection to visual search. In this study we adopted a change-detection paradigm in which twenty subjects were randomly assigned to two conditions: single and dual task. The secondary task was a simplified version of PASOT, which requires a verbal effort. Subjects were administered a set of 46 pictures in which the change consisted either in the removal of a person or an object. The target elements were comparable in position and dimension, keeping as a within-factor only their social meaning. Since the change-detection performance is enhanced with highly informative targets, we hypothesized a lower detection time for persons with respect to

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objects, with the PASOT performance remaining stable across the person vs object trials. Results from a two-way mixed ANOVA supported this prediction, given the significant main effects of condition and kind of target. These findings suggest that the processing of social stimuli requires less cognitive resources than other equally salient elements.

◆ **Failures to see: Attentive blank stares revealed by change blindness**

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Change blindness illustrates a remarkable limitation in visual processing by demonstrating that substantial changes in a visual scene can go undetected. Because these changes can ultimately be detected with top-down driven search processes, many theories assign a central role to spatial attention in overcoming change blindness. Surprisingly, O'Regan et al (2000 *Visual Cognition* 7 191–212), using blink-contingent changes, reported that change blindness could occur even when observers fixated the changing location. However, eye blinks produce a transient disruption of vision that is independent of any associated changes in the retinal image. We determined whether these attentive blank stares could occur in the absence of blink-mediated visual suppression. Using a flicker change-blindness paradigm, we confirm that, despite direct attentive fixations, obvious scene changes often remain undetected. We conclude that change detection involves object- or feature-based attentional mechanisms, which can be misdirected despite the allocation of spatial attention to the position of the change.

[Supported in part by NSF fellowship 2005031192 to GPC.]

◆ **Sensing before seeing in comparative visual search**

A J Galpin, G Underwood ¶ (Department of Psychology University of Salford, Salford, UK; ¶ University of Nottingham, Nottingham, UK; e-mail: A.J.Galpin@Salford.ac.uk)

Rensink (2004 *Psychological Science* 15 27–32) presented evidence suggesting that visual changes occurring during a flicker may be sensed without an accompanying visual experience. Sensing was said to have occurred if the delay between a sense response and a seeing response exceeded 1 s. Here, we present a series of studies in which participants had their eye movements monitored whilst searching for a difference between two simultaneously presented images (comparative visual search). We attempted to elucidate possible sensing of differences by imposing more conservative criteria: separate keys indicated sensing and seeing responses, and participants were required to verify and rate their sensing responses. The results showed that sensing was not random: fixation position and confidence ratings were different when a difference was present compared to catch trials. Furthermore, the uniformity of objects in the display and the type of difference appear to affect seeing and sensing differently, suggesting that these processes are dissociated. Possible mechanisms are discussed.

[Supported by a University of Nottingham studentship awarded to AJG.]

◆ **An ERP study of visual-change detection: Is the N2 component a marker of consciousness?**

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The event-related brain-potential technique can be used for establishing the time course of neural events underlying the change detection of a visual stimulus. Change detection would be related to an increased negativity around 200 ms (N2) after stimulus onset (Koivisto and Revonsuo, 2003 *Psychophysiology* 40 43–429) and to an enhanced positivity in the P3 time range (Turatto et al, 2002 *Cognition* 84 B1–B10). In this ERP study, participants were presented with a sample screen composed of coloured squares. After a delay, a test screen appeared where one of the item was cued. The task was to detect the colour change of this item. The cue allowed us to assess if the increased amplitude of N2 is correlated with the change-detection mechanism or only with the attentional processes related to target detection. The participants had to rate the level of confidence of their answer (high, medium, low). This categorization allowed us to explore phenomena such as change detection with and without visual experience, implicit detection, illusion of change, and their corresponding EEG activity.

◆ **The effect of memory priming on unconscious information processing**

M Kaplar, L Bernath (Department of Psychology, University of Pecs, Pecs, Hungary; e-mail: kaplar.matyas@gmail.com)

We examined how memory priming affects unconscious information processing. Our goal was to show that there are not only quantitative but qualitative differences between processing conscious and unconscious stimuli. The experiment had three phases in two groups of subjects: (i) change-blindness task; (ii) memory priming with a specially prepared text; (iii) change-blindness

task. The two groups differed only in the target words in the priming text. The two change-blindness tasks were the same in structure and complexity, only the content and the target changed. As control we applied classical memory-priming and naming trial, using the priming text of the first paradigm and conscious stimuli (words/pictures). Our hypothesis was that memory priming as a type of semantic, conscious priming will not affect the speed of solving the change-blindness task as unconscious information, but will appear among classical, conscious circumstances. Finally, in an fMRI study we examined the neural activation differences between classical visual-search task and change-blindness task.

◆ **Time needed to detect changes in colouration of a moving grating**

C Murd, M Tamm, K Kreegipuu, J Allik (Department of Psychology, University of Tartu, Tartu, Estonia; e-mail: carolinamurd@hotmail.com)

It was demonstrated that the time needed to detect changes in colouration of a single moving stimulus becomes shorter as its velocity increases (Kreegipuu et al, 2006 *Vision Research* 46 1848–1855). In this study the observer's task was to indicate the change in colour, from green to red or vice versa, of a sinusoidal grating moving at one of five velocities: 0, 1.53, 3.06, 6.13, or 9.2 deg s⁻¹. Velocity of a moving grating, unlike that of a single, moving object, had no effect on time required to detect changes in colouration ($F_{4,3105} = 0.95$, $p = 0.43$). This result was confirmed in a temporal-order judgment task in which the observer was instructed to indicate which of the two adjacent moving gratings changed its colouration first. Possible explanations why velocity enhances detection of changes in colouration of a single object but not of a grating are discussed.

◆ **Assessing the attentional priority of cast shadows: A change-detection study**

M Nucci, G Galfano, M Pastore (Department of General Psychology, University of Padua, Padua, Italy; e-mail: massimo.nucci@unipd.it)

Recent evidence has shown that, at least under some contexts, cast shadows can affect both visual-recognition and visual-search performance. In the present study, we investigated the extent to which cast shadows of simple objects receive attentional priority by using a change-detection paradigm combined with a flicker one-shot technique. Images consisted of 6 pyramids and 6 spheres with an achromatic surface colour on a uniform fixed grey background. Change (50% of trials) was represented by one of the objects casting a shadow with an inconsistent shape, a shadow with a different lighting direction, or both. Critically, two conditions were created: a real-shadow condition and a reversed-contrast-polarity condition, in which shadows were likely perceived as 2-D contrast. Change-detection performance was higher in the real-shadow condition than in the reversed-contrast-polarity condition, particularly when change involved the shape of the shadow. These findings seem to confirm that cast shadows can represent salient cues for our visual system. [Supported by MIUR.]

◆ **The role of perceptual salience, semantic relevance, and hemispheric asymmetry in detecting scene changes**

S Spotorno, S Faure ¶ (Dipartimento di Scienze Antropologiche, University of Genoa, Genoa, Italy; ¶ University of Nice–Sophia Antipolis, Nice, France; e-mail: spotorno@nous.unige.it)

Change detection when transient signals are disturbed is often poor, but is modulated by top–down and bottom–up effects. In this study, we explored (i) the role of objects' perceptual salience and semantic relevance for the general meaning of a scene, with an original multiple-criterion method to evaluate these dimensions, and (ii) the hemispheric asymmetry in change perception using a new technique that combines one-shot change detection and tachistoscopically divided visual field. Realistic coloured scenes were presented centrally on the screen and thirty-two participants indicated whether a change occurred. Salience, relevance, and their interaction all affected both speed and accuracy; performance was worst for changes neither salient nor semantically relevant. However, only for low-salience changes did relevance affect speed. The RTs were shorter when a change occurred in the left visual field, suggesting a right-hemisphere advantage for detection of visual change. The theoretical implications are discussed, focusing on the processes that may underlie salience and semantic relevance effects together with the nature of the right-hemisphere contribution in change detection.

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◆ **A narrow field of view can affect memory storage and search behaviour during a visual change-detection task: Comparison between vision and haptics**

T Yoshida, Y Miyazaki¶, K Yokoi§, H Wake#, T Wake¶ (Department of Psychology, Harvard University, Cambridge, USA; ¶Chukyo University, Nagoya, Japan; §University of Tokyo, Tokyo, Japan; # Kanagawa University, Yokohama, Japan; e-mail: q52608@sakura.kudpc.kyoto-u.ac.jp)

It is known that 2-D images that are immediately interpretable by sight are not easily recognized by touch. Previously, we reported much smaller memory capacity during tactile exploration than visual exploration using a change-detection task, suggesting that we have little or no memory to integrate tactile information over different time and locations in space for a coherent percept. To test the possibility that the limited field of view of the haptic exploration can explain our results, we tested the same task under restricted field of view using the gaze-contingent moving-window technique. As the field of view decreased, the estimated memory decreased and the number of fixations per second increased. The distribution of the saccade amplitude showed no peak distribution in the whole-view condition, but showed a peak around 2.5 deg in moving-window conditions. These results suggest that vision behaves like haptics when the field of view is equivalently restricted

[Supported by a grant from JSPS and NISSAN Science Foundation to TY.]

DEVELOPMENT

◆ **Newborn babies prefer biological-motion displays**

E Di Giorgio, L Bardi, H Bulf, F Simion (Dipartimento di Psicologia dello Sviluppo e della Socializzazione, University of Padua, Padua, Italy; e-mail: hermann.bulf@unipd.it)

Recent evidence demonstrates that some non-human animal species possess an inborn bias to detect biological motion. Up to now, no conclusive data have been available concerning the ontogenetic origin of the sensitivity to biological motion in the human species. No discrimination of biological motion point-light displays was in fact reported for infants below the age of 3 months. Here, we tested a sample of 44 newborn babies aged 44 ± 4.7 (mean and SE) hours. Newborns were capable of discriminating (recognition following habituation) biological vs non-biological point-light animations (experiment 1) and, when first exposed to the two displays (spontaneous preference), selectively preferred to look at the biological motion (experiment 2). The biological-motion inversion effect was also present at birth: babies preferred an upright to an upside-down biological-motion animation (experiment 3). These data are consistent with those obtained for other species (inexperienced chicks) and provide the very first evidence supporting Johansson's hypothesis that detection of biological motion is an intrinsic capacity of the visual system in the human species.

◆ **Lost in space: Using satellite tracking to measure the development of landmark integration**

B Hood, A D Smith, K Cater, I D Gilchrist (Department of Experimental Psychology, University of Bristol, Bristol, UK; e-mail: bruce.hood@bristol.ac.uk)

Recent claims that young children reorient using the geometric shape of space, and can only use landmarks when spatial language appears later in development, have been challenged by issues of ecological validity in laboratory environments. Here we report innovative use of GPS technology to evaluate children's spatial representation in a natural setting. Twenty-four children (aged 3 and 5 years) observed an object hidden at one of 4 proximal locations. They were then disoriented and required to retrieve the object. The array was either a small (25 m²) or large (100 m²) square, and locations were either identical or coloured distinctly. Participants performed with greater overall accuracy in the large condition, suggesting that proximal locations and distal landmarks were better integrated when the search array was larger. There was also an interaction with age: 3-year-olds were more likely to use distinct proximal cues and showed a greater effect of array size. This demonstrates that young children can utilise landmarks to reorient, and that this is modulated by environmental context.

[Supported by the Medical Research Council of Great Britain.]

◆ **Perception of shape from shading and line junctions in infants**

T Imura, M K Yamaguchi¶, S Kanazawa§, N Shirai#, Y Otsuka‡, M Tomonaga, A Yagi◇, (Primate Research Institute, Kyoto University, Inuyama, Japan; ¶Chuo University, Hachioji, Japan; §Shukutoku University, Chiba, Japan; # Tokyo Metropolitan University, Hachioji, Japan; ‡Tokyo Women's Medical University, Shinjuku-ku, Japan; ◇Kwansei Gakuin University, Nishinomiya, Japan; e-mail: imura@pri.kyoto-u.ac.jp)

We examined the perception of shape from shading and line junction in infants aged 5–8 months. In experiment 1, infants were presented a pair of displays: a 2-D – 3-D display, alternating between

2-D and 3-D images, and a 2-D–2-D display, alternating between two 2-D images. The 3-D image consisted of black-and-white borders aligned with the peaks of a serrated aperture, creating the appearance of a 3-D folded surface. The 2-D image consisted of black-and-white borders misaligned with the peaks of a serrated aperture, which does not create a 3-D impression for adults. Only 7- and 8-month-olds looked longer at the 2-D–3-D display than the 2-D–2-D display. In experiment 2, we used images with double-cycle rectangular-wave grating to impair shading information. 7- and 8-month-olds did not exhibit a significant difference in preference between the two test displays. The results indicate that these infants are sensitive to shading and line junction cues, suggesting that infants integrate multiple depth cues to perceive the 3-D structure of objects.

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◆ **Infants' visual working memory for shape, luminance, and colour, tested with iso-salient feature changes**

Z Kaldy, E Blaser (Department of Psychology, University of Massachusetts Boston, Boston, USA; e-mail: zsuzsa.kaldy@umb.edu)

We compared infants' visual working memory (VWM) for shape, luminance, and colour. Importantly, interdimensional salience mapping (ISM) allowed us to generate comparison objects with iso-salient differences from a common baseline object. Stimuli were computer-generated. In experiment 1 (ISM; fourteen infants) salience was calibrated in a preferential looking paradigm by pitting a baseline object (a yellow geometric figure) against a range of objects that increased either in luminance, colour (saturation), and complexity. In experiment 2 (VWM; 32 infants) in a violation-of-expectation paradigm, an object (either baseline or comparison) was briefly occluded, then either the same object or the other object was revealed. Looking times were measured. Iso-salient feature differences were successfully measured in experiment 1. Experiment 2 showed that shape, but not luminance, was maintained in VWM. (Preliminary results show VWM for colour, too.) Our aim was to demonstrate a method for producing psychophysically comparable stimuli. VWM results were consistent with our ecological memory hypothesis, which predicts that more stable features are better remembered.

◆ **Developmental and learning effects on anticipatory eye movement in infants**

T Otobe, M Kato, T Hasegawa¶, Y Konishi (Infants' Brain and Cognitive Development, Tokyo Women's Medical University, Shinjuku, Japan; and CREST, Japan Science and Technology Agency; ¶Ochanomizu University, Bunkyo, Japan; e-mail: otb@ibcd.twmu.ac.jp)

Developmental change of learning effect on anticipation was studied in 3- and 4.5-month-old infants. Using eye-tracking system, we recorded their eye movement (EM) when looking at an animation in which 1 out of 3 cartoon faces made a 1 s bounce following a 2 s interval in a fixed order. Each subject was presented with 72 bounces in total. We first separated anticipatory EM and reaction by a 200 ms cut-off point from the onset of bounce of the target face. Second, direct anticipations were extracted from anticipatory EMs by two criteria: (i) EMs occurred after looking at the previous bounce, and (ii) there is no EM to faces other than the current target between offset of the previous bounce and onset of the current one. As a result, there is no statistically significant difference between two age groups in the proportion of anticipatory EM. However, only 4.5-month-olds showed significant increase of the proportion of direct anticipation. These findings suggest that 4.5-month-old infants can develop their expectation by repeated experiences within a relatively short period.

[We thank Y Nishikawa, M Nishikawa, K Nishida, and S Ito for recruiting subjects. This study was supported by CREST, JST.]

EYE MOVEMENTS

◆ **A graphical calibration method of three-dimensional eye-position recordings**

R Bolzani, M Benassi, S Giovagnoli, K Gummel¶, J Ygge§ (Department of Psychology, University of Bologna, Bologna, Italy; ¶St Petersburg State Paediatric Medical Academy, St Petersburg, Russia; §Karolinska Institutet, Stockholm, Sweden; e-mail: roberto.bolzani@unibo.it)

Many mathematical methods have been proposed for the calibration of the eye-position recordings in 3-D measurements involving rotation matrices in an off-line evaluation. Here, a new graphical method is proposed for calibrating horizontal, vertical, and torsion measurements, taking into account the theoretical values of torsion from Listing's law. The calibration is made by means of a dot moving on a projection screen along the corners of an ideal square 40 deg wide. Plotting the recorded data in an $x-y$ diagram, with the horizontal position on the x -axis and the torsion values on the y -axis, a X-shaped figure is obtained. From Listing's law it is

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possible to prove that the crossing point of the two tracks gives the horizontal coordinate of the primary position. By repeating the same procedure for the vertical and torsion values we find the vertical coordinate of the primary position. The recorded data give also the horizontal and vertical amplitude of the signal related to 40 deg eye movements.

◆ **Contrast sensitivity during the initiation of smooth-pursuit eye movements**

D I Braun, A C Schütz, K R Gegenfurtner (Allgemeine Psychologie, Universität Giessen, Giessen, Germany; e-mail: doris.braun@psychol.uni-giessen.de)

During saccades visual stability is achieved by perceptual suppression. We explored whether a similar suppression changes the detection of briefly presented line targets during the initiation of smooth pursuit, elicited by horizontal step-ramps and simple ramps. A blurred 0.3 deg wide horizontal line appeared for 10 ms either 2 deg above or below the pursuit trajectory at various times. The subject had to pursue the ramp stimulus and to indicate whether the target line appeared above or below the pursuit trajectory. The contrast of this line was set just above detection threshold for each subject. Unlike in saccades, no suppression was found for the detection of the line during pursuit initiation elicited by a step-ramp stimulus. With ramp stimulus, pursuit initiation was accompanied by initial saccades causing saccadic suppression. A slight attenuation of contrast sensitivity was found at stimulus onset of ramps and step-ramps which is probably due to attentional blinks.

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◆ **Integrated real-time eye, head, and body tracking in front of a wall-sized display**

L H Canto-Pereira, T G Tanner, S Herholz, R W Fleming, H H Bülthoff (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: luiz.canto@tuebingen.mpg.de)

Most devices for eye- or gaze-tracking require constrained head and body movements in order to achieve high temporal and spatial accuracy, or a limited field of view or observer positions (eg for keeping the eyes visible for video tracking). This may lead to unnatural viewing conditions, possibly systematically altering gaze patterns in experiments. Furthermore, head and eye movements often cannot be analyzed independently. We present a novel system integrating high-speed eye- and head-tracking, thus enabling observers to move freely in front of large (wall-sized) displays. The system is modular, making it easy to track additional markers for body parts or pointing devices, if desired. Tracking is performed by an Eyelink II (500 Hz) and three Vicon MX motion capture cameras (180 Hz, error < 1 mm), respectively. Gaze direction (based on independent eye and head direction) are calculated in real-time (error < 0.8°, latency < 6 ms), thus allowing gaze-contingent displays. We present possible applications of the system in psychophysics and data visualization.

◆ **Where is the visual centre of a blob?**

F Cristino, R Baddeley (Department of Experimental Psychology, University of Bristol, Bristol, UK; e-mail: f.cristino@bristol.ac.uk)

Where do we point our eyes when viewing simple visual objects? For fixation crosses, and Gaussian blobs, almost all definitions of the visual centre give the same location—the mean. For asymmetric objects, there are in contrast a number of plausible definitions of centre. We therefore investigated four hypotheses about where the visual centre is: the maximum of the luminance, the mean, the median, and the centre of gravity of the edges. These were calculated both in visual and superior collicular coordinates. To test these hypotheses, we recorded subject's eye movements to simple asymmetric luminance blobs, where these blobs were constructed from power-law-transformed beta distributions. By comparing subject's average fixation landing positions to those made by the various models, we could identify what characteristics of the blobs were important in determining where we fixate. We found that the best predictor of fixation location was a robust version of the mean—in particular a so-called *M* estimator [Huber, 1981 *Robust Statistics* (New York: John Wiley)] with $M = 1.55$.

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◆ **Eye movements on natural videos: Low-level feature correlations at successive fixations**

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We investigated the relationship between low-level image features at successive fixations during free-viewing of natural dynamic scenes. We recorded 37 000 fixations from fifty-four subjects watching 18 high-resolution video clips of outdoor scenes. Colour, local orientation, and motion were

computed on a Gaussian multiresolution pyramid (6 spatial, 3 temporal levels). We also computed geometrical invariants that have been used to predict eye movements before. We then examined the distributions of differences between features at successive fixations, ie their temporal correlations along the scanpath. We compared the recorded scanpaths with randomly generated scanpaths with varying degree of similarity to natural scanpaths (saccade length, direction, etc). In most conditions, we found statistically significant differences in the distributions. However, we found that these feature correlations along the scanpath are mainly due to spatio-temporal correlations in natural scenes and a bias in target selection (eg moving objects are fixated more often). Therefore, we conclude that low-level features at the current centre of fixation contribute little to the selection of the next saccade target.

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◆ **Comparison between principles of grouping based on eye-movement recording**

A I Fontes, J M Merino, S Fontes (Department of Psychology, Universidad Nacional de Educación a Distancia, Madrid, Spain; e-mail: aifontes@psi.uned.es)

We monitored eye movements of the subjects while they carried out the task of grouping. Our goal was to compare the three principles of grouping: good continuation, proximity, and similarity. The data show that the necessary response time to realize the task is similar when the grouping is for good continuation and for proximity, but when the grouping is by similarity the response time is greater. There are fewer fixations in similarity, followed by good continuation, and proximity. The greatest fixations duration is in similarity and there are no differences between good continuation and proximity. Two factors can explain these results: (i) the characteristics of the stimuli have a greater influence on guiding the saccades than proximity and (ii) major peripheral pre-processing and minor central-foveal processing may explain the decrease of the fixations duration under similarity.

◆ **A call for attention!—TV news broadcasts and the effects of competing news presentations on perception**

V Gattol, T Ditye, C C Carbon, F Hutzler (Faculty of Psychology, University of Vienna, Vienna, Austria; e-mail: valentin.gattol@gmx.at)

In our fast-moving society, news networks are challenged to supply an ever-growing array of information simultaneously. Recent developments in TV news broadcasts have shown to incorporate new presentation techniques, such as crawlers and additional headlines transporting different stories at the same time. We analyzed to which degree viewers are actually capable of processing these various contents altogether; recall data were supplemented by eye-movement measures and aesthetic evaluations of the different broadcast designs. Stimuli consisted of news-broadcasts that were varied in the type of information (no add-on, highly relevant, little relevant) and the way of presentation (crawler vs static). Content recall of the main story was strongly reduced in both add-on-conditions and modulated by relevance. Crawlers showed increased fixation times but did not differ from the static subtitles in content recall for the add-ons. Further, aesthetic evaluations revealed that plain broadcasts (no add-on) were generally preferred and judged as more reliable as well as less overcrowded and strenuous.

◆ **Oculo-manual coupling during smooth pursuit: A transcranial magnetic stimulation (TMS) study**

T Giancesini, L Falciati, C Maioli (Department of Biomedical Sciences and Biotechnology, University of Brescia, Brescia, Italy; e-mail: tiziana.giancesini@email.it)

When we make an aiming movement towards a moving visual object, eye-hand coupling is of paramount importance for accurate motor performance. Some studies have suggested that both gaze and manual tracking control systems are driven by a common command signal. However, it has never been demonstrated that a motor plan for the arm is produced even when the object is tracked by the eyes alone. By using TMS, we show for the first time that ocular tracking is linked to changes in the excitability of the motor-control system of the relaxed upper limb. Excitability changes are compatible with a subthreshold neural activation encoding a manual tracking response to the same target pursued by the eyes. In addition, these excitability changes are accompanied by a generalized inhibition of the arm corticospinal system and are affected by the upper-limb posture. We provide direct evidence that, if the arm is held in a congruent postural configuration, tracking a moving object always entails a coordinated motor plan, which involves both gaze and hand.

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- ◆ **Eye movements for pictures of social scenes—instructions do not prevent fixation of faces**
P F Heard, A Williams, U Leonards¶ (Department of Psychology, University of the West of England, Bristol, UK; ¶ University of Bristol, Bristol, UK;
e-mail: priscilla.heard@uwe.ac.uk)

Following Yarbus's findings of instructions influencing scene exploration, [Yarbus, 1967 *Eye Movements and Vision* (New York: Plenum)] we measured eye movements in participants viewing pictures from children's story books. Three kinds of instructions were used: (a) Scenario with feelings: can you tell me what is happening and what the people are feeling? (b) Object-based: eg how many people are wearing yellow? (c) Individual emotion: eg how do you think the person in the front feels? Eye-movement patterns differed significantly between these three sets of instructions, specifically with respect to fixation frequencies for faces. As expected, face fixations were significantly more common in 'individual emotion' than 'scenario with feelings' conditions, and both emotional conditions showed more fixations to faces than the object condition. Surprisingly, however, face fixations reached 30% of total fixations even in the object condition. In emotional but not object-based conditions, women looked significantly more often at faces than did men. Results are discussed with respect to social influences on visual cognition, and possible implications for autism.

- ◆ **Human interaction with emotional virtual agents: Differential effects of agents' attributes on eye movement and EMG parameters**
J R Helmert, F Schrammel, S Pannasch, B M Velichkovsky (Applied Cognitive Research Unit, Institute of Psychology III, Technische Universität Dresden, Dresden, Germany;
e-mail: helmert@applied-cognition.org)

Gaze direction and facial expression are crucial features of a human face in a communicative situation. Facial features are often investigated in static settings while their dynamic aspects are neglected. Varying a paradigm (Schilbach et al, 2006 *Neuropsychologia* **44** 718–730), we showed subjects short films of virtual agents entering the scene and turning either towards the observer or towards an imaginary third person left or right from the observer. Then, the agent displayed an emotional facial expression (angry, neutral, happy). Subjects' eye movements and facial muscle activity were recorded. Fixation duration was a solid indicator in all sections of the films, differentiating between the agents' sex, turning direction, and emotional expression, respectively. The EMG activity of the corrugator and zygomatic muscles reflected the valence of the displayed emotional expression, being significantly enhanced when observers were gazed at directly. We speculate that eye-to-eye contact amplifies and mediates sensorimotor and mental responses to facial expression, contributing in this way to such higher-order cognitive functions as constituting a theory of mind.

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- ◆ **Eye movements while searching for a set**
M Jacob, S Hochstein (Interdisciplinary Center for Neural Computation, Department of Neurobiology, Hebrew University, Jerusalem, Israel; e-mail: michaljb@gmail.com)

We are studying the sequence of events leading to detection of a set when subjects play the SET® game. Previously, we reported preferences for particular types of sets and detection time effects of training, similarity, and number of sets available in each round (Jacob and Hochstein, 2005 *Perception* **34** Supplement, 237). We now report player eye-movements and fixations to compare cognitive states before and during set detection. In particular, we compare fixations on cards belonging to a detected set with those on cards that belong to a valid but undetected set in the same display. Detected set cards are fixated more frequently than undetected set cards, and in the search sequence there are fewer intervening fixations on other cards between fixations on detected than on undetected set cards. These findings raise the question of what comes first: does observing certain cards more frequently and more closely lead to finding a set, or does an implicit sense of the presence of a set lead to these features and ultimately to the explicit "aha" discovery of the set?

[Supported by the US–Israel Binational Science Foundation and the Israel Science Foundation Center of Excellence.]

- ◆ **Perception of pictorial space and motion: An eye movement study**
Z Kapoula, D Oudiette, M P Bucci (Groupe Iris, CNRS, Collège de France, Paris, France; e-mail: zoi.kapoula@college-de-france.fr)

Ten science and ten art students (mean age 23 years) took part in the experiment. They explored the painting of Francis Bacon *Study of a Dog* on a computer screen for 1 min without specific instructions. In another task they performed reflexive saccades to a single target. Eye movements were recorded with the Chronos video system. After recording, subjects described the painting

and drew it from memory. Art students gave more details of spatial aspects and motion. Their drawings reproduced the spatial composition of the painting more faithfully. Eye movements by artists explored a larger area including spatially important points. For both groups of subjects fixation was more unstable while exploring the painting than when fixating single targets; fixation instability in depth tended to be of higher mean velocity for art students who reported motion perception than to non-artists (1.3° s^{-1} vs 1° s^{-1}); durations of fixation were also longer (354 ms vs 289 ms). Thus, combined subjective tests and physiological analysis of eye movements provide a useful tool to corroborate pictorial perception.

◆ **The effect of motion type, acceleration, and direction of motion on oculomotor pursuit and overtracking responses after the disappearance of a moving target**

L Komidar, A Podlesek, V Bucik (Department of Psychology, Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia; e-mail: luka.komidar@ff.uni-lj.si)

Eye movements play an important role in localizing the final position of a moving target: when observers track continuous target motion with their eyes, the remembered final position of the target is displaced in the direction of motion. We examined the effect of motion type, acceleration, and direction of motion on oculomotor pursuit and overtracking responses. We discovered that in continuous-motion conditions online gain control was susceptible to motion acceleration. In the case of apparent motion, tracking eye movements consisted of a combination of saccades, post-saccadic drift, and intervals characterized by relatively stable oculomotor gain. In continuous- as well as apparent-motion conditions, overtracking responses had a duration of about 200 to 250 ms. Overshoot after smooth motion resulted in gradually degrading smooth pursuit, whereas overshoot after apparent motion consisted of an anticipatory saccade and post-saccadic drift. Compared to the pursuit of continuous motion, the pursuit of apparent motion resulted in larger overshoots. The results support the perceptual account of forward displacement.

◆ **Shaping induces long-term enhancements in pursuit-like-smooth movements under image-stabilization condition**

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Barnes et al showed in 1995 that some participants may generate slow eye movements for a short period of time under image-stabilization condition. Would, under this condition, subjects learn to produce consistent smooth movements similar to normal pursuit? We recorded eye movements in four participants instructed to smoothly move their eyes so that a stabilized target was horizontally displaced across the screen. A reinforcing auditory stimulus was delivered during periods of saccade-free smooth movements based on eye-velocity criteria. The criteria were progressively adjusted to shape the velocity to a fixed value. Learning dramatically affected steady-state eye velocity under stabilization: velocity was close to velocity during pursuit (20.5 vs 21.1 deg s^{-1} on average) and the frequency of saccades was reduced by half. These effects were maintained several days after learning. Our learning procedure induced long-term modifications in the probability of occurrence of the target behavior as well as in the topography of the response itself.

◆ **The relationship of spatio-temporal characteristics of eye movements in scene perception**

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The anatomical distinction of two visual pathways is also represented in most models of perception and action with different names, eg preattentive vs attentive (Norman, 2002 *Behavioral Brain Sciences* **25** 73–144) or ambient vs focal (Trevarthen, 1968 *Psychologische Forschung* **31** 299–337). In previous work we could demonstrate the dominance of one or other system by the combined analysis of fixation durations 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]. We present results from experiments which investigated the influence of image characteristics, different cognitive tasks, and mood induction on the dynamic balance of the two visual systems on eye movements. We show that (i) there is an overall change in eye-movement parameters over the time course of scene inspection, (ii) levels of processing differences in tasks result in changes in saccadic amplitudes, and (iii) mood induction influences eye movements only early in the time course of scene perception.

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◆ **Low-level sustained accommodative-vergence loads, asthenopia, and accommodative-vergence functioning**

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The effects of sustained accommodative-vergence loads on eye strain and musculoskeletal discomfort were assessed. Five females and one male with a mean age of 31 years (range 20–37 years, SD 6.18 years) were included in the study. The accommodative-vergence response was assessed with an infrared video-refractor (PowerRefractor R 03, Plusoptix, Dortmund, Germany). A polychromatic LED was introduced into the optical axis of the viewing eye, or in the midline in the case of binocular viewing. The subjects were asked to compensate for the blur incurred (+1.50, -0.25, -1.0, and -3.0 D) by reflexively or voluntarily adjusting the dioptric strength of the crystalline eye lens during 120 s trials. The participant's level of oculomotor load was stable and task-appropriate. The results indicate that the effects of the levels of loads used here resulted in very low levels of symptoms of discomfort. A general decrease in the rate of binocular accommodative relaxation time (during near-to-far trials), from -5.16 D s^{-1} to -4.65 D s^{-1} was apparent. The baseline shift in individual rates of eye-lens adjustments correlated with simultaneous reductions in response amplitudes in non-congruent stimulus conditions requiring contraction of the ciliary muscle.

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◆ **Effect of scene transitions on trans-saccadic change detection in natural scenes**

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Saccades are rapid shifts of gaze that direct the fovea from one point of interest to another. On each saccade, the entire scene streams across the retina at hundreds of degrees per second. However, this streaming is not apparent, owing to a reduced visual sensitivity toward motion during saccades. It has been reported that the apparent motion of scenes that translate trans-saccadically is perceived as slower than the equivalent inter-saccadic transitions [Herpers et al, 2004, in *Dynamische Perception* (Amsterdam: IOS Press) pp 77–82]. However, this conclusion could be an artifact of the 2IFC method that was used. We confirmed the apparent slower speed of the trans-saccadic scene changes, as compared to inter-saccadic shifts, using a magnitude estimation technique. On each trial, subjects indicated the magnitude of the transition on a scale of 0 to 9, relative to a reference transition assigned a value of 5. The pooled mean estimate for the detected trans-saccadic shifts was significantly smaller than the inter-saccadic shifts. We conclude that during saccades, the magnitude of the velocity signal is attenuated as well as its detectability.

◆ **Competition between luminance and colour in target selection for smooth-pursuit and saccadic eye movements**

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Numerous studies have indicated a high degree of similarity between smooth-pursuit and saccadic eye movements. Both types of movement are assumed to be driven by shared cortical pathways, and target selection in pursuit and saccades seems to be determined by common decision signals. But are pursuit and saccades guided by the same visual signal? We had human observers track a horizontally moving stimulus which split into two components, one defined by luminance, the other by colour. The two stimuli either jumped to new positions, requiring a saccade, or moved in two diagonal directions, requiring pursuit. Observers were instructed to choose the more salient stimulus. Results show a clear difference in pursuit and saccadic choice patterns. Whereas initial pursuit tended to follow luminance, saccades went in the direction of colour. An early pursuit response towards luminance was often reversed to colour by a later saccade. These substantial differences in decision direction show that luminance and colour are processed in different ways for pursuit and saccadic target selection.

◆ **Eye movement after occlusion during position-anticipation task**

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In position-anticipation task of a free-falling object that is suddenly occluded, all subjects underestimated the moving distance of the object after occlusion, as reported by Takeichi et al (2005 *Perception* 34 Supplement, 231). This underestimation is observed under the various conditions of object velocity and trigger stimulus, as reported in Takeichi et al (2006 *Perception* 35 Supplement, 217). However, it is unclear whether the moving distance underestimation means a

slowdown of the velocity image or an anticipation failure with the proper velocity image. Therefore, eye movement during the task was measured to substitute for the velocity image of the subject. If the eye-velocity slowdown is observed after the occlusion, this might suggest a velocity image slowdown. During the task, the eye stopped at the occlusion point, and repeated the stop-and-go motion until the trigger stimulus. The average velocity from the occlusion point to the stimulus point was much less than the actual object velocity and almost equal to the anticipation velocity. This strongly suggests that velocity image slowdown caused the anticipation velocity slowdown.

◆ **Free vs constrained gaze in a multiple-object-tracking paradigm**

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The multiple-object-tracking (MOT) paradigm is useful for studying how observers allocate their attentional resources over several moving targets. Despite claiming no effect of eye movements on performance, previous studies provided no clear evidence for this assumption. We investigated how eye movements affect performance in an MOT task under different viewing conditions (free eye movements vs fixation control vs instruction to fixate but without monitoring). Subjects ($N = 4$) performed an MOT task (120 trials per condition) while eye movements were recorded (250 Hz, error $< 0.4^\circ$). Allowing free eye movements led to significantly higher performance (93%) than with proper fixation control (75%) and without monitoring (83%, all pairwise t -tests: $p < 0.001$). Thus, high performance in previous studies without fixation control could possibly be explained by fixation losses. On the basis of eye-movement data and subjective reports we suggest an alternative to traditional multifocal attention models. It predicts that observers group targets together and track a single 'mental' object.

◆ **Effect of increasing verbal and visuospatial memory workload on saccadic eye-movement latency**

A Tarnowski (Department of Psychology, Warsaw University, Warsaw, Poland; e-mail: adam.tarnowski@psych.uw.edu.pl)

The effect of working memory on saccadic latency has been studied in two experiments. In the first experiment subjects had to memorized sets of letters (1, 3, 5, or 7), and then were asked to detect them on a serial display. When set size increased, saccade reaction times (SRTs) decreased in gap and overlap conditions, and manual reaction times (RTs) increased. In the second experiment subjects had to memorize the location of a set of squares, and then detect squares appearing in memorized positions. In effect, their SRTs increased with increasing set size. The results of the first experiment, contrary to Sternberg's classical findings, can be interpreted in terms of automation of perceptual processes. When two processes (verbal material rehearsal and controlling eye movements) compete for executive resources, and one of them can be easily automated, it will work in a faster automated way. Manual choice responses cannot be performed without executive resources, and this explains Sternberg's effect, replicated in current experiment in MRT, but not SRT. This effect is not possible when both tasks have to be maintained by the same slave structure, and this explains positive correlation of SRTs with visuospatial memory workload.

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◆ **Effects of within-object fixation position on subsequent eye movements**

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During reading and visual search, spatial and temporal aspects of eye-movement control depend on fixation position within an object. Such effects of fixation position on eye movements were observed in preferred landing sites of saccades, optimal viewing position, and inverted optimal viewing position for fixation durations. However, underlying mechanisms and relations between these effects are only poorly understood. In the present study, subjects fixated a number of symbols in a predefined order until they had found a target symbol. By variations of the task across sessions, we manipulated effects of within-object fixation position on subsequent eye-movement behaviour. The preferred landing site was shifted towards the most informative position within a symbol, fixation durations increased at positions informative for the upcoming saccade, and refixation rates reflected task demands. Interestingly, we did not observe systematic relations between the different effects. We conclude that these eye-movement effects are highly sensitive to task demands. Furthermore, the present findings support the hypothesis of a loose coupling of spatial and temporal control of saccades.

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◆ **Which neural pathway supports the microsaccadic response to visual stimuli?**

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When a stimulus appears at fixation, the microsaccadic frequency is first inhibited, and then undergoes a rebound before returning to the baseline (approximately 1 Hz). There is evidence that such response changes dramatically when the stimulus is an oddball, indicating that high-order cognitive processes, rather than a simple reflex, control the microsaccadic response. The present study aimed at isolating the relative contribution of cortical and retino-collicular pathways in controlling microsaccades. We used an oddball task in which the stimuli were either equiluminant with the background (ie invisible to the superior colliculus, SC) or consisted of a luminance change. The microsaccadic response elicited by equiluminant stimuli was indistinguishable from that evoked by non-equiluminant ones. The only crucial difference was a delayed (34 ms) microsaccadic response for the equiluminant non-target stimuli. The present findings suggest that, at least in the case of equiluminant stimuli, the control of microsaccades does not take place at the SC level, but rather it involves the contribution of color-sensitive cortical structures.

[The authors wish to thank Bradford Z Mahon for his useful comments on the manuscript.]

◆ **Eye movements on natural videos: Predictive power of different low-level features**

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We used eye movements recorded in fifty-four subjects, who viewed two high-resolution videos of outdoor scenes, to define an empirical salience (ES) measure as the density of saccade landing points. We used ES to label a data set of local movie blocks ($17 \times 17 \times 8$ pixels extracted from the original videos) as 'salient' and 'non-salient' (1000 samples per class). We then computed different representations: Laplacian, colour opponency, motion, and spatio-temporal curvature K . Next, we used two different classifiers [maximum likelihood on feature-vector length (ML), k -nearest-neighbour on full-feature vectors (kNN)] to classify the movie blocks into the two classes for all representations. The error rates reflect the predictive power of the different representations. Under all conditions, K produced the lowest error rates. For the movie with many moving objects, motion was second best, but it was worst for the other movie. We conclude that simple low-level predictors can make predictions with only 15% errors (ML classifier) and 9% errors (kNN classifier) if the training and test samples are taken from the same movie.

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◆ **Do eye movements anticipate the most likely outcome of conditional events?**

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When observing a naturally moving object through space, its relation to other objects can cause common events for example, occlusion, collision or containment. When visually tracking a moving object that becomes temporarily occluded, our eyes can even saccadically anticipate its trajectory. Developmental studies show that this capacity emerges already during the first months of life. What has not yet been investigated, however, is whether these anticipatory eye movements persist when course of the moving object becomes conditional. In our study, we presented adults with potential containment events, the outcome of which depended mainly on the width relation between the moving object and the opening of the container. Because of this conditional containment relation, different object trajectories can be anticipated. Our results suggest that perceived conditional event outcomes are reflected by anticipatory eye movements in adults.

◆ **Competition between pictorial and physical depth cues: Vergence eye movements under reverspective conditions**

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'Reverspectives' (by artist Patrick Hughes) consist of truncated pyramids with their smaller faces closer to the viewer such as to allow a realistic scene to be painted on them. With their pictorial perspectives that reverse the physical depth arrangement, reverspectives provide a bistable paradigm of competing depth percepts, with illusory depth being strongest monocularly and beyond (individually varying) critical viewing distances (Pappathomas, 2002 *Perception* **31** 521–530). 'Properspectives' are the same solid pyramids, painted on the inside, thus possessing a pictorial perspective that conforms with (and thus augments) real depth. Vergence eye movements were recorded (EyeLink II system) comparatively for monocular and binocular reverspective and binocular proerspective conditions (optimized to obtain illusory, illusory/veridical, or veridical

depth percepts, respectively). Gaze locations were signaled by LEDs, inserted in 8 positions on the model. While fixating identical LED-positions, the eyes converged with veridical depth percepts and diverged with illusory depth percepts. These results indicate that pictorial cues are as effective as physical cues for vergence control.

PLASTICITY

◆ Deaf individuals have faster processing of visual transients events

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Previous literature suggests that deaf individuals may show improved performance during attention-demanding visual tasks compared to hearing. These enhanced visual abilities were particularly observed at the parafoveal and peripheral portions of the visual field. We compared eleven deaf individuals and eleven normal-hearing ones in a simple RT task, a task that requires divided attention only. One or two small squares appeared transiently for 50 ms at parafoveal (3°) or peripheral (8°) locations, along diagonals of the computer display. Pair of stimuli always appeared at symmetrical positions with respect to fixation. Results showed that deaf participants were on average 45 ms faster than normal-hearing ones in all conditions (means 265 vs 310 ms, respectively). A redundant-target effect emerged for both groups (two stimuli faster than one). The results of this simple paradigm challenge previous interpretations stressing that enhanced visual abilities in the deaf emerge selectively under condition of focused attention. Moreover, they suggest that faster processing of visual transients needs to be taken into account when interpreting enhanced performance in deaf population.

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◆ Supranormal spatial navigation and larger hippocampal volume in the blind

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In the absence of visual input, the question arises how complex spatial abilities develop and how the brain adapts to the absence of this modality. We therefore explored navigational skills in both early- and late-blind individuals, and also explored structural changes in the hippocampus, a structure well known to be involved in spatial processing. Remarkably, we not only show that blind individuals possess superior navigational skills than matched sighted blindfolded controls on several spatial tasks, but also show for the first time a significant volume increase of the hippocampus in blind individuals, irrespective of whether their blindness was congenital or acquired. Overall, our results shed new light not only on the construction of spatial concepts and the non-necessity of vision for its proper development, but also on the hippocampal plasticity observed in adult blind individuals who have to navigate in this space.

◆ Neuronal plasticity in the cat primary visual cortex: A neuronal correlate of memory?

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The orientation selectivity is believed to be a stable built-in property of adult V1 cells. However, shifts in orientation preference have been demonstrated by a non-optimal short-term stimulus exposure. We tested if a second adaptation will produce larger shifts or stronger responses in V1 neuronal activity of anaesthetized cats, prepared for electrophysiological recordings in conventional fashion. Sine-wave gratings were applied on receptive fields to determine the optimal orientations of cells. Then a grating up to $\pm 90^\circ$ away from preferred orientation of the cells was applied for 12 min. In this first step, attractive and repulsive shifts of the preferred orientation were observed in 45% and 21% of cases, respectively. After recovery, cells were again submitted to the same stimulus. Following this second adaptation, repulsive shifts were less frequent (15%). Moreover, responses for the acquired optimal orientation significantly increased. These increases were limited to the imposed orientation. Results suggest that neuronal responses may be strengthened following the second adaptation; hence neurons have learned from the first experience.

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◆ The multimodal occipital cortex: Insights from the blind and the sighted

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Blindness-induced plasticity is a common finding in neuroimaging studies of individuals with severe visual disabilities. The recruitment of visual cortices in blind subjects has been observed

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across a wide variety of tasks, and notably during sound localization. The goal of the present study was to assess the subjects' ability to process spectral information during sound localization as well as the underlying neural processing. While undergoing a PET scan, subjects were asked to localize different auditorily-simulated spatial positions. Groups of early blind, late blind, and sighted subjects performed the task. Consistent with previous findings, the blind groups showed significant activation in several visual areas. To our surprise, however, the sighted subjects showed also activation of the right lingual gyrus, while significantly deactivating regions of the middle occipital cortex bilaterally. To our knowledge, this is one of the first indications that occipital cortex may contribute to auditory spatial processing in the sighted. These data strongly suggest that the occipital cortex of sighted individuals might not be as unimodal as once thought.

SACCADES

◆ **Processing emotional stimuli: Comparison of saccadic and manual-choice reaction times**

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Most studies investigating reaction times to visual stimuli have used manual responses. A subject's reaction time is a combination of time taken both for perceptual processes and for motor preparation/execution. The latter component is shorter for saccadic eye movements than manual responses and therefore may be a more sensitive indicator of variations in perceptual processing times. In experiment 1, two faces, one emotional (fearful or happy) and one neutral, appeared simultaneously for 20 ms in the left and right visual fields. Participants' ($N = 10$) saccadic and manual reaction times towards emotional and neutral faces were investigated. Saccadic reaction times showed a strong bias towards emotional stimuli, whereas manual responses showed no emotion effect. Experiment 2 extended the findings to emotional and neutral schematic faces, showing the same pattern of results as in experiment 1. These findings suggest that oculomotor responses are more sensitive to emotional stimuli than manual responses. The results also extend previous reports of preferential detection of emotionally meaningful stimuli.

◆ **Investigation of the effect of remote and near distractors on the accuracy of saccadic eye movements**

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Saccade accuracy is reduced by the presence of distracting stimuli close to the target. This can be attenuated by the presence of remote distractors (McSorley and Findlay, 2003 *Journal of Vision* 3 877–892). A series of experiments was conducted to further investigate the effect of varying distractor characteristics on saccade accuracy: we varied the number, location, and similarity to target of remote distractors (RDs). All stimuli were Gabor patches, differing in spatial frequency. Initially, local and RDs were visually similar to target stimuli and appeared in potential target locations. In a second experiment, similarity between RDs and target stimuli was reduced. In a third experiment, dissimilar RDs were positioned in non-target locations (4.5 deg from fixation). Finally, target side was constrained so that RDs were no longer in an attended location. We found that the location and similarity to target of RDs and the size of the RD effect modulated saccade accuracy. Results are discussed in terms of established oculomotor models.

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◆ **Mislocalization in dark-adapted and light-adapted subjects**

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Spatial localization of brief stimuli across saccades shows transient distortions of perceived positions: stimuli appear shifted in saccade direction and compressed towards the saccade target. The strength and spatial pattern of this mislocalization are influenced by several parameters, eg contrast. Therefore we asked whether mislocalization of stimuli in darkness also depends on luminance. Since dark adaptation changes luminance thresholds we also compared mislocalization in dark-adapted and light-adapted states. Perisaccadic mislocalization was measured with near-threshold and above-threshold stimuli in dark-adapted and light-adapted subjects. In both adaptation states, near-threshold stimuli gave much larger mislocalization than above-threshold stimuli. Furthermore, when the stimulus was presented near-threshold, the bars were perceived closer together, indicating a stronger compression of perceived position. Stimulus luminances that produced strong mislocalization in the light-adapted state produced little mislocalization in the dark-adapted state, presumably because they were now well above threshold. We conclude that the strength of perisaccadic mislocalization depends on the strength of the stimulus: stimuli with near-threshold luminance, and hence low visibility, are more mislocalized than clearly visible stimuli.

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◆ **Saccadic and tracking performance in children with fetal alcohol syndrome**

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Fetal alcohol syndrome (FAS) has become an increasing problem in Russia. Investigations of visual functions by traditional methods do not seem to outline all problems these children may have. We therefore evaluated saccadic and tracking performance in FAS children. Fifty FAS children, aged 10–16 years, were included in the study and compared to a matched (by age and sex) control group of fifty children without FAS. The Clinsac and Clintrac tests were used for quantification of sequential tracking and smooth visual tracking, respectively. The FAS children showed a poorer result: a longer mean time and a larger number of attempts in both tracking tests. The FAS children in the Russian orphanage group showed poorer tracking ability compared to matched control children. This may have implications for other visual functions such as reading. [Supported by the Bernadotte Foundation and the Swedish Institute.]

◆ **Experimental evidence for an attention-related explanation of perisaccadic compression**

F H Hamker, M Zirnsak, M Lappe (Department of Psychology, Westfälische Wilhelms-Universität, Münster, Germany; e-mail: fhamker@uni-muenster.de)

Perisaccadically flashed stimuli are mislocalized towards the saccade target. The optimal integration theory suggests that an object's location is determined from the prior probability of the object's spatial position and the sensorimotor estimate of a stimulus position. It predicts that a reliable position information should lead to little or no mislocalization. Alternatively, we have suggested that the compression of visual space is the result of an enhanced processing capacity around the saccade target. This model predicts that mislocalization occurs independent of position reliability. We tested the different predictions by flashing the letter E giving the middle dash of the letter (–) as a continuously visible reference, such that the subjects knew exactly the position of the flashed letter. Our results show a strong mislocalization of the flashed letter towards the saccade target, ruling out the optimal integration theory. Our results rather support the idea that the mislocalization towards the saccade target relates to attention and critically depends on an oculomotor feedback signal changing the receptive field structure in visual areas. [Supported by the Federal Ministry of Education and Research grant (BMBF 01GW0653).]

◆ **Cognitive tasks release the eyes**

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In an earlier study, Trottier and Pratts (2005 *Vision Research* 45 1349–1354) hypothesized that, during a saccade task toward a peripheral target, the instruction can act as a top–down disinhibition of the superior colliculus and therefore reduce the saccadic latencies. Using another paradigm (a cue preceding the appearance of the target) we replicated their results and showed the same effect with prosaccades and a kind of antisaccades. Saccade latencies were shorter when people were instructed to not simply look at a target (glance) but to identify some of its properties (identification). We compared this effect to the classical gap effect and showed differences that are supposedly mediated by different cerebral mechanisms. Preliminary data with an agnostic patient who does the identification task at a chance level show the same strong effect of the task on saccade latencies. The patient did not make saccades when the target appeared to the left side of the screen during the glance task, whereas he did it for the identification task. The task appears to have a strong effect.

◆ **Spatial statistics of natural images predict gaze direction**

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Spatial statistics of natural images can be divided into three categories, each following different distributions as determined by statistical algorithms (Geusebroek and Smeulders, 2003 *Ninth IEEE International Conference on Computer Vision* volume 1, p.130). Two of these classes (random and regular) are associated with local texture perception. We hypothesized that regular textures draw attention and wondered whether this classification can predict bottom–up saccade behaviour. While we tracked their gaze, subjects ($N = 5$) made saccades to circularly arranged arrays of 8 textures (one of them classified as regular, the other random; textures were from the Columbia–Utrecht texture database: <http://www.cs.columbia.edu/CAVE/curet/>). In a total 3877 trials, 851 saccades went to the location with the regular texture, whereas each of the other 7 locations received on

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average 432 saccades. This indicates that the presence of a texture classified as regular nearly doubled the chance of subjects directing their gaze to that particular position. While these results provide no proof that humans classify the world into regular and random, they suggest that the brain may compute something analogous to this statistic to determine regions of interest.

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◆ **Saccadic adaptation-induced shift scales with adaptation magnitude**

E Zimmermann, M Lappe (Psychologisches Institut II, Westfälische Wilhelms-Universität Münster, Münster, Germany; e-mail: eckartzi@uni-muenster.de)

We investigated the effect of saccadic adaptation on the perceived localization of briefly flashed bars. When the stimuli are presented ~ 200 ms before the onset of the saccade, subjects usually tend to mislocalize them. In order to elucidate whether this effect is directly linked to the sensorimotor transformation of saccadic adaptation, we compared different degrees of adaptation with respect to the localization error. Three conditions (10%, 20%, 30% adaptation of the intended saccade) were established, such that the adapted saccade always had an 10° amplitude. The results demonstrate that, although in the adapted state subjects always make the same saccade, the extent of the mislocalization increases linearly with the amount of saccadic adaptation. In addition, we used two different paradigms to generate saccades: an overlap paradigm (to generate more voluntary saccades) and a no-overlap paradigm (to generate more reflexive saccades). The similar pattern of perceptual judgments in these two paradigms implies that the localization error originates at a level in the oculomotor system where both types of saccades are processed together.

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SPATIAL VISION

◆ **Information quality improves perception at large eccentricities**

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Performance in different visual tasks decreases with eccentricity, but can be equalized by changing some physical characteristics of the stimulus, eg size. Nevertheless, increasing the stimulation area will only vary the amount of recruited cells, while spatial frequency (SF) is also related to the quality of the information available. Here, we test the following assumption: increasing stimulus area is not essential when recruited cells are already equalized on the basis of information quality that could be processed at each eccentricity. Two detection threshold experiments were run. (i) Sinusoidal gratings (size: 8 deg) were presented at 8 SFs ($0.125-5$ cycles deg^{-1}) and 6 eccentricities ($0^\circ-60^\circ$), showing an exponential increase in time threshold with increasing SF. (ii) SFs were chosen in order to equalize time threshold (as a magnifying factor) at each eccentricity. New time thresholds were measured for six sizes ($2^\circ-12^\circ$). Results did not show significant differences between 4 and 12 deg of size, suggesting that changes in the quality of the stimuli could be used as an amplifying factor at large eccentricities.

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◆ **Spatial integration of contours: Orientation counts when local elements are close**

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Integration of local elements into a global contour is a general property of the human visual system. A well-established property of this process is its dependence on orientation and distance between elements. Here, we present a systematic study of detection thresholds as a function of orientation, distance, and age of subjects (6 to 70 years), using a closed chain of Gabor patches (target) embedded in a background of randomly oriented and positioned Gabors. For all ages tested, we found a clear orientation dependence when patches were closely spaced, but thresholds do not depend on orientation when the distance increases to 4.5 deg. These results reinforce the hypothesis of two distinct mechanisms underlying contour integration (Ciamelli et al, 2007 *Experimental Brain Research* in press): a bottom-up, orientation-dependent, process operating only at short distances, and a top-down, orientation-independent, process active when local elements are too far apart and the task is more difficult.

◆ **The effect of glare on reaction times on peripheral vision**

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In previous works we have shown that the effect of glare on reaction times (RTs) in foveal vision depends on the spatial frequency of the stimulus. This is due to the selectivity of magno and parvocellular pathways with regard to spatial frequency. In this work we extend this study to peripheral vision, considering mesopic adaptation. We measured RTs of achromatic sinusoidal gratings (1, 2, 4, 8 cycles deg^{-1}) as a function of contrast for different eccentricities (0, 7, 14, 23 deg) and glare (0, 15, and 60 lux). For all situations RTs increase linearly when they are plotted versus the inverse of contrast. The slope of these lines increases with increasing glare for all eccentricities. For low spatial frequencies the slopes do not change for different eccentricities, which means that eccentricity does not modify the effect of glare on RT. However, for high spatial frequencies, the effect of glare is strengthened by eccentricity. These results are consistent with the evidence supporting the hypothesis that RTs and the contrast sensitivity function are driven by the same mechanisms.

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◆ **Perceived self-body tilt in dynamic visual stimuli**

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Perceived self-body orientation is affected by shearing force acting on the otoliths and the tactile receptors and by visual pattern falling on the retinae. We examined how the vestibular-tactile inputs produced by tilting the body interact with the visual inputs produced by seeing irregular pattern rotating in the frontal plane. While gazing at the pattern, each observer was tilted at various angles in roll and judged his or her body tilt verbally. The variables examined were body tilt, and velocity and direction of the visual pattern. We found that perceived body tilt for the CW rotating pattern was displaced CCW, whereas perceived body tilt for the CCW rotating pattern was displaced CW. We also found that the slope of the linear function fitted to the tilt judgments, in particular to body tilts over 50° , increased with the velocity of the visual pattern. It is suggested that shearing force is effective for small body tilts whilst visual pattern is effective for large body tilts.

◆ **The relation of carrier and envelope during perception of spatial-frequency modulation**

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Preattentive vision is thought to include two stages: the ability of the visual system to perceive modulation of spatial frequency (SF) is provided by spatial pooling of the first-order filters by means of the second-order filters. The aim of our research was to determine the possible relation of carrier frequency with optimal envelope frequency. We used a staggered texture composed of vertical Gabors ($2.3 \text{ cycles deg}^{-1}$). Their SF was sinusoidally modulated. Modulation frequencies were selected to form 5 patterns in which proportions of envelope and carrier were $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$. Then we determined detection thresholds of modulation of their textures by the method of constant stimuli. All observers demonstrated U-shaped dependence: the optimum falls at the ratio of $\frac{1}{16}$. The result was the same for both directions of modulation: parallels and transverse to Gabor orientation. We have computed and made sure that the experimental dependence is not defined by spectrum differences. Thus the optimal frequency of SF modulation is specified by the carrier.

◆ **Dissociating allocentric and egocentric frames of reference: A visual search study**

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The perception/action model proposes that vision for perception and vision for action are subserved by two separate cortical systems, the ventral and dorsal streams, respectively [Milner and Goodale, 1995/2006 *The Visual Brain in Action* (Oxford: Oxford University Press)]. The ventral stream codes spatial information relative to the external environment (allocentric coding) and can store this information, whereas the dorsal stream codes spatial information relative to the observer (egocentric coding) but cannot store the information. As the temporal characteristics of egocentric and allocentric processing are not fully understood, in this study we compared the spatial priming effect of target locations defined in either allocentric or egocentric coordinates. A differential effect of priming was observed: facilitation to repeated trials was significantly greater for allocentrically defined targets, compared to those defined egocentrically. These results demonstrate a dissociation

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between the influence of memory in allocentric and egocentric visual processing. Furthermore, they suggest that allocentric coding is a prerequisite for long-term representation.
[Supported by a Wolfson Research Institute Scholarship.]

◆ **Common features of different illusory patterns**

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

Three-spot horizontal stimuli were combined with different types of contextual objects: the Müller-Lyer wings, single vertical stripes, or spot pairs arranged vertically. The spatial parameters of the contextual objects were given values that made the end-points of the wings, stripes, and the flanking spots to have identical spatial coordinates, so that the different contextual objects turned into structural parts of the same imaginary triangles. The length of the diagonal sides of the triangles, and the magnitude of the internal angles between the sides were considered to be independent variables in measurements of length-matching errors. The experimental data showed a uniformity of the illusory processes caused by different contextual objects within a certain range of the length of the sides (0–8 min of arc). The internal-angle variations yielded coinciding curves for all the flanking objects when their sides were not longer than 8–10 min of arc. The results obtained indicate an essential contribution of the end-points of the line segments to the effect of the illusions of extent.

◆ **Influence of stimulus structure on the perception of straightness**

A Bielevičius, A Bertulis, A Bulatov (Department of Biology, Kaunas University of Medicine, Kaunas, Lithuania; e-mail: arubiel@vision.kmu.lt)

Subjects reported a bent axis of a horizontal stimulus consisting of three white dots when accompanying black spots were shown: one spot above or below the central dot, and the other two, below or above the end dots with the same black-to-white centre distances. The diameter of the spots was 2 min of arc; the luminance 75 cd m^{-2} and 0.5 cd m^{-2} , and the background luminance 11 cd m^{-2} or 22 cd m^{-2} . Variations of the black-to-white distance produced changes both in the strength and the sign of the perceived distortions. The central white spot appeared to be shifted from the stimulus axis in a direction implying repulsion between the contrasting spots when the distances between them were short (up to 2 min of arc) and the black spots were partly shielded by the white ones. At longer distances, the central spot appeared to be shifted in the opposite direction implying an attraction effect. The perceived distortion strength varied monotonically with the distance reaching repulsion and attraction maxima at 1.5–2 and 6–9 min of arc and approaching zero at 2–3 and 20–30 min of arc, respectively.

◆ **Surround suppression saturates, cross-orientation suppression does not**

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It is clear that masking from parallel surrounds (doughnuts) and superimposed orthogonal masks involves different processes, but detailed comparisons have not been made. We measured contrast-masking functions for target patches of grating (1.25 cycles, 1 cycle deg^{-1} , 100 ms) for both types of masking. In a foveal condition, there was little masking for the doughnut, but masking was an accelerating function of contrast for the crossed mask. In a second condition, stimuli were 4.5° into the periphery. Superimposed masking was similar to that in the fovea, but surround masking was a saturating function of mask contrast. These effects can be understood in the context of a two-stage model of gain control. Accelerating effects are achieved by suppression at stage 1 where the masking transducer is linear, and the target response becomes compressive a few percent above threshold. Surround effects are achieved by first passing the mask through its own compressive stage before impacting the target. Thus, surround masking involves higher-order processing than superimposed masking (Petrov et al, 2005 *Journal of Neuroscience* **25** 8704–8707).
[Supported by the EPSRC.]

◆ **Stevens's law and the 2-D geometry of curvature in experts and other observers**

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We investigated representations of 2-D curve geometry in individuals with varying perceptual experience. Sixteen individuals, eight of whom were professional users of mathematical tools for spatial free-form design (experts) participated as observers. 88 arcs with varying height-to-width ratio consisting of 22 halves of concentric circles and 66 halves of ellipses, geometrically derived from the concentric circles through planar projection by affinity, were presented in unique random sequences of single stimuli. Observers had to give a number between 0 and 10 that was to reflect the subjective magnitude of the curvedness of a given arc. Results show that Stevens's

law predicts internal representations of 2-D curvature as a function of the height-to-width ratio of the curves in seven of the experts and all the normal individuals. The findings suggest that 2-D curve representations are driven by a unique visual mechanism that is sensitive to the geometry of the visual area covered by the curve.

◆ **Visual performance derived from reaction times at low luminance levels: The effect of eccentricity**

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Low luminance and periphery are fundamental aspects in the study of vision in night driving. We investigated how reaction times (RTs) depend on eccentricity for a variety of spatial frequencies and contrasts, considering mesopic adaptation. If RTs are closely related to contrast sensitivity, we expect low and high spatial frequencies to produce different results. We measured RTs as a function of contrast for the detection of achromatic sinusoidal gratings of 1, 2, 4, and 8 cycles deg^{-1} displayed at 7, 14, and 23 deg of eccentricity besides the foveal condition. Results show that RT increases linearly when it is plotted against the reciprocal of contrast for all eccentricities and spatial frequencies. For 1 and 2 cycles deg^{-1} the slope of the lines does not depend on eccentricity but RTs at the periphery are all similar and higher than those obtained on the fovea. However, for 4 and 8 cycles deg^{-1} the slope increases monotonically with eccentricity showing that high spatial frequencies are processed differently at the periphery.

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◆ **Nonlinear pooling mechanisms underlying edge detection**

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We investigated pooling mechanisms underlying detection of luminance edges. Classification images for detection of a vertical edge were estimated over a range of noise contrasts. Estimated integration fields are well-approximated by 2-D Gaussian derivative filters. While the spatial-frequency tuning of these filters is roughly consistent with physiological data, the estimated filters are much longer than receptive fields found in early visual cortex. Are these long integration fields the result of nonlinear pooling over more localized mechanisms? We evaluated a pooling model in which local filter responses were half-wave rectified and combined by Minkowski summation. We found that the nonlinear pooling model is more predictive of the trial-by-trial human data than the standard linear template model. Maximum-likelihood estimates of model parameters indicate length tuning of the local mechanisms ranging from 0.6 to 2.3 deg (Gaussian space constant) with an optimal pooling exponent of roughly 2, consistent with an energy model of spatial integration.

[Supported by NSERC and PREA.]

◆ **Light-scattering effect on colour-pattern VEP response**

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To assess the effect of light scattering on colour pattern VEP (CP-VEP), the quality of stimuli was reduced with a light-scattering occluder. The results were compared with results of visual acuity and retinal stray-light measurements. In CP-VEP studies, white-black, red-black, green-black, and blue-black gratings were used. For visual acuity measurements, black Landolt optotypes on the coloured backgrounds were used. Retinal stray light was measured with a compensation comparison method (Van den Berg et al, 2005 *Investigative Ophthalmology & Visual Science* 46 ARVO 2005, abstract 4315). We found good correlation between CP-VEP and psychophysical visual-acuity test results. Our results show that reduction of the perception of stimuli with different colours due to light scattering is not related only with the presence of retinal stray-light effect in the eye, and physiological behaviour of spatially organized neural receptive fields should be taken into account.

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◆ **Effect of figure-ground segregation on blur adaptation**

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We investigated the effect of figure-ground segregation on blur adaptation. The adaptation stimulus was dynamic white noise blurred by a 2-D Gaussian filter. A circular region (2 deg in diameter) located 2 deg horizontally away from the fixation point was flipped with different

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timings from the surround region of the stimulus so as to segregate the figure-ground with an illusory contour. After 5 min of adaptation, Landolt visual acuities were measured both at the figure and ground regions. Although the spatiotemporal characteristics of the adaptation stimulus were homogeneous, the improvement of Landolt visual acuity was significantly larger in the figure than in the ground region. This result suggests that figure-ground segregation facilitates blur adaptation.

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◆ **Spatiotemporal classification images for detection of a broad-band signal**

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e-mail: jussi.saarinen@helsinki.fi)

We used the classification image (CI) method to investigate the spatiotemporal dynamics (sd) in detection of a Gaussian bump target (spatial sd 0.25 deg, temporal sd 10, 20, or 40 ms). Stimulus was masked by spatially one-dimensional, temporally varying white noise, lasting for 500 ms at 100 Hz. CIs for different stimulus-response categories (hit, miss, correct rejection, false alarm) were analysed separately. Linear analysis of target-present trials revealed a template resembling the target stimulus spatially but slightly elongated in time. However, target-absent CIs in shorter signal durations were almost flat. Next, we analyzed the local Fourier spectra of the CIs. Noise masks were windowed in space. FFT was then computed for each stimulus-response category. Analysis of false-alarm trials revealed a Fourier amplitude template tuned to target frequencies. Results show that both the spatial and temporal information for the stimulus are used efficiently across the duration. However, flat linear target-absent CIs imply that short-duration signals are detected in phase-insensitive manner.

◆ **Eye dominance under constrained and unconstrained sighting conditions**

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In traditional tests of eye dominance observers are asked to sight an object, with both eyes open, through a small hole in a piece of cardboard. Given the size of the hole, observers must align it with one or the other of their eyes to perform the task. The eye used to perform the task (ie the eye over which the hole is centered) is identified as the sighting, dominant eye. In the experiments reported here, we manipulated the constraint of having to use only one eye, by varying the size of the hole in the card. We found that with constrained hole sizes observers centered the hole over one of their 'real' eyes and with unconstrained hole sizes they centred the hole over their 'imaginary' cyclopean eye. The results are discussed in terms of the possible function of the sighting dominant eye.

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◆ **Visual suppression during dynamic accommodation**

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Accommodation is the process by which the eye changes its power in order to perceive sharp images at different viewing distances. As we do not see blur during this process, visual suppression seems to occur. In the present study we investigated this possibility by measuring contrast sensitivity during dynamic and static accommodation. Human subjects observed a screen which briefly showed sinusoidal gratings of low, intermediate, and higher spatial frequencies (SFs). An accommodation stimulus was presented between 1 m and 33 cm in front of the subject. Using a 2AFC technique, contrast thresholds for the different SFs were measured. Measurements were taken every 200 ms after initiation of an accommodative response, for the dynamic condition, and in five different distances for the static. We found that contrast sensitivity for higher SFs was reduced in all our subjects during dynamic accommodative responses compared with the static equivalent. Low and intermediate SFs did not show significant changes. We conclude that the visual system employs suppression during dynamic accommodation at higher spatial frequencies.

◆ **Higher-level processes in the second-order system**

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Second-order mechanisms respond to changes in texture or contrast that cannot be mediated by a linear mechanism, and are modeled as a set of linear-nonlinear-linear cascades, each tuned with respect to orientation and spatial frequency. We asked whether the output of second-order mechanisms was further subjected to nonlinearities and/or linear summing or differencing circuits, as are the outputs of first-order linear mechanisms. We isolated each potential stage of processing with masking and two-cue conditions while making fine discriminations based on small differences in the spatial frequency, orientation, and contrast of the second-order grating.

Vertical and horizontal second-order grating stimuli were created by contrast-modulating binary noise. Orthogonally oriented gratings served as masks or as a second cue to discrimination. Our results suggest that, for spatial frequency and contrast judgments, a gain-control pool including both orientations exists, followed by a summing circuit similar to first-order mechanisms. A very different result was found with orientation judgments.

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◆ **Is there a crowding effect with detection and coarse discrimination of simple features?**

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Levi et al (2002 *Journal of Vision* 2 167–177) and Pelli et al (2004 *Journal of Vision* 4 1136–1169) have reported no crowding effects with detection (and coarse discrimination) of simple visual features. The present study tests the generality of these findings. A target Gabor patch, surrounded by either two or six distractor Gabors, was presented briefly in the periphery of the visual field. Each Gabor patch was oriented either vertically or horizontally (selected randomly). Observer's task was either to detect the presence of the target (presented with probability 0.5), or to identify the orientation of the target. The target–distractor distance was varied. Results were similar for the two tasks, but different for two and six distractors. With two distractors, performance dropped only at the smallest target–distractor distance. With six distractors, a normal crowding effect was observed that vanishes at a target–distractor distance of about $0.5E$ (where E is eccentricity of the target). The idea that feature detection and coarse discrimination are immune to crowding seems to be valid for restricted conditions only.

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◆ **Fast high-capacity watermarking of MPEG-2 coded video**

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Video watermarking capacity is an evaluation of how much information can be hidden within a digital video. We wanted to achieve high capacity without significant loss of quality. We have chosen spatial-domain watermarking; frequency-domain methods are generally not fast enough for real-time processing, while compressed-domain methods have rather low watermarking capacity. One of our methods works in the YUV colour space, by inserting four times less information in the U and V channels than in the luminance channel. Watermark information is inserted redundantly in every 3–5 frames for improvement of watermark detection after MPEG-2 recoding. Watermarking bits are inserted by modifying the mean of 4×4 pixel blocks. For detection improvement we also used a cyclic or Reed–Solomon error-correcting code. For different 720×480 pixel PAL MPEG-2 video sequences with bit rate of 6548 kb s^{-1} we have achieved watermarking capacity of $645\text{--}865 \text{ kb s}^{-1}$ with perfect detection and mean PSNR of 34.67. After recoding the sequences at 3274 kb s^{-1} , we have obtained a mean detection rate of 99.48%.

◆ **When is foveal 'crowding' abnormal?**

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Clinical tests of visual acuity (VA) that employ multiple, neighbouring optotypes assume that visual 'crowding' at the fovea is negligible. Findings from recent studies suggest that crowding effects can affect high contrast acuity thresholds at the fovea. The absence of data to describe the distribution of crowding effects within 'normal' vision makes it difficult to establish when a measured reduction in VA (with crowding) can no longer be considered to be within the normal range and is therefore indicative of abnormal development or pathology. The aim of this study was to quantify the effects of crowding on VA in the normal population. We measured acuity thresholds, with and without crowding, in central vision (ie at the fovea and at 1° , 1.5° , and 2°) in eighty normal subjects with the age range of 29.3 ± 10.7 years. The statistical distribution of the differences between the two measures of VA shows significant crowding effects at the fovea that increase linearly with eccentricity and provides a useful template to identify those subjects that show abnormal sensitivity to crowding.

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◆ **Judgments of visual directions of targets pointed at in near space**

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We examined how accurately an observer can judge the direction of a target pointed at by an experimenter. We also determined the observer's implicit localization of the experimenter's reference center for visual direction. The experimenter and observer sat side by side at a table. 120 cm across was a stimulus (9 deg wide) that was horizontally flanked by two others, 50 cm on each side. The experimenter pointed at the center of one of the stimuli with his index finger and the observer reported which part of it was pointed at. Results from eight observers showed that the reported target location was 2.0° off to the side of the index finger from that pointed at. The reference center, taken as the mean position of the intersections of three lines each obtained by connecting the index finger and the reported target location, was located in front of the experimenter's nose. The results suggest that observers may have taken into account the experimenter's visual ego-center as the reference center for visual direction.

◆ **Dependence of pictorial depth structure on the observer vantage point**

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Geometrical analysis suggests that when observers move laterally with respect to a linear-perspective image, the 3-D spatial structure of the perceived scene should undergo lateral shear in opposite directions. Corresponding empirical findings range from strong transformations in accord with geometrical predictions to small or negligible effects. We report three experiments in which the same stimulus (a photograph of a car parked in a street) was used under different presentation conditions. In the first experiment the stimulus was presented as a large billboard in downtown Belgrade (with Google Earth used to establish observer locations relative to image), in the second as a poster hanged in a hall, and in the third as an image embedded within a computer-designed simulated scene of a hall. The perceived direction of the street and the car was assessed by different tasks in the three experiments. Consistent effects of the observer vantage point were obtained, somewhat variable in the first experiment but rather regular in the second and third, reasonably well predicted by geometrical analysis, but involving some systematic deviations.

◆ **What counts for crowding: A salience account**

A Tomassini, S Baldassi (Department of Psychology, University of Florence, Florence, Italy; e-mail: enfant0terrible@libero.it)

The detrimental influence of nearby flankers on visual discrimination is known as crowding. We probed crowding by using a visual enumeration task. Enumeration of small quantities (up to four items) is thought to rely on a process named subitizing. It requires the segmentation of every item to be enumerated, so it can be a probe task in the study of crowding. The experiment required subjects to report the numerosity of targets (45° oriented Gabors) presented among a variable number of distractors (horizontally oriented Gabors). Results show that crowding affects subitizing accuracy, confirming the need of correct segmentation. Moreover, the number of distractors had a striking effect on crowding: few distractors elicited a normal crowding effect while it was remarkably reduced by increasing the number of distractors. This result may be accounted for by a salience-based facilitation of the targets, probably occurring at earlier levels of visual processing (eg V1). However, inserting a black frame around the targets' quadrant abolished the numerosity effect, possibly because of some kind of competition between salient stimuli.

◆ **Perception of orientation with an oblique and upright frame in infancy**

A Tsuruhara, S Kanazawa[¶], M Yamaguchi (Department of Psychology, Chuo University, Hachioji, Japan; [¶] Shukutoku University, Chiba, Japan; e-mail: tsuruhara@isl.titech.ac.jp)

We investigated whether infant's perception of orientation could be affected by the orientation of the frame surrounding the pattern. Previous studies have shown that infants look longer at the principal orthogonals than at oblique patterns; that is, infants prefer vertical or horizontal patterns to oblique patterns. And in adults, the 'rod-and-frame effect', the effect of orientation of surrounding frame on the perception of internal stimulus orientation, has long been known. In this study the preference of infants aged 4–8 months for vertical and oblique patterns was examined by using preferential looking technique. An oblique or an upright square surrounded the patterns. The results showed that, with an upright frame, the preference for the vertical pattern, which was shown in previous studies, was reversed, and that, with an oblique frame, the preference disappeared. The externality effect was shown earlier to disappear in infants about 2 months old. Our results suggest that the orientation of the frame could affect the perception of stimulus orientation in infants.

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◆ **Bisection of visual size and stimulus dimensionality**

F Ventimiglia, W Gerbino, C Fantoni (Department of Psychology, University of Trieste, Trieste, Italy; e-mail: ventimig@psico.units.it)

Size is a basic attribute of visual experience. Bisection (ie assessing the perceived middle given two reference objects) provides evidence about stimulus properties relevant to visual size. Candidate measures for the perceived middle are the geometric mean, which is dimensionally invariant, and the arithmetic mean of either 1-D, 2-D, or 3-D extents. We ran three experiments to test whether the perceived middle depends on dimensionality (2-D vs 3-D objects), spatial proximity of reference objects, and their relative size. In experiments 1 and 2 observers classified a depicted disk as more similar in size to a small vs large disk. In experiment 3 other observers classified a real cube and judged whether it appeared more similar to a small vs large cube. The perceived middle was intermediate between the geometric mean and the arithmetic mean of the linear extent (radius for disks and side for cubes), irrespective of stimulus dimensionality and spatial proximity. Bisection data suggest that visual size is biased towards a 1-D representation of objects. [Supported by MIUR-PRIN 2005119851.]

◆ **Third-derivative filters predict edge locations in spatial vision**

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Edge detection is crucial in visual processing. Previous computational and psychophysical models have often used peaks in the gradient or zero-crossings in the 2nd derivative to signal edges. We tested these approaches using a stimulus that has no such features. Its luminance profile was a triangle wave, blurred by a rectangular function. Subjects marked the position and polarity of perceived edges. For all blur widths tested, observers marked edges at or near 3rd derivative maxima, even though these were not 1st derivative maxima or 2nd derivative zero-crossings, at any scale. These results are predicted by a new nonlinear model based on 3rd derivative filtering. As a critical test, we added a ramp of variable slope to the blurred triangle-wave luminance profile. The ramp has no effect on the (linear) 2nd or higher derivatives, but the nonlinear model predicts a shift from seeing two edges to seeing one edge as the ramp gradient increases. Results of two experiments confirmed such a shift, thus supporting the new model. [Supported by the Engineering and Physical Sciences Research Council.]

◆ **Non-Euclidean property of photographic space**

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Here, the geometrical properties of photographs were investigated with non-Euclidean triangles. In an open space, three small objects were presented. Object A was at A(0 m, 4 m), object B was at B(-7.5 m, 24.7 m), object C was at C(9.6 m, 30.3 m). The stimulus configuration was photographed. In an experimental room, the photograph was presented on the screen and it was observed at the distance of 109.6 cm from the screen. Ten subjects adjusted the locations of midpoints (D, E, and F) of BC, AC, and AB of the triangle ABC. Further, the subjects adjusted points X, Y so that $BX = EF$, $CY = EF$ on the side BC. If photographic space is hyperbolic, one would expect BX (or CY) on BC to be shorter than $BC/2$. The result showed that BX on BC tended to be shorter than $BC/2$. Hyperbolic property was found for the direction AD. Also, the shape of triangle ABC was hyperbolic.

◆ **Facilitation for the detection of luminance-defined and contrast-defined blobs**

S J Waugh (Department of Optometry and Ophthalmic Dispensing, Anglia Ruskin University, Cambridge, UK; e-mail: s.j.waugh@anglia.ac.uk)

The nature of lateral spatial interactions for luminance-defined and contrast-defined stimuli may give insight into underlying processes of spatial vision. Detection thresholds for luminance-defined and contrast-defined blobs in the presence of fixed modulation, laterally placed blobs (separations from the test blob of 0–6 deg) were measured for foveal vision. Blobs were constructed by adding or multiplying random-dot noise with a Gaussian ($SD = 0.25$ deg). A dip in threshold for both luminance-defined and contrast-defined test blobs occurred for separations of 1–1.5 deg, although whether this dip resulted in actual facilitation was dependent on the observer and the modulation depth of the flanking blobs. Psychometric functions were often flatter when the flanking blobs were at the facilitory separation, indicating a possible contribution through the reduction of spatial uncertainty. However, the effects of separation on test blob threshold sometimes followed a different pattern with differently defined flanking blobs. The dependence of the threshold dip, or facilitation, on flanker modulation depth and on flanker type suggests a significant neural contribution. [Supported by Anglia Ruskin University Research Capacity Fund.]

Tuesday

TEXTURE◆ **Temporal stimuli and texture segmentation.**

S Fomins, M Ozolinsh, G Ikaunieks (University of Latvia, Riga, Latvia;
e-mail: sergejs.fomins@gmail.com)

Lateral interactions between the V1 subunits, mediate the response of cells in V1 and lead to the process known as contextual modulation. Recent data show that not only V1 is engaged in the segregation, but also higher cortical areas. The temporal stimuli were used to obtain the reaction times. Stimuli consisted of the four textures imposed on the monotonous horizontally oriented texture background. The square texture stimuli comprised of the diagonally oriented bars were to be recognized from the other vertically oriented. The center of the stimuli was filled with similar-orientation, empty, vertical, and opposite orientation textures. Stimulus exposure times ranged from 0.01 to 0.15 s. The results show only a slight increase in the RT for empty center stimuli over same-orientation center and vertically filled stimuli. The exposure times for the orthogonal center-orientation stimuli were not sufficiently long to fulfill the task and could be viewed as serially processed. Visual attention was obligatory for these stimuli to be recognized. [Supported by a Latvian State Scholarship.]

◆ **Mask interrupts texture segregation but not grouping processes**

A Grieco, G Campana, C Casco, S Roncato (Department of General Psychology,
University of Padua, Padua, Italy; e-mail: alba.grieco@unipd.it)

Although texture segregation models confine border extraction to high-level processes, recent findings suggest the involvement of low-level mechanisms (Grieco et al, 2006 *Vision Research* **46** 3526–3536). To investigate whether texture segregation is restricted to early-filtering mechanisms, or whether they involve later-levels of analysis, we measured how a backward-masking stimulus, known to interrupt re-entrant signals from high-level areas (Lamme et al, 2002 *Journal of Cognitive Neuroscience* **14** 1044–1053), affects subject's accuracy in target-present (requiring texture segmentation) and target-absent (requiring distractors grouping) trials in a detection task, after a learning session without backward-masking. Here, we show that, although learning effects in texture segregation were specific to contrast polarity, indicating low-level filtering mechanisms, the improvements were abolished by a backward-mask presentation, suggesting the involvement of re-entrant signals from high-level areas. Instead, learning of distractor grouping was not specific to contrast polarity, nor was it affected by backward masking, indicating a high-level learning process. This finding raises an important challenge that must be faced in understanding the mechanisms underlying texture segregation and grouping by similarity. [Supported by Grant (PRIN 2003) to SR.]

◆ **Within-object and between-object performance in a texture-orientation discrimination task**

S J Hawley, F Jacob (Department of Psychology, Rutgers University, RUCCS, Piscataway,
USA; e-mail: shawley@ruccs.rutgers.edu)

We evaluated the existence of within-object benefit for sensitivity to an intrinsic object property, rather than the more typical detection of superimposed features or parts. Our objects were composed of line-element textures. Subjects made a same–different orientation judgment about two areas of texture, belonging either to the same object or to different objects. We found no difference in texture-orientation sensitivity (d') between within-object and between-object conditions, but observed intriguing patterns in subjects' responses. Subjects were more likely to judge orientations belonging to different objects as same, and vice versa, suggestive of a response bias. Interestingly, subjects showed greater sensitivity to orientation differences that deviated from parallel or perpendicular to the main object axis, compared to 30° or 60° textures. This may be related to texture-orientation regularities in natural objects. Our results provide a different perspective to the standard view of within-object benefit, both in terms of the type of object property investigated and in the pattern of responses revealed. [Supported by NIH R01 EY15888.]

◆ **Consistent intra-individual aesthetic judgment of textures**

R H A H Jacobs, F W Cornelissen (Department of Ophthalmology, University Medical
Center [UMC] Groningen, Groningen, The Netherlands;
e-mail: richardjacobs01@hotmail.com)

As a first step towards elucidating the mechanisms underlying human emotional and aesthetic responses to textures, we examined the consistency of pleasantness ratings to a diverse set of visual textures. To this end, subjects rated the aesthetic pleasantness of a set of textures twice. Textures were presented one by one on a computer screen. While inter-subject correlations were low, reasonable intra-subject correlations were obtained. In a third run, subjects rated a set of textures selected on the basis of the individual ratings made in the second run. This time,

we obtained very high intra-subject correlations, indicating that subjects consistently express an aesthetic preference for at least some textures.

[Supported by the European Commission within the project “Syntex”]

◆ **Cue combination in texture-figure perception**

G Meinhardt, M Persike (Department of Psychology, Johannes Gutenberg University Mainz, Mainz, Germany; e-mail: meinhard@uni-mainz.de)

Subjects detected and identified texture figures in fields of compound Gabor micropatterns with greatly spaced spatial-frequency components. Targets were defined by feature contrast in the high-frequency component, the low-frequency component, or both components, by manipulating spatial frequency and orientation. Surprisingly, target detection and identification was best when the two greatly spaced spatial-frequency components differed from the surround in the same feature. The smallest benefit compared to single-feature targets was observed for variation of the same grating component in both features. Statistical testing verified that the observed order of visibility among feature combinations as well as the magnitude of the summation effects cannot be explained by probability summation across feature dimensions. The results are discussed in terms of joint coding models (Rubenstein and Sagi, 1990 *Journal of the Optical Society of America A* 7 1632–1643) and early channeling—later fusion-processing schemes, as proposed by A Treisman.

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◆ **Interactions between colour and luminance in the processing of visual textures modulated in orientation, contrast, spatial frequency, and disparity**

P M Pearson (Department of Psychology, University of Winnipeg, Winnipeg, Canada; e-mail: p.pearson@uwinnipeg.ca)

Independence of colour and luminance in visual texture processing was assessed with orientation-, contrast-, spatial-frequency-, and disparity-modulated visual textures. Test and mask patterns were textures comprising 1000 Gabors. Characteristics of the Gabors varied sinusoidally across the display and the observer’s task was to identify the interval which contained the greatest amplitude of modulation. Test patterns were superimposed on a mask in which the texture modulation was independently manipulated and thresholds for the detection of modulation in the test textures were measured as a function of the modulation of the mask. Thresholds were measured in four conditions: isochromatic test on isochromatic masks; isoluminant tests on isoluminant masks; isochromatic tests on isoluminant masks; and isoluminant tests on isochromatic masks. Whereas subthreshold summation was evident for orientation- and disparity-modulated textures, such was not the case for contrast- or spatial-frequency-modulated textures. These results are consistent with differential mechanisms underlying the processing of orientation- and disparity-modulated textures and the processing of contrast-, or spatial-frequency-modulated textures.

[Supported by an NSERC grant to PMP]

◆ **Spatial pooling of low-order and high-order image statistics**

J D Victor, M M Conte (Department of Neurology and Neuroscience, Weill Medical College, Cornell University, New York, USA; e-mail: jd victo@med.cornell.edu)

Neural computations underlying texture segregation are generally considered to consist of two stages: an initial array of subunits that extract local image features, and a second stage at which subunit signals are pooled and compared. Previously, we showed that this framework provides an adequate account of texture discrimination for first-, second-, and fourth-order (isodipole) image statistics. Differences in psychophysical thresholds for these statistics were due primarily to differences in the efficiency of the subunit stage, not spatial pooling. Here, we analyze the characteristics of spatial pooling in more detail. Stimuli consisted of alternating stripes of binary textures, defined either by first-order (luminance) or fourth-order (isodipole) statistics. Check size and strip size were varied over a four-octave range. To a crude approximation, psychophysical performance depended on the number of checks per strip, but this scaling behavior breaks down differently for first- and fourth-order statistics. Additionally, studies based on ‘missing-fundamental’ modulation of image statistics showed that edge enhancement is stronger for first-order statistics than for fourth-order statistics.

[Supported by NIH NEI EY7977.]

VISUAL AWARENESS

◆ **Temporal characteristics of history-dependence in ambiguous-figure perception**

J W Brascamp, T Knapen, N Stolk, R van Ee, A van den Berg (University of Utrecht, Utrecht, The Netherlands; e-mail: j.w.brascamp@bio.uu.nl)

When an ambiguous stimulus reappears, a percept that dominated recently has an enhanced probability of gaining dominance first. This was formerly believed to involve only a ‘lag one’

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facilitatory influence of the most recent percept on the next, but we have recently demonstrated an influence of perception beyond the latest percept. Here, we studied how the influence of prior perception decays over time. We presented an ambiguous stimulus intermittently (binocular rivalry or ambiguous rotating sphere) until one percept dominated on a preset number of consecutive presentations. Then, following a pause of preset duration, we resumed intermittent presentation and asked if the dominant percept equalled the one before the pause. During the pause subjects received visual stimulation or viewed a blank screen. We found that the influence of past perception decayed most slowly without visual stimulation. Moreover, decay was faster for a percept that dominated briefly than for one that dominated on many presentations.

◆ **Unique up-shifted decision criteria in attentional blink and repetition blindness**

F Caetta, A Gorea (Laboratoire Psychologie de la Perception [LPP], Paris Descartes University – CNRS, Paris, France; e-mail: f.caetta@gmail.com)

Caetta et al [2007 *Journal of Vision* 7(7) 1–12] have shown that, in addition to a drop of sensitivity (d'), motion induced blindness is also characterized by an almost equivalent increase of decision criterion (c). Here we show that attentional blink (AB) and repetition blindness (RB) display the same $d' - c$ negative correlation. AB and RB paradigms were used to assess d' and c for the detection (presence/absence) of a target letter as a function of its temporal lag relative to the presentation of another (AB) or the same (RB) letter whose detection was close to perfect. Target d' followed the classical U-shaped (AB) and monotonically increasing (RB) functions of temporal lag with a maximum d' drop of about 1.1. The main observation is that subjects use a unique absolute criterion well above the optimal criterion (about 0.54 sigma units). Our data confirm that at least some unawareness phenomena are caused/accompanied by decisional changes possibly related to attentional modulations [“Decision and attention”, in *Neurobiology of Attention* Eds L Itti, G Rees, J K Tsotsos (London: Academic Press/Elsevier) pp 152 – 159]

◆ **Evidence against an active filling-in process through the blind spot**

P Cardoso-Leite, A Gorea (Laboratoire Psychologie de la Perception [LPP], Paris Descartes University – CNRS, Paris, France; e-mail: pdrcardoso@gmail.com)

Whether our lack of awareness of our blind spot (BS) is due to an active filling-in (AFI) process or to the mere absence of its internal representation has been debated for decades. Here, we bring evidence in favour of the latter. Increasing a stimulus area proportionally increases its brightness and decreases the response time (RT) to the onset of this surface. If phenomenal completion of a surface through the BS is due to an AFI, then its brightness should increase and RT should decrease when the surface expansion occurs within the BS. Instead, brightness-matching and RT measurements show that as soon as the surface protrudes into the BS (and yields phenomenal completion), its brightness stops increasing and RT stops decreasing. Hence, both subjective and objective assessments indicate that completion through the BS is not sustained by any increment of the underlying internal activity at least up to the locus of spatial integration. As AFI is supposed to occur at the V1 level, the present results disqualify the AFI hypothesis.

[Supported by a grant from Agence Nationale de la Recherche (ANR-06-Neuro-042-01) to AG.]

◆ **Motion-induced blindness in seeing a movie of driving scenes**

K Inoue, T Kikuchi (Institute of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Japan; e-mail: inoue421@human.tsukuba.ac.jp)

Salient static stimuli disappear and reappear alternately for several seconds when they are surrounded by moving stimuli (motion-induced blindness, MIB). We examined whether MIB occurs in seeing a movie of driving scenes, which was taken in a car running on an express way. The movie or a frame (picture) in the movie was presented with a red small disk. Observers reported disappearance and reappearance of the disk with a mouse over a period of 30 s and a cumulative time of disappearance was measured. The cumulative time of disappearance in the movie condition was twice as long as that in the picture condition, suggesting that MIB occurs in seeing the movie of driving scenes. In experiment 2, observers saw the movie with eye movements, resulting in the reduction of the cumulative disappearance time. In conclusion, MIB could be a cause of misses in driving and the misses might be prevented by eye movements.

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◆ **Negative compatibility effect can be evoked by non-masking flankers**

P Jaskowski, M Tomanek (Department of Cognitive Psychology, University of Finance and Management, Warsaw, Poland; e-mail: jaskowski@vizja.pl)

Visual targets that follow a prime stimulus and a mask can be identified faster when they are incompatible rather than compatible with the prime (negative compatibility effect—NCE). According to the self-inhibition hypothesis, the initial activation of the motor response is elicited by the

prime based on its identity. This activation leads to benefits for compatible trials and to costs for incompatible trials. This motor activation is followed by an inhibition phase, leading to NCE if perceptual evidence of the prime is immediately removed by the mask. The object-updating hypothesis enhances the role of mask relevancy (ie whether the mask possesses features searched for by the participants). We show that NCE may appear even if non-masking neutral flankers are presented instead of masks. Moreover, although with relevant flankers NCE is larger, NCE occurs with irrelevant flankers provided it is as short as 8 ms. Therefore, masks/flankers can evoke an inhibition phase independently of whether it removes evidence for the prime and of their relevancy. [Supported by a Grant H01F 090 30 from Polish Committee for Scientific Research.]

◆ **Motion-aftereffect-induced blindness**

M Lages, W Adams ¶, E Graf ¶ (Department of Psychology, University of Glasgow, Glasgow, Scotland, UK; ¶ University of Southampton, Southampton, UK; e-mail: m.lages@psy.gla.ac.uk)

Motion-induced blindness describes the occasional disappearance of salient visual objects in the presence of moving features (Bonneh et al, 2001, *Nature* **411** 798–801). It has been suggested that surface completion and depth ordering modulate this phenomenon (Graf et al, 2002 *Vision Research* **42** 2731–2735). Here, we tested whether motion adaptation and the ensuing motion aftereffect (MAE) is sufficient to trigger disappearance. In two experiments observers adapted to a static/rotating spiral or disc displayed at high contrast in a split-screen Wheatstone configuration for 30 s. Immediately afterwards a stationary test pattern was presented for 30 s with three salient target dots in a triangular arrangement. Observers reported dot disappearance and reappearance by pressing and releasing labeled keys. Motion adaptation (static, cw, and ccw rotation) and relative disparity of target dots (–4 cm, 0 cm, and +4 cm) were systematically varied. The results clearly suggest that the MAE facilitates dot disappearance of salient targets. In addition, we found that target depth relative to the MAE systematically modulates disappearance.

◆ **Subliminal priming effect in patients with Parkinson's disease (PD)**

M Michalak, P Jaskowski ¶, E J Gorzelanczyk (Institute of Psychology, Kazimierz Wielki University, Bydgoszcz, Poland; ¶ University of Finance and Management, Warsaw, Poland; e-mail: michalak@ukw.edu.pl)

We presented the double arrow (\ll or \gg) as a prime, followed by a mask composed of random lines; the target consisted of arrows identical to the prime stimuli. Primes and masks were presented left and right from fixation with the target at fixation. Three prime-target intervals (ISIs) were used: 80 ms, 160 ms, and 240 ms. Participants had to make speeded responses with their left or right hand depending on the side the arrows in target stimulus pointed to. Three groups were tested: PD patients ($N = 12$); age-matched controls ($N = 12$); and young controls ($N = 12$). Negative compatibility effect (NCE) was found for all ISIs in the young control group. In the other two groups we found a positive priming effect for short intervals which turned into NCE at ISI = 160 ms for the age-matched control group and at ISI = 240 ms for the PD patients. This finding suggests that the negative priming phase occurs later in PD patients than in normals. We hypothesize that this is because of the patients' perceptual problems.

◆ **Perceptual learning can reverse subliminal priming effects**

A Przekoracka-Krawczyk, P Jaskowski ¶ (Faculty of Physics, University of Adam Mickiewicz, Poznań, Poland; ¶ University of Finance and Management, Warsaw, Poland; e-mail: aniaprzek@o2.pl)

Choice reaction times to visual stimuli may be affected by subliminal primes. Responses are faster when prime and target are identical (congruent trials) than when they point to different responses (incongruent). This phenomenon is called positive compatibility effect (PCE). However, under some conditions, the benefits in congruent trials change into congruent costs (negative compatibility effect—NCE). We show that the presentation of a mask plays a crucial role in this reversal. We demonstrate that stable NCE occurs when the test block is preceded by a training block where the masks and targets are displayed while PCE occurs if only targets are presented in the training block. This suggests that perceptual learning improves the recognition of searched-for features in the mask. Once recognized, these features could trigger the preparation of the alternative response. This suggestion is supported by further experiments, where we show that NCE occurs later provided the mask pattern is very complex. Furthermore, prolongation of the mask-target interval leads to NCE also with the complex mask.

Tuesday

◆ **The cost of visual feature binding**

K J Seymour, J McDonald, C Clifford (Department of Psychology, University of Sydney, Sydney, Australia; e-mail: kileys@psych.usyd.edu.au)

The binding problem: if modularity underlies processing of different visual attributes, how does a unified percept arise? We examined processing costs related to binding colour or contrast polarity with global motion or global form. We quantified these costs to allow meaningful comparisons between different attributes. We employed a 2IFC conjoint detection and binding task. Consider the motion–colour scenario. In each interval, 50% of dots were red and 50% green. In one interval, dots of one colour moved leftwards while the other dots moved randomly. In the other interval, all dots moved randomly. Subjects judged which interval contained the translational motion (detection) and which colour these dots were (binding). Performance was measured as a function of three threshold variables: duration, contrast, and coherence. Significant differences in detection and binding performance were observed in all conditions. For all threshold variables, the binding cost was greater for global form than for global motion. These results demonstrate a consistent processing cost to visual feature binding whose magnitude depends upon the features' being bound.

[Funded by the Australian Research Council.]

◆ **Neural correlates of changes in visual perception**

F Taya, T Sekine¶, T Tanabe¶, K Mogi (Fundamental Laboratories, Sony Computer Science Laboratories, Inc., Shinagawa-ku, Japan; ¶Tokyo Institute of Technology, Midori-ku, Japan; e-mail: taya@csl.sony.co.jp)

In the comparison of two images separated either spatially or temporarily, in principle only differences can be perceived. It cannot be known whether the images are the same. Change blindness, where subjects experience difficulties in finding a difference between two images presented sequentially and separated by blanks, has been studied in the context of visual short-term memory (vSTM). It is interesting to consider changes in perception after knowing the difference in the images, as dramatic changes in visual awareness accompany the change detection. Here, we studied changes in visual awareness during the search for differences between two visual images. We recorded the brain activities using electroencephalography (EEG) and compared activities elicited when subjects are unaware of differences with the activities invoked when the subjects are aware of the differences. By using temporal signatures tagged by the stimuli, we found that activities in frontal regions were correlated with the state of subjective perception. On the basis of these results, we discuss the changes of brain states induced by those in visual awareness.

◆ **Video quality evaluation with a metric based on perceptually significant areas**

M R Udrea, C C Oprea, D N Vizireanu, I Pirnog (Department of Telecommunications, Politehnica University of Bucharest, Bucharest, Romania; e-mail: mihnea@comm.pub.ro)

In subjective video quality evaluation, an important role is played by human visual system characteristics, but also significant parts correspond to the human attention system (which tells the eye where to look) and to the memory system (which guides the eye to areas of the same type previously discovered as presenting distortions). The quality metric proposed in this work first estimates the perceptually important areas using the key elements that attract the attention: motion, contrast, colour. For these areas a distortion measure is then computed and significant results temporarily stored. The information reached at this point, regarding the area type and its distortion measure, is used in the assessment of subsequent frames, simulating the memory behaviour, and also is renewed for each new frame evaluated. We propose an embedded reference-free video quality metric and show that its performance is much better than the standard PSNR in evaluating the perceived video quality. The results are also shown to correlate with the subjective results obtained for several test sequences.

◆ **Backward (retroactive) priming of a prime trace acquired with and without awareness, by subsequent target stimuli**

A N Sokolov, P Guardini¶, M Pavlova§ (ZNL Center for Neuroscience and Learning & Department of Psychiatry, Ulm University Medical School, Ulm, Germany; ¶University of Padua, Padua, Italy; §Children's Hospital, University of Tübingen Medical School, Tübingen, Germany; e-mail: alexander.sokolov@uni-ulm.de)

Visual priming is commonly viewed as enhanced or impaired subsequent target processing by a preceding prime stimulus. Here, we ask how, if at all, subsequent targets modulate memory-trace processing of preceding primes (ie backward priming) accomplished with and without awareness. On a trial, participants saw a prime, a mask, and a target in succession, pressing a respective key to report the identity of the prime (a square with or without gaps in its outline that was

either congruent or incongruent with the target). In experiments 1 and 2, prime identification was either above or at chance level, respectively. With prime awareness (experiment 1), target–prime congruency yielded reduced response times, while without prime awareness (experiment 2), reduced error rates were obtained for the congruent primes. The results show for the first time the existence of backward, retroactive priming of a prime trace by subsequent target stimuli. Moreover, the findings suggest an awareness-dependent dissociation of backward priming: backward priming engages either response processing or solely sensory representations with discriminable and indiscriminable prime identity, respectively.

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VISUAL LEARNING AND MEMORY

◆ **High-fidelity short-term memory for changeable but not for invariant facial attributes**

É Bankó, Z Vidnyánszky (Faculty of Information Technology, Peter Pazmany Catholic University, Budapest, Hungary; e-mail: banko.eva@itk.ppke.hu)

Processing of invariant and changeable facial attributes takes place, to a large extent independently, in different visual pathways. However, the way in which coding in these two processing routes differs is still an unresolved question. Here, we investigated how efficiently can humans compare facial emotions and identity as a function of the delay between the presentation of the two faces. We found that separating the stimuli by several seconds impairs observers' ability to discriminate their identity but not their emotional expressions. We also show that emotion discrimination is just as good at the beginning with novel face stimuli as it is after several hours of practice, whereas fine-grained facial-identity discrimination needs practice. By revealing high-fidelity visual short-term memory for facial emotions but not for facial identity, these results provide evidence for a functional dissociation in the processing of changeable and invariant facial attributes. Our findings also imply that face processing has adapted to the statistics of the visual input associated with the different facial attributes.

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◆ **Better visual short-term-memory retrieval for opposite-gender names**

S Borji, A Borji ¶ (School of Dentistry, Kerman University of Medical Sciences, Kerman, Iran; ¶ Institute for Studies in Theoretical Physics and Mathematics, Tehran, Iran; e-mail: shima.borji@yahoo.com)

It has been proposed that the salience of visual cues modulates the capacity limit of visual working memory (Fougnie et al, 2006 *Psychological Science* 17 526–534). Our aim here was to examine the hypothesis that gender could affect the retrieval of visual working memory for human names. On each trial, a sample array consisting of 6 or 8 names was presented for 500 ms (half from each gender). This was followed by a 900 ms blank interval and then 2000 ms presentation of test array consisting of two names. Observers were asked to select the name presented in the sample array. To choose names, in a control task we selected names for which subjects have same performance over names from the same gender. Six subjects participated in our task (three males and three females). All subjects showed significantly higher performance for recalling names from opposite gender compared with names from the same gender. Current study shows that gender is important when remembering names in a visual-working-memory task.

◆ **Human observers use personal exploration patterns in novel object recognition**

L L Chuang, Q C Vuong ¶, I M Thornton §, H H Bühlhoff (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; ¶ University of Newcastle, Newcastle, UK; § University of Wales Swansea, Swansea, Wales, UK; e-mail: lewis.chuang@tuebingen.mpg.de)

Humans learn and recognize objects through active exploration. Sixteen participants freely explored 3-D amoeboid objects in a virtual-reality environment during learning. They handled a device whose spatial coordinates determined the object's position relative to its viewpoint. These exploration patterns were also recorded for testing. In a subsequent old/new recognition test, participants either actively explored or passively viewed old (learned) and new objects in the same setup. Generally, active participants performed better than passive participants (in terms of sensitivity: $d' = 1.08$ vs 0.84 , respectively). Despite this, those participants who passively viewed objects animated with their personal motion trajectories for learned objects maintained comparable performance to that of participants who actively explored the objects ($d' = 1.13$). In contrast, passive observers' performance decreased when these trajectories were temporally reversed ($d' = 0.69$) or when another observer's motion trajectories were used ($d' = 0.70$). While active exploration generally allowed better recognition of objects compared to passive viewing, our observers could rely on idiosyncratic exploration patterns—in which particular aspects of object structure were revealed over time—to achieve equivalent performance.

Tuesday

◆ **The hemispheric specialization of monkey's prefrontal cortex in visual-recognition learning: Differences in spatial and non-spatial information processing**

K N Dudkin, I Chueva, F Makarov (Pavlov Institute of Physiology, Russian Academy of Sciences, St Petersburg, Russia; e-mail: cognition@pavlov.infran.ru)

Our aim was to find mechanisms of hemispheric specialization of the prefrontal cortex for invariant visual recognition. We investigated visual-discrimination learning processes on three groups of rhesus monkeys: control, and after removal of the left and the right prefrontal cortices sulcus principalis. Stimuli involved geometrical figures of various shape, size, and orientation (non-spatial information), and spatial-relationship information. As compared with control monkeys, after removal of the left and right prefrontal cortices, learning processes became unstable for discrimination of all stimuli, and as a result the training periods were significantly lengthened, especially for spatial information. The transformation of stimuli with non-spatial information did not influence correct decisions (the invariance of discrimination) for all monkeys. However, the invariance for spatial-information discrimination after transformation of spatial relationships was achieved only in monkeys after removal of the right prefrontal cortex. These results indicate that the left (but not right) prefrontal cortex takes part in invariant visual recognition by providing spatial information processing. Other cortical areas provide the invariance of non-spatial information recognition.

◆ **Influence of sleep on face recognition and associated activity in right hippocampus and fusiform cortex**

S Duhoux, F Andersson, P Vuilleumier, S Schwartz (Department of Neuroscience, University of Geneva, Geneva, Switzerland; e-mail: stephanie.duhoux@medecine.unige.ch)

Learning new faces is a common, efficient, and socially important ability. Recent research suggests a role of sleep in memory consolidation. However, little is known about how sleep affects memory for faces. We hypothesised that sleep after exposure to new faces improves face-recognition performance and modulates activity in face-responsive areas. We conducted an fMRI experiment in which subjects learned a set of faces and were then tested in an old/new recognition task 12 h later with or without intervening sleep (two groups). In the recognition task, configural/featural information was manipulated by means of chimeric versions of previously learned faces. Preliminary results show higher recognition accuracy for subjects who slept between learning and testing sessions. This effect was associated with increased activity in right hippocampus and right medial fusiform gyrus selectively for old faces (same features, same configuration) compared to distractors (same features, different configuration) and new faces. These results suggest that sleep might strengthen hippocampal-fusiform interactions underlying the recognition of newly learned face identities.

[Supported by the Swiss National Science Foundation (3100A0-102133).]

◆ **Electrophysiological correlates of perceptual learning in contour integration**

P Gerván, M Zimmer, G Kovács, I Kovács (Department of Cognitive Science, Budapest University of Technology and Economics, Budapest, Hungary; e-mail: pgervan@cogsci.bme.hu)

An event-related potential (ERP) study was conducted to investigate the neural correlates of perceptual learning in a contour integration (CI) paradigm. In the CI task observers had to determine the direction where an egg shape was pointing to at six various levels of difficulty. The contour was composed of Gabor patches embedded in a background of randomly positioned and oriented Gabors. Eleven subjects practiced in the contour integration task over five days. We obtained ERPs on the first, third, and fifth days. On the basis of measurements of learning effects at the CI task we identified a learner group ($N = 5$) whose performance developed at least one level during the five days and a non-learner group ($N = 5$) whose performance did not improve significantly. We focused on the effect of perceptual learning on the early occipital negative component (N1; $\sim 100 - 120$ ms). We observed significant differences in N1 amplitude between the first and fifth day. In a further analysis, we also investigated the N1 amplitude differences between the learner group and the non-learner group.

[Supported by OTKA NF60806 to IK.]

◆ **Task-irrelevant temporal order and learning of arbitrary visuo-motor associations**

O Hamid, J Braun (Department of Cognitive Biology, Otto von Guericke University, Magdeburg, Germany; e-mail: hamid@nat.uni-magdeburg.de)

We are interested in incidental learning of task-irrelevant context and its possible contribution to cognitive flexibility. In primates trained to identify complex visual objects (eg delayed-match-to-sample tasks) inferotemporal neurons show selectivity for (task-irrelevant) temporal object order (Miyashita, 1988 *Nature* **335** 817–820). We developed a paradigm to study task-irrelevant

temporal order effects with human observers. Eight individuals viewed highly distinguishable, fractal objects and learned (by trial and error) to react with one of four motor responses. One response was rewarded for each object. Certain objects were consistently preceded by other objects (“prophets”), others lacked this temporal context. Otherwise, all objects shared the same frequency and repetition probability. The rate of association learning was significantly higher for objects embedded in a consistent temporal context, demonstrating that task-irrelevant sequence information is also learned by human observers. How learning is accelerated (what additional resources are allocated) remains unclear. A statistically optimal decision model fails to predict accelerated learning for objects with a consistent temporal context.

◆ **The strategies of coding in spatial memory**

V A Lyakhovetskii, E Bobrova ¶ (Department of Biomedical Engineering, St Petersburg Electrotechnical University, St Petersburg, Russia; ¶ Pavlov Institute of Physiology, Russian Academy of Sciences, St Petersburg, Russia; e-mail: seva@decosp.spb.ru)

Among the most fundamental questions of spatial-memory research is what object features are coded. Previously it was shown that chess positions are coded in relative (the move length and its direction) or in absolute (numbers of the squares) coordinates depending on the type of transition by the piece (Lyakhovetskii et al, 2006 *Perception* 35 Supplement, 105). Using a similar paradigm, we studied the recall of hand movements. The blindfolded volunteer had to remember and immediately reproduce by pen the sequence of 7 hand positions on a sheet of A4 paper. Each of forty-seven right-handed volunteers completed one run with the right hand and one run with the left hand. The developed neural network, by means of different coding schemes, reproduced the percentage and the pattern of errors for both experiments. It was concluded that (a) relative coding is used for memorizing right-hand movements but a mixture of relative and absolute coding is used for memorizing left-hand movements; (b) irrespective of modality (tactile or visual) common principles of spatial coding exist.

[Supported by RFBR grants #06-04-49488 and #06-06-80152.]

◆ **Role of geometrical and numerical information when locating the central element in sets of identical and aligned elements**

T Mattarello, E Cenghialta, L Regolin (Department of General Psychology, University of Padua, Padua, Italy; e-mail: taniam84@libero.it)

Domestic chicks display excellent visuo-spatial and cognitive abilities. For example, they can be successfully trained to discriminate the centre in a set made of identical horizontally aligned beads. In previous research such a task has been employed to investigate chicks’ behavioural asymmetries when responding to lines made of identically spaced objects (Regolin, 2006 *Cortex* 42 101–103). Chicks selectively pecked in the centre, although it remained unclear on which kind of cue (numerical or geometrical) they relied to locate the central object. The present work employed four asymmetrical stimuli constructed so as to put into conflict numerical and geometrical information (lines of nine beads in which the fifth bead was not in the geometrical centre of the line). Birds relied on either numerical or geometrical cues, depending on inter-bead spacings and, possibly, on perceptual groupings.

◆ **Temporal characteristics of visual one-shot learning**

K Mogi, Y Tamori ¶ (Fundamental Research Laboratory, Sony Computer Science Laboratories, Shinagawa-ku, Japan; ¶ Kanazawa Institute of Technology, Matto, Japan; e-mail: kenmogi@qualia-manifesto.com)

Good hidden figures, eg the Dalmatian [Gregory, 1970 *The Intelligent Eye* (London: Weidenfeld and Nicolson)], are characterized by a marked contrast between the unperceiving and perceiving states, the transition being accompanied by a sense of “aha!”. As hidden figures can be used only once per subject, a method of systematic production is useful. The results of mechanical filtering of images are usually either too obvious or difficult to perceive, and do not result in a dramatic phenomenal change accompanying the one-shot learning. Here, we present a large number of good hidden figures produced by a combination of computer processing and manual retouching. We state the heuristic rules employed in retouching. Using these stimuli, we conducted a series of mega-lab experiments revealing the nature of one-shot learning on the longer time scale. The distribution of the occurrence of one-shot learning reveals an underlying random cognitive process, in contrast to conventional visual recognition completed within a characteristic time. Our finding puts significant constraints on the neural mechanisms involved in human insight as exemplified in one-shot learning.

Tuesday

◆ **Mental kinetics in visual memory**

J Ninio (Laboratoire de Physique Statistique, École Normale Supérieure, Paris, France; e-mail: jacques.ninio@lps.ens.fr)

Over 50 reaction-time (RT) distributions were generated from a set of 500 000 RTs measured in published (eg Ninio, 2004 *Acta Psychologica* **116** 263–283) or unpublished studies on visual memory. Most distributions for single subjects and restricted experimental conditions clearly deviate from the shifted lognormal distributions, classically supported by data pooled from various subjects or experimental conditions. The distributions were simulated with a 4-parameter model involving a lag, two consecutive elementary kinetic steps (exponential decays), and a Gaussian widening. The second kinetic step fits rather well the descending parts of the distributions. The steep ascending parts are controlled by the Gaussian and the first kinetic step. A number of issues, previously discussed in terms of comparative mean RTs, are re-examined in terms of shape modifications in the RT distributions. Discussed topics include same versus different judgments and symmetry versus repetition recognition in short-term visual memory, serial position effects in working memory, stimulus complexity effects, left/right idiosyncrasies, and how the ratios of erroneous versus correct responses vary with time.

◆ **Theta-wave activation during memorizing spatial information**

M Ohmi (Kanazawa Institute of Technology, Hakusan, Japan; e-mail: ohmi@his.kanazawa-it.ac.jp)

Spatial memories consist of the exocentric information of bird's-eye view coupled with the egocentric information that is real-time change of sight. Here, the neural processes that encode the egocentric visual context to the exocentric representation of space have been investigated. Observers were asked to memorize spatial configuration of a virtual-reality maze while viewing a slide show which depicted the change of sight corresponding to the exploration of the maze. Spontaneous MEG responses during the memorizing process have been measured. Theta-wave activation was found at all parts of the brain including frontal and parietal regions. The results confirm the reports of previous PET and fMRI studies that showed localization of spatial memories; exocentric representation at hippocampus, egocentric information at parietal region, and spatial working memory at frontal region. The phase of theta-band responses at the frontal region was synchronized with presentation of the visual stimulus. It suggests that the exocentric and egocentric informations are bound by theta-band coherence at frontal region during memorization of spatial information.

◆ **Altering motion perception by motion – colour pairing**

A Schlack, V Vivian, T D Albright (Vision Center Laboratory, The Salk Institute for Biological Studies, La Jolla, USA; e-mail: anja@salk.edu)

Recently, we showed that macaque MT neurons start to respond selectively to stationary shapes once animals have learned to associate these stimuli with motion (Schlack and Albright, 2007 *Neuron* **53** 881–890). We hypothesize that this neuronal plasticity might (i) play a role to disambiguate motion stimuli in noisy environments (ie influence perception) and (ii) be found when motion is associated with other stimulus features (eg colour). To test these hypotheses, we trained human observers to associate colours (red and green) with motion directions (up and down). We tested the influence of colour on perception of motion direction in noisy environments before and after the learning period. After training, human subjects used stimulus colour as a cue for motion-direction discrimination: the colour of the stimulus significantly biased the perceived motion direction in favour of the learned colour–motion association. These results support our hypothesis that associative learning is not limited to certain stimulus features. Rather, it seems to be a ubiquitous mechanism that alters responses in the brain as well as biases visual perception. [Supported by NIH.]

◆ **Adaptation changes the category boundary: Evidence from a discrimination task**

E Scilipoti, F Domini, L Welch (Department of Cognitive and Linguistic Sciences, Brown University, Providence, USA; e-mail: erika_scilipoti@brown.edu)

Perceptual categorization influences the representation of a stimulus: differences are enhanced between items belonging to different categories and reduced for items of the same category. Here we investigated the possibility that global aftereffects could bias the representation of a category boundary. Earlier Suzuki reported on global shape-distortion effects generated by brief presentations of an adapting stimulus. We examined observers' curvature discrimination on shapes that belonged either to the same category (convex) or to different categories. The adapting stimulus was either a concave or a convex shape. On each trial, the adaptor was presented briefly, followed by a brief test stimulus. Observers compared the test stimulus curvature to a standard. The standard stimulus was either the symmetric 'category boundary', or a convex or concave shape.

We studied whether a shift in the categorical representation of the curvature shapes could be related to a change in the perceived curvature after adaptation. Different degrees of distortion were observed for conditions close to the category boundary and distant from the category boundary.

◆ **Motion detection improvement from speed discrimination transfers between eyes**

C-H Tseng, Y Huang, E Natsukawa (Institute of Cognitive Science, National Cheng-kung University, Tainan, Taiwan; e-mail: CH.Tseng@alumni.uci.edu)

We investigated whether the improvement of observers' motion-detection sensitivity after practice in speed discrimination (Tseng et al, 2006 *Journal of Vision* 6(6):219, 219a) is eye-specific. We measured observers' sensitivity for motion detection in eight major directions (N, S, W, E, NE, NW, SE, SW) for both eyes separately before and after the learning phase, as in Tseng et al (loco cit.). During the learning phase, observers underwent six sessions of hourly speed discrimination in one specific direction with one specific eye only (called trained eye). Most of our observers showed a moderate improvement in coherence-threshold detection at the trained eye and a reduced one at the untrained eye (60% of what is observed at the trained eye). The improvement is across *all* directions after the speed discrimination task has been completed, in contrast to the direction-selective tuning observed after motion-detection or direction-discrimination training.

[Supported by NSC 95-2413-H-006-019-MY2 to CT; EN is supported by a fellowship from NCKU]

Wednesday

WEDNESDAY

ORAL PRESENTATIONS

LIGHTNESS AND BRIGHTNESS

◆ **How attention and contrast gain control interact to determine contrast and assimilation in lightness perception**

M E Rudd (Howard Hughes Medical Institute, University of Washington, Seattle, USA; e-mail: mrudd@u.washington.edu)

It is here argued that the effect of spatial context on lightness can best be understood by assuming that luminance ratios at edges form the basic building blocks used to construct lightness percepts. Two important processes influence the way that edge information from different parts of an image is perceptually combined. The first, weighted edge integration, is a flexible process, subject to attentional control, whereby local luminance ratios are summed spatially in a way that depends on the observer's goals (Rudd et al, 2005 *Journal of Vision* 5(8) abstract 561). The second, contrast gain control, is a stimulus-driven process whereby the weights assigned to edge ratios are adjusted on the basis of the proximities and contrasts of other nearby edges (Rudd and Popa, 2007 *Journal of the Optical Society of America A* in press). I illustrate how these two processes interact by describing an experiment in which changing only the instructions reverses the direction of the lightness-inducing effect of the local surround from contrast to assimilation and conclude with a model of how these processes may be instantiated in visual cortex.

◆ **Three types of processing for shadows: Ignore, select, or suppress?**

T Troscianko, M To ¶, D J Tolhurst ¶, P G Lovell (Department of Experimental Psychology, University of Bristol, Bristol, UK; ¶ University of Cambridge, Cambridge, UK; e-mail: tom.troscianko@bris.ac.uk)

The literature suggests that shadows are (a) coarsely processed; (b) subject to image-inversion effects; and (c) possibly suppressed by the human visual system. We ran an experiment in which subjects estimated the difference between two complex natural images, when either shadows or other aspects of the scene were manipulated. Both upright and inverted images were presented. The results show no significant effects of inversion for these complex scenes, suggesting that shadows have no special status and are not suppressed. In a separate study (Lovell et al, 2007 *Perception* 36 Supplement, this issue) we present data showing that shadows are coarsely processed in a sparse search image, and are subject to inversion effects. However, there is no evidence of suppression. It therefore seems that the situations in which shadows are discounted may be those in which judgments of material properties, eg lightness, are made. This suggests that previous evidence suggesting suppression may need to be re-evaluated. The rules determining shadow processing appear to be complex and in need of further investigation.

[Supported by EPSRC/Dstl (GR/S56405).]

◆ **Does simultaneous lightness contrast depend on physical or perceived intensity of the background?**

A L Gilchrist, A Radonjić, V Ramachandran ¶ (Department of Psychology, Rutgers University, Newark, USA; ¶ University of California at San Diego, La Jolla, USA; e-mail: alan@psychology.rutgers.edu)

In the classic simultaneous-lightness-contrast illusion, the inducing backgrounds differ both in luminance and perceived lightness. Which of these factors is crucial to the illusion? We explored this question using the Mach-book illusion. Two equiluminant targets were added to the display, one centered on each face of the Mach book. Twenty observers gave Munsell matches while viewing the book (concave) form and twenty viewed it in the tent (convex) form of the illusion. False perspective and false shadows were used to control 3-D appearance. If the illusion depends on background luminance only, it should be equally strong in both conditions. If it depends on background lightness, the illusion should be stronger in the book condition. We obtained neither of these outcomes. In the tent condition the targets differed by 4.0 Munsell steps while in the book condition the targets differed by 0.2 Munsell steps. We obtained the same results, though slightly weaker, in a separate study in which observers voluntarily reversed the depth. Theoretical implications are discussed.

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◆ **Explaining and classifying brightness-perception illusions by a new receptive-field approach**
K Ghosh, S K Pal (Center for Soft Computing Research: A National Facility, Indian Statistical Institute, Kolkata, India; e-mail: kuntal_v@isical.ac.in)

Failure of isotropic difference-of-Gaussian (DOG) models of receptive field (RF) to explain brightness perception illusions like White effects, led many researchers to either discard low-level RF

models in favour of orientation-selective nonlinear versions of DOG or totally abandon spatial-filtering-based approaches. However, even explaining low-level brightness-contrast illusions like, say, simultaneous brightness contrast with an isotropic DOG model requires judicious choice of parameters (scales, coefficients). Hence, a supportive role of high-level vision even in such simple cases cannot be ruled out. Such an interplay between low-level and high-level vision is predicted by a simple model of the extra-classical RF that modifies the classical DOG model with an additional wider Gaussian representing the extended disinhibitory surround (Ghosh et al, 2006 *Biological Cybernetics* **94** 89–96). It is further concluded that such an approach classifies brightness-perception illusions including checkerboard, Todorović and Howe stimuli into three groups that represent either purely contrast-based (eg Mach band), or predominantly holistic (eg White effects), or intermediate (eg grating induction) perceptual phenomena.

[Supported by the Department of Science and Technology, Government of India IRHPA Scheme.]

◆ **Remote effects on lightness**

P Kramer, P Bressan (Department of General Psychology, University of Padua, Padua, Italy; e-mail: peter.kramer@unipd.it)

With the help of the double-anchoring theory of lightness (Bressan, 2006 *Psychological Review* **113** 526–553), we investigated the occurrence and reversal of simultaneous contrast in the dungeon illusion (Bressan, 2001 *Perception* **30** 1031–1046). In this display, target disks surrounded by contextual disks contrast with them rather than with the immediate background. We show that the dungeon illusion reverses if the luminance of the target is either lower (double decrement) or higher (double increment) than the luminances of both the background and contextual disks, rather than in-between them. We also show that remote luminances outside the display of primary interest affect these inverted-dungeon displays in ways that depend on the strength of grouping between target and contextual disks. As a consequence, the double-decrement inverted-dungeon illusion decreases, and the double-increment inverted-dungeon illusion increases, with remote luminance. We conclude that far-away luminances that are normally ignored as of marginal importance can play a critical role in lightness.

◆ **Local, but not global, skewness explains a wide range of reflectance perception**

I Motoyoshi, T Nishizawa ¶, K Uchikawa ¶ (Human and Information Science Research Laboratory, NTT Communication Science Laboratories, Atsugi, Japan; ¶ Tokyo Institute of Technology, Yokohama, Japan; e-mail: motoyosi@apollo3.brl.ntt.co.jp)

It has been shown that the perceived glossiness and lightness of natural surfaces are predicted by early visual mechanisms that compute the skewness of the image histogram (Motoyoshi et al, 2007, in press). If this computation is done globally for the whole image, however, the mechanism output saturates at relatively low specular reflectance, and strongly depends on the intensity of highlights. These characteristics are consistent neither with physics nor with perception. If the mechanism is local and its output is spatially summed, the theory may accommodate a wide range of reflectance and illumination. On the basis of this idea, we propose a revised model of reflectance perception. The model assumes that the perceived specular reflectance is given as the spatial average of local subband skewness, and the perceived diffuse reflectance as the mean of the luminance image without regions having high local skewness. The model predicts human matching data for various surfaces including metals [Motoyoshi et al, 2007 *Journal of Vision* **7** 451a (abstract)] and is useful for segmentation of highlights from the body surface.

RIVALRY

◆ **Weak suppression during image rivalry**

R P O'Shea, R Bhardwaj, D Alais ¶, A Parker ¶ (Department of Psychology, University of Otago, Dunedin, New Zealand; ¶ University of Sydney, Sydney, Australia; e-mail: r_oshea@otago.ac.nz)

During binocular rivalry, one stimulus is visible, dominant, while the other stimulus is invisible, suppressed; after a few seconds, perception reverses. To determine whether these alternations involve competition between the eyes or between the images, we measured suppression depth—the ratio of contrast thresholds during dominance and suppression—with 100 ms monocular probes. We did this with conventional rival stimuli and with rival stimuli swapping between the eyes at 1.5 Hz (both sorts of rivalry were shown either with or without 18 Hz flicker). The conventional conditions cause rivalry that could involve competition between the eyes. The eye-swapping conditions cause rivalry that must involve competition between the images. Probes were either a small spot or a contrast increment to one of the rival stimuli. We found that conventional conditions yielded large suppression depth and eye-swapping conditions yielded small suppression depth (flicker had little effect). Weak suppression during image rivalry is consistent with rivalry involving competition between eyes and between images.

Wednesday

◆ **Comparison of interocular suppression for binocular rivalry and flash suppression**

D F Nichols, H R Wilson (Center for Vision Research, York University, Toronto, Canada; e-mail: dnichols@cvr.yorku.ca)

During binocular rivalry (BR) and flash suppression (FS), stimuli from one eye can be entirely suppressed from visibility by overlapping stimuli in the other eye. Interocular suppression that results from either BR or FS is perceptually indistinguishable within this overlapping region. Furthermore, with large (maximum 3 deg), monocular, centrally fixated sinusoidal gratings surrounded by contiguous annuli of rivalrous gratings it was demonstrated that interocular suppression of the entire central grating was possible by either technique. However, they showed different spatial integration effects (the magnitude of the suppression peaked at a small annulus width for FS but increased monotonically for BR over the same range of widths) and were differentially affected by the ipsilateral surround (the magnitude of the suppression was unaffected by the nature of the ipsilateral surround for FS, but suppression decreased when the ipsilateral surround was removed for BR and no longer occurred when the surrounds were fused). The differences between the techniques are likely attributable to the sustained (BR) versus transient (FS) stimulation of the contralateral eye.

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◆ **Stimulus motion propels traveling waves in binocular rivalry**

T Knapen, R van Ee, R Blake¶ (Physics of Man, Helmholtz Institute, University of Utrecht, Utrecht, The Netherlands; ¶ Vanderbilt University, Nashville, USA; e-mail: t.h.j.knapen@phys.uu.nl)

In visual perception, transitions between the two mutually exclusive percepts that alternate when the two eyes view conflicting stimuli (binocular rivalry) may take shape as traveling waves. The properties of these waves point to a neural substrate of binocular rivalry alternations that has the hallmark signs of lower cortical areas. In a series of experiments, we showed a potent interaction between traveling waves in binocular rivalry and stimulus motion. The course of the traveling wave is biased in the motion direction of the suppressed stimulus that gains dominance by means of the wave-like transition. Thus, stimulus motion may propel the traveling wave across the stimulus to the extent that the stimulus motion dictates the traveling wave's direction completely. Using a computational model, we show that a speed-dependent asymmetry in lateral inhibitory connections between retinotopically organized neurons can explain our results. We argue that such a change in suppressive connections may play a vital role in the resolution of dynamic occlusion situations.

◆ **Binocular rivalry for temporally modulated stimuli depends on a form-based parsing mechanism**

J J A van Boxtel, R van Ee, C J Erkelens (Helmholtz Institute, Utrecht University, Utrecht, The Netherlands; e-mail: j.j.a.vanboxtel@phys.uu.nl)

A central problem in perception is how to parse a continuous stream of information into meaningful events, resolve ambiguities, and shape awareness. We presented the eyes with temporally modulated incompatible images (gratings) which resulted in frequent perceptual alternations between the images in the two eyes: binocular rivalry. We show that rivalry ensues even when individual presentations are separated by up to 400 ms before being re-presented to the eyes. This temporal limit to rivalry was found to be independent of inter-ocular timing differences, contrast reversals, stimulus energy, and eye-of-origin information, suggesting that it reflects the temporal gain of the visual form or pattern pathway. Indeed, when investigating the dependence on form (an aspect processed in the ventral pathway) and motion (an aspect processed in the dorsal pathway) information, we find that this temporal limit depends on form conflict and not on motion conflict. Our findings demonstrate that binocular conflict resolution for dynamic visual scenes depends on a form-based parsing mechanism, which is largely unaffected by low-level stimulus characteristics.

◆ **Attending to auditory signals slows binocular rivalry**

D Alais, A Parker, J van Boxtel¶, C Paffen¶, R van Ee¶ (School of Psychology, University of Sydney, Australia; ¶ Helmholtz Institute, Universiteit Utrecht, Utrecht, The Netherlands; e-mail: davida@psych.usyd.edu.au)

Diverting attention to a competing visual distractor task slows binocular rivalry alternations. Here we test whether competing auditory tasks also slow rivalry. The distractor task was a 500 Hz amplitude modulated tone with intermittent intensity pulses. In a signal-detection paradigm, a brief auditory cue was presented and subjects indicated whether or not an intensity pulse had just occurred. We calculated d' . Two levels of task difficulty were used, and two kinds of perceptual alternations: rivaling orthogonal gratings, and a Necker cube. Observers tracked alternations for 6 min while doing the distractor task. The distractor slowed alternation rates for both kinds of stimuli. The effect was stronger for the Necker cube, and was stronger for the more difficult

distractor task. Tracking of pseudo-rivalry alternations confirmed that the slower reversal rate was not due to missed alternations while doing the distractor task. Perceptual alternation rate is therefore partially determined by attentional resources and will slow when attention is diverted. These resources appear to be central and supramodal.

◆ **Voluntary control over visual rivalry can be enhanced by sound that is consistent with scene interpretation**

R van Ee, A L Parker[¶], J J van Boxtel, D M Alais^{¶¶} (Helmholtz Institute, University of Utrecht, Utrecht, The Netherlands; ^{¶¶} University of Sydney, Sydney, Australia; e-mail: r.vanee@phys.uu.nl)

Voluntary attentional control over ambiguous stimuli constitutes a window on conscious processing. To date the interaction between different sensory modalities in voluntary control over ambiguous perception has not been examined. Here, we asked whether auditory information facilitates voluntary control over visual rivalry. We presented observers with a binocular rivalry stimulus along with sound that was either consistent or inconsistent with one of the two rivalrous stimuli. The visual stimuli consisted of a looming pattern in one eye and a radial pattern in the other eye. The sound stimulus consisted of auditory looming. When auditory and visual looming were consistent, subjects ($n = 6$) were able to exert about 25% more voluntary control than without sound. When auditory and visual information were inconsistent, voluntary control was disrupted by about 15%. Thus, consistent sound helped voluntary control, inconsistent sound disrupted it. We suggest that feedback from auditory areas helped maintain a representation of the bimodal looming stimulus during rivalrous suppression.

FORM AND MOTION

◆ **A common neural mechanism for second-order motion, texture segregation, and illusory contours**

C L Baker, Y Song (McGill Vision Research, McGill University, Montréal, Canada; e-mail: curtis.baker@mcgill.ca)

Different neural mechanisms are often invoked to account for seemingly different visual percepts: illusory contours (alignment of end-stopped responses), texture segregation (surround modulation), and second-order motion (nonlinear distortion, FRF). Here we describe neurophysiological evidence supporting a single model which is a plausible candidate for all three percepts. We recorded neural responses in cat A18 to several of these stimuli, with texture carriers including gratings, lines, and broadband patterns. Any neuron which was responsive to one of these was also responsive to any of the others, with consistent selectivity for contour orientation and direction of motion. Such invariant responses, found in both simple and complex cells, suggested a filter-energy rather than feature-based model. We simulated responses of early-stage, fine-scale filters, whose rectified responses drive a coarse-scale filter tuned to orientation and motion direction. The model shows specific agreement with our neurophysiological data, and suggests a common neural mechanism for robust and invariant coding of contour attributes. [Supported by Canadian CIHR MOP9685.]

◆ **A tilt aftereffect caused by motion: evidence for ‘motion streaks’**

D M Apthorp, D M Alais (School of Psychology, University of Sydney, Sydney, NSW, Australia; e-mail: deboraha@psych.usyd.edu.au)

Fast-moving visual features are thought to leave neural ‘streaks’ that can be detected by orientation-sensitive cells. Here, we tested whether ‘motion streaks’ can induce classic tilt aftereffects (TAEs). Participants adapted to drifting random Gaussian blob arrays (4.5 deg display diameter; 6.4 deg s^{-1}). Adaptation directions were 15°, 30°, 45°, 60°, 75°, and 90° clockwise from vertical, and strong and weak streaks were compared. Fixed and random-walk dots were used; coherence was held constant at 50%, while streak length was controlled by manipulating the number of fixed-walk frames carrying the dot motion (rather than manipulating speed), so that an equal number of coherently moving dots was always present, and speed was matched. With strong motion streaks, robust TAEs were obtained, similar in magnitude and orientation tuning to those caused by adaptation to tilted lines. These effects were absent in the weak streak conditions. Similar results were found in a tilt-illusion paradigm. This pattern of results indicates that motion streaks (resulting from temporal integration) do adapt orientation-sensitive cells.

Wednesday

◆ **Global form and global motion sensitivity are equally resistant to blur**

O Braddick, F Akthar ¶, S Anker ¶, J Atkinson (Department of Experimental Psychology, Oxford University, Oxford, UK, ¶ University College London, London, UK; e-mail: oliver.braddick@psy.ox.ac.uk)

We have developed tests of global motion and form coherence sensitivity to assess integrative visual processes in dorsal and ventral cortical streams, identifying differential development and 'dorsal stream vulnerability' in neurodevelopmental disorders. Here we investigate how these global threshold measures are affected by deficits in visual acuity. We tested form and motion coherence thresholds with our directly comparable stimuli: concentric patterns of short arcs or short motion trajectories, with variable percentages of randomly oriented elements. Young adult participants viewed through 0–12 dioptre plus lenses. Even lenses which greatly reduced visual acuity had relatively small effects on coherence thresholds; eg a +5 D lens increased average thresholds from about 15% to 19% but reduced acuity fivefold. These effects of blur showed no systematic difference between form and motion thresholds. We conclude that (a) the integrative processes detecting global form and motion can tolerate remarkably degraded image information; (b) the relative deficits we have found in development for motion vs form sensitivity cannot be explained as effects of reduced acuity.

[Supported by MRC research grant G0601007.]

◆ **Neural dynamics of bistable form/motion binding: fMRI and eye movements**

J Lorenceau, J-B Poline ¶, A-L Paradis, C Lamirel, E Artiges ¶, B Thirion ¶, A Caclin § (Cognitive Neuroscience and Cerebral Imaging, CNRS–LENA, Paris, France; ¶ CEA, SFHS, Orsay, France; § INSERM, Bron, France; e-mail: jean.lorenceau@chups.jussieu.fr)

We studied bistable perception with diamond-like stimuli, alternately perceived as a contour-bounded moving shape or unbounded moving contours. fMRI analyses reveal a BOLD increase in the LOC and VI for transitions toward bounded percepts, while transitions towards unbounded states are correlated with a BOLD increase in hMT+. This network extends to V2/V3 only during stable bounded perception. This ventral/dorsal balance is similar for endogenous and exogenous transitions induced by smooth changes of line-end luminance, local motion, or shape, known to control motion binding. Eye movements show slightly more numerous saccades and blinks before transitions, although too rare to account for BOLD changes. In addition, pupil dilation precedes perceptual transitions, with different dynamics for transitions towards or away from coherence. Altogether, our results do not support a predictive coding scheme between the LOC and VI (Murray et al, 2002 *Proceedings of the National Academy of Sciences of the USA* **99** 15164–15169) and suggest it may rather occur between the LOC and hMT+. Finally, the extended network seen during bounded states suggests the progressive involvement of recurrent LOC/V2/V3 loops.

[Supported by the French Ministry of Research, ACI «Cognitive Neuroscience» to JL.]

◆ **Absolute changes in binocular disparity can produce perception of motion-in-depth**

I P Howard (Department of Biology, York University, Toronto, Canada; e-mail: ihoward@cvr.yorku.ca)

It has been reported that an overall change in binocular disparity does not create an impression of motion-in-depth in a stereoscopic random-dot display, unless there is a stationary stimulus that provides relative disparity (Erkelens and Collewijn, 1985 *Vision Research* **25** 583–588; Regan et al, 1986 *Investigative Ophthalmology & Visual Science* **27** 584–597). I hypothesized that absence of looming may inhibit the impression of motion-in-depth in a stereoscopic display. The image of a radial pattern filling the visual field does not change as it moves in depth. Subjects tracked with unseen hand the perceived to-and-fro motion-in-depth of a single dot, a random-dot display, and a radial pattern. The random-dot display produced little or no motion, the single dot produced some motion, but the radial display produced considerable motion. I conclude that vergence tracking of a display that changes in overall disparity does create motion-in-depth when there is no contradictory information about lack of looming.

[Supported by the Natural Sciences and Engineering Research Council of Canada.]

◆ **Global structure influences motion-discrimination thresholds**

D Kane, P J Bex ¶, S C Dakin (Department of Visual Science, Institute of Ophthalmology, University College London, London, UK; ¶ Harvard Medical School, Boston, USA; e-mail: d.kane@ucl.ac.uk)

In order to overcome the aperture problem, local motion signals must be integrated across space to signal the global movement of large objects. We considered the role of low spatial-frequency (SF) information and global spatial organisation in global-motion perception. A drifting naturally contoured carrier (5 deg × 5 deg) was viewed through 81 circular apertures (radius = 0.17 deg). Subjects indicated the carrier direction (2AFC; clockwise or anticlockwise

from vertical). Global/coarse-scale structure was disrupted either by removing low SFs or by randomly switching the exposed local pattern between apertures. Both conditions preserve local motion. Removal of low SFs did not significantly elevate direction-discrimination thresholds, but disrupting global structure did. To our knowledge this is the first demonstration that solution of the aperture problem can improve the precision of a perceptual judgment. Taken together, these results indicate that global direction discrimination can be supported by integrating high SF local signals. Furthermore, this process is most sensitive when the spatial arrangement of signals is similar to that observed in natural images.
[Supported by the Wellcome Trust.]

BINOCULAR VISION

◆ **Electrophysiological effects of interocular incongruence during sequential and simultaneous binocular stimulation**

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Human binocular vision normally results in the fusion of information from both eyes. If, however, that information provided by the eyes conflicts, rivalry entailing perceptual alternations occurs instead of fusion. Here, I investigate electrophysiological responses to incongruent and congruent binocular information presented either sequentially or simultaneously. Initially, one eye viewed a grating and the other viewed a grey field. Then, during sequential binocular stimulation, the grating to the first eye was turned off and the grating to the second eye was turned on; thereafter stimulation went back to the original. During simultaneous binocular stimulation, the stimulus to the first eye remained while a grating to the second eye was turned on. The grating presented to the second eye was either of the same (congruent) or perpendicular (incongruent) orientation to that presented to the first eye. Stimuli to both eyes were flickered at different frequencies. Spectral EEG amplitudes at the stimulus-driving frequencies differed depending on interocular incongruence for simultaneous presentation only; whereas event-related potentials yielded larger amplitudes for incongruent than congruent stimuli for sequential and simultaneous presentation.

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◆ **Absolute and relative aspects of disparity interactions**

C W Tyler (Brain Imaging Center, Smith-Kettlewell Eye Research Institute, San Francisco, USA; e-mail: cwt@ski.org)

Target detection is affected by the presence of auxiliary stimuli. What form does this interaction take when the auxiliary (mask) stimulus is disparate with respect to the target? The full answer to this question forms a high-dimensional (16+) space. Five dimensions (target disparity, mask disparity, position, width, and polarity) were examined. Both stimuli were vertically elongated Gaussians, with the test 5 deg to the left of fixation. The interaction effect with a high-contrast auxiliary was measured by the masking sensitivity paradigm. The interaction effect was always in the masking direction, but showed a strong dependence on the five variables tested, with both absolute and relative aspects. The absolute disparity masking consisted of two components, a projection of the monocular masking effects into disparity space and a generic component that was uniform throughout the effective disparity range. This masking was enhanced by a size- and polarity-specific center/surround masking effect keyed to the target disparity, forming a dumbbell shape in disparity–position space. Moreover, the range and sign (masking vs facilitation of this center/surround effect was scaled relative to the size and polarity of the test stimulus.

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◆ **Determining the matching tokens in binocular stereopsis: An empirical and modeling study**

B J Rogers, K Minami (Department of Experimental Psychology, University of Oxford, Oxford, UK; e-mail: bjr@psy.ox.ac.uk)

Using peaks-add versus peaks-subtract luminance profiles, Heckman and Schor (1989 *Vision Research* **29** 593–607) reported that the phases of components had no effect on thresholds for detecting binocular disparities. In contrast, Rogers and Moore (2000 *Investigative Ophthalmology & Visual Science* **41** s948) reported that the phases of spatial frequency components do matter and they concluded that edges, not spatial frequency components, are primary tokens in stereoscopic matching. Here, empirical data and computational modeling were used to resolve the contradictory findings. The observers' task was to detect sinusoidal depth corrugations created by disparate vertical gratings (0.4; 0.8; 1.6 cycles deg⁻¹) with different luminance profiles including (i) odd-harmonic Fourier components and (ii) missing fundamental square waves, in either peaks-subtract or peaks-add phases. The phases of the components affected thresholds at low but not high grating frequencies. The results were modeled and the discrepancies resolved when high-contrast

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edges in the filtered profiles were used as matching tokens, but only when the filters had realistic bandwidths. There was no evidence that different spatial frequencies are processed independently.

◆ **Interocular suppression is scale invariant, but ipsiocular suppression is weighted by flicker speed**

D H Baker, T S Meese, K Patel, W Sarwar (School of Life and Health Sciences, Aston University, Birmingham, UK; e-mail: bakerdh@aston.ac.uk)

In human and cat there are two routes to suppression for orthogonal masks: a broadband, non-adaptable, ipsiocular pathway, and a more narrowband, adaptable interocular pathway. We investigated the strength of both types of suppression in humans across spatio-temporal scale using orthogonal pairs of superimposed Gabor patches (mask and target) flickering at four spatial (0.5, 1, 2, 4 cycles deg⁻¹) and two temporal (4 and 15 Hz) frequencies. Mask and target were presented to the same eye or different eyes in 2IFC cross-orientation masking experiments. Masking functions were normalized to baseline detection thresholds and fit by a two-stage model of contrast gain control (Meese et al, 2006 *Journal of Vision* 6 1224–1243) developed to accommodate cross-orientation masking. The weight of ipsiocular suppression was proportional to the square-root of stimulus speed (TF/SF), as in the binocular case (Meese and Holmes, 2007 *Proceedings of the Royal Society of London, Series B* 274 127–136). However, dichoptic-masking functions superimposed, showing that the interocular, presumably cortical, process is scale-invariant. These findings have implications for studies of amblyopia, binocular rivalry, and single-cell physiology.

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◆ **Objective evaluation of binocular interaction at different levels in the human brain**

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We investigated objectively the binocular interaction at different levels of the human brain. Twenty subjects with good binocular vision were assessed with a method of orientation-selective fMRI adaptation. The subjects were adapted monocularly to phase-reversing, oblique sinusoidal gratings, after which cortical activation evoked by either the same (monoptic) or the other (dichoptic) eye was tested, either for the same or for an orthogonal orientation. Strong adaptation effects were seen under all conditions. Monoptic adaptation was stronger than dichoptic adaptation in area V1 and at extrastriate levels. The dichoptic adaptation in area V1 was about 75% of the monoptic adaptation, a figure very similar to the psychophysically determined values for interocular transfer of pattern adaptation. The interocular transfer of adaptation measured with functional imaging was consistently stronger in areas on the ventral than on the dorsal visual pathway. The differential interocular transfer of adaptation suggests different mechanisms of binocular combination in the two visual pathways, possibly underlying different functional roles.

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◆ **Binocular combination at threshold: Temporal filtering and summation of signals in separate ON and OFF channels**

M A Georgeson, T Meese (School of Life and Health Sciences, Aston University, Birmingham, UK; e-mail: m.a.georgeson@aston.ac.uk)

How does the brain combine spatio-temporal signals from the two eyes? We quantified binocular summation as the improvement in 2AFC contrast sensitivity for flickering gratings seen by two eyes compared with one. Binocular gratings in-phase showed sensitivity up to 1.8 times higher, suggesting nearly linear summation of contrasts. The binocular advantage decreased to 1.4 at lower spatial and higher temporal frequencies (0.25 cycle deg⁻¹, 30 Hz). Dichoptic, antiphase gratings showed only a small binocular advantage, by a factor of 1.1 to 1.2, but no evidence of cancellation. We present a signal-processing model to account for the contrast-sensitivity functions and the pattern of binocular summation. It has linear sustained and transient temporal filters, nonlinear transduction, and half-wave rectification that creates ON and OFF channels. Binocular summation occurs separately within ON and OFF channels, thus explaining the phase-specific binocular advantage. The model also accounts for earlier findings on detection of brief antiphase flashes and the surprising finding that dichoptic antiphase flicker is seen as frequency-doubled (Cavonius et al, 1992 *Ophthalmic and Physiological Optics* 12 153–156).

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PERCEPTUAL MECHANISMS

◆ **Critical-band masking estimation of 2nd-order filter properties**

M S Landy, C A Henry (Department of Psychology and Center for Neural Science, New York University, New York, USA; e-mail: landy@nyu.edu)

Standard models of texture segregation comprise (i) a linear filter (to enhance a constituent texture), (ii) a nonlinearity (to compute 'texture energy'), (iii) a second linear filter (to enhance the texture modulation), and (iv) a decision stage. We estimated the spatial frequency sensitivity of the 2nd-order filter using critical-band masking. Stimuli were 2nd-order sine-wave gratings masked by 2nd-order low-pass or high-pass noise. A grating plus noise was used to modulate between two carrier textures (vertical and horizontal gratings). Modulator and carrier phase were randomized. Observers judged the orientation (vertical or horizontal) of the modulator grating. Threshold modulator contrast was determined for several noise cut-off frequencies. A sigmoid was fit to the low-pass and high-pass data. For all combinations of carrier (2 and 4 cycles deg^{-1}) and modulator (0.125 and 0.25 cycle deg^{-1}) frequency, estimated 2nd-order channels were approximately one-octave wide with peak sensitivity at 0.25–0.36 cycle deg^{-1} , ie higher than the test frequencies. Human data are compared with simulations of the standard texture-segregation model. [Supported by NIH EY16165.]

◆ **Orientation and spatial frequency tuning of brightness perception**

V R Salmela, P Laurinen (Department of Psychology, University of Helsinki, Helsinki, Finland; e-mail: viljami.salmela@helsinki.fi)

We studied the effect of surround spatial structure on spatial-frequency (SF) and orientation tuning of brightness perception. Two identical square patches (1° ; 33 cd m^{-2}) were superimposed on positive and negative phases of a square-wave grating (4 deg). The SF of the grating was either 0.25 cycle deg^{-1} (simultaneous contrast) or 0.5 cycle deg^{-1} (White's illusion). The whole stimulus was masked with bandpass-filtered white noise. Either the SF of the isotropic noise (0.5–7.5 cycles deg^{-1} ; width 1 octave) or the orientation of the mask (0° – 90° ; width 30 deg; SF 1.8 cycles deg^{-1} ; width 3 octaves) was varied. Contrast thresholds were measured by adjusting the contrast of the grating until the patches were visible and appeared different in brightness. For both simultaneous contrast and White's illusion, bandpass tuning peaking at 3 cycles deg^{-1} was found. Orientation tuning was found only for White's illusion: orthogonal orientation to the surround grating most effectively masked the illusion. Thus, changing the spatial structure of the surround alters the orientation tuning, but not the SF tuning.

◆ **Top – down control over visual-contrast sensitivity**

S de la Rosa, B Schneider, M Gordon¶ (Department of Psychology, University of Toronto, Toronto, Canada; ¶ University of South Alabama, Mobile, USA; e-mail: stephan@psych.utoronto.ca)

The visual system is able to adjust its contrast sensitivity to the ambient contrast level. Others have shown that this adjustment is driven by stimulus parameters in a bottom–up fashion and higher order processes by means of attention. We present evidence that contrast sensitivity is under true top–down control. We paired an absolute identification paradigm with a cueing paradigm to measure identification accuracy for four low-contrast stimuli that were intermixed with an occasional high-contrast stimulus. Foreknowledge of the presentation of the high-contrast stimulus was manipulated by presenting valid and invalid cues. In experiment 1 we found that identification and discriminability of low-contrast stimuli was impaired only when the occurrence of the high-contrast stimulus was unpredictable but not when it was predictable. Only a top–down gain-control mechanism whose functions were to maximize discriminability while protecting the system from overload was consistent with the results. Experiment 2 provided further support for the idea that an important function of gain control is to protect visual mechanisms from overload.

[Supported by a grant from the Natural Sciences and Engineering Research Council of Canada to BS.]

◆ **The spatial specificity of adaptation underlying the direction aftereffect (DAE)**

P Wenderoth, M Wiese (Department of Psychology, Macquarie University, Sydney, Australia; e-mail: peterw@vision.psy.mq.edu.au)

Research on motion direction repulsion has produced conflicting evidence as to the site of the underlying neural activity. We adapted and tested observers with drifting dot and drifting grating stimuli in repeated-measures designs. DAEs were measured when adapting and test stimuli were spatially superimposed and spatially separated. If grating and dot DAEs have a common neural substrate, the degree of spatial specificity of the two DAEs should be the same. A difference in spatial specificity would cast doubt on the usual assumption that gratings and dots can be employed interchangeably to measure direction repulsion. We found that when inducing and test stimuli were spatially separated, both DAEs were much smaller but dot DAEs were about double

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the size of grating DAEs. This may indicate that grating DAEs reflect predominantly low-level adaptation of smaller (V1?) receptive fields whereas dot DAEs reflect more direct adaptation of larger MT receptive fields. Further experiments were designed to unconfound retinotopic and spatiotopic effects.

◆ **Revealing recovery from adaptation below perceptual thresholds**

F A J Verstraten, C Paffen, T Carlson¶, M J van der Smagt, H Hogendoorn (Helmholtz Institute, Utrecht University, Utrecht, The Netherlands; ¶ Harvard University, Cambridge, USA; e-mail: f.a.j.verstraten@uu.nl)

The motion aftereffect (MAE) is one of the oldest documented visual phenomena and it is often believed that this illusory motion reflects the recovery from adaptation of previously stimulated neurons. We show that the visible MAE does not reflect the recovery from adaptation process at all. Only part of the recovery process is perceived as illusory movement. To reveal the invisible component of the recovery from adaptation, we used successively presented orthogonal moving patterns whose MAE is unidirectional and hence shows the relative contribution of both directions. We have shown that the invisible component of the recovery from adaptation can be revealed by ‘piggybacking’ it onto the visible aftereffect of the orthogonal component. This method makes it possible to measure motion adaptation below perceptual thresholds, and may generalize to other adaptation phenomena.

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◆ **Peripheral vision; good for biological motion, bad for signal/noise segregation**

R F Hess, B Thompson, B Hansen, N F Troje¶ (Department of Ophthalmology, McGill University, Montréal, Canada; ¶ Queens University, Kingston, Canada; e-mail: robert.hess@mcgill.ca)

Visual processing is highly regional, the fovea is specialized for spatial resolution whereas the periphery is specialized for the detection of movement (Schneider, 1969 *Science* **163** 896–902). Biological motion, having both evolutionary and social importance, is detected by the human visual system with a high degree of sensitivity. From a survival point of view one would expect peripheral vision to be, if not specialized, at least highly sensitive to the detection of biological motion. A recent study suggests that it is not; the fovea is more specialized for the detection of biological motion (Ikeda et al, 2005 *Vision Research* **45** 1935–1943). We show that this is not the case; the periphery is actually highly sensitive to the detection of biological motion, but it suffers from not being able to detect signals when embedded in visual noise—a procedure commonly used to quantify sensitivity to biological motion.

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MOTION

◆ **Heritability of interindividual variation in illusory-motion perception: A study that exploits the Internet**

C Becker, J D Mollon (Department of Experimental Psychology, University of Cambridge, Cambridge, UK; e-mail: cb486@cam.ac.uk)

Visual motion may be perceived when observing static stimuli, such as the rotating wheels studied by Fraser and Wilcox (1979 *Nature* **281** 565–566) or the rotating snakes (eg Murakami et al, 2006 *Vision Research* **46** 2421–2431). It is an unsolved problem whether the two illusions share a common mechanism. Interestingly, not all observers agree on the presence of motion in these stimuli. We studied illusions of the two types using web-based surveys that allowed testing of large numbers of participants. The websites allowed randomization of stimulus presentation and the automatic recording of experimental results. Strategies were developed for ensuring that stimuli subtended similar visual angles, and were presented at similar eccentricities, for all participants. In a study with more than 300 participants we found substantial individual variation in the perception of Fraser–Wilcox stimuli, but little variation in the snakes illusion. However, we found some indication that the responses to the different illusions are correlated.

◆ **Spatiotopic selectivity of BOLD responses to visual motion in human area MT**

S A Crespi, G d’Avossa¶, M Tosetti§, L Biagi§, D C Burr#, M C Morrone‡ (Department of Psychology, Università degli Studi Milano-Bicocca, Milan, Italy; ¶ Washington University School of Medicine, St Louis, USA; § Fondazione ‘Stella Maris’, Calabrone, Italy; # Università degli Studi di Firenze, Florence, Italy; ‡ Università Vita-Salute San Raffaele, Milan, Italy; e-mail: sofia.crespi@unimib.it)

Gaze direction affects responses to visual stimuli in many cortical areas of the monkey, and in humans there is good psychophysical evidence for spatiotopic integration of motion stimuli. Here, we demonstrate that human middle-temporal cortex encodes motion in a spatiotopic fashion and

therefore could mediate the spatiotopic integration of motion signals, converting retinotopic information into a spatiotopic reference frame. We isolated the portion of hMT complex responding to contralateral stimuli in each subject, then selected those voxels, within this portion, that responded to coherent flow against speed-matched random motion. We then measured fMRI BOLD responses to motion in four screen positions and for three different gaze directions. In V1 gaze did not alter the retinotopicity of the responses: the response curves for the three different fixations were almost identical when plotted in retinal coordinates, but widely spaced in screen coordinates. MT showed the opposite, with the curves displaced in retinal coordinates, but aligned in spatial coordinates, showing that retinotopic selectivity changes with eye position producing a clear spatiotopicity.

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◆ **Two-stroke apparent motion is abolished at low luminance**

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In two-stroke apparent movement, repeated presentation of a two-frame pattern displacement followed by a brief inter-stimulus interval (ISI) can create an impression of continuous forward motion (Mather, 2006 *Vision Research* 46 2015–2018). Does the ISI in two-stroke motion just break the connection between adjacent frames, switching off the motion signal they normally generate, or does it actually generate a reversed motion signal? Reversed apparent motion in two-frame stimuli separated by a brief ISI has been reported in several previous papers. Takeuchi and De Valois (1997 *Vision Research* 37 745–755) found that this effect was abolished at scotopic luminances. The present experiment tests whether two-stroke apparent motion is also abolished at low luminances. Subjects performed a direction-discrimination task using standard apparent-motion stimuli or two-stroke stimuli. Data showed reliable direction discrimination at both luminance levels with standard apparent motion, but only at high luminance with two-stroke apparent motion. Results therefore indicate that the ISI in two-stroke stimuli does contribute a reversed motion signal.

◆ **Dynamic inference for motion tracking**

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When the visual information about an object’s motion differs at the local level, the visuomotor system needs to integrate information across time to solve this ambiguity and converge to the final motion solution. For an oblique line moving horizontally, edge-related motion cues differ from terminator-related information, the latter being coherent with the line’s global motion. We have previously shown that ocular tracking of this kind of stimuli is transiently biased toward the edge-orthogonal direction, before converging to the global motion direction. Here, we model the dynamic convergence to the global-motion solution as a recursive update of inferential knowledge in the velocity space. We assume that motion estimation is based on a prior distribution and two independent likelihood functions representing edge-related and terminator-related information. Importantly, the shape of the Bayesian functions is constrained by smooth-pursuit eye-movement data. Model predictions about the dynamic convergence to the correct motion solution are compared to human smooth-pursuit recordings when varying different stimulus parameters (speed, contrast).

[Support: AM was funded by an EU Marie Curie fellowship.]

◆ **An alternative route to motion discrimination**

H Bridge, O Thomas, S Jbabdi, A Cowey (FMRIB Centre, University of Oxford,
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Blindsight subjects can discriminate the direction of motion despite being unable to report seeing the stimulus. Since the middle temporal area (MT) is sensitive to visual motion and functionally active in blindsight subjects, it may underlie this ability. A direct pathway from macaque lateral geniculate nucleus (LGN) to MT has been demonstrated recently (Sincich et al, 2004 *Nature Neuroscience* 7 1123–1128). We used diffusion tractography to investigate whether this pathway exists in five control subjects and blindsight subject GY. A pathway from LGN (defined anatomically) to ipsilateral MT+ (defined functionally) was present in all control subjects. This pathway was also present in both hemispheres in GY. In addition, he showed a strong contralateral pathway from left LGN (lesioned side) to right MT+, and a weaker right LGN to left MT+ pathway. Such a pathway was absent in all control subjects. Retinotopic mapping showed

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a greater representation of the ipsilateral visual field in GY compared to controls. Together, these results suggest a reorganisation of the visual pathways in subject GY. [Supported by The Royal Society (Dorothy Hodgkin Fellowship to HB).]

◆ **A simple motion-detector model explains the spinning-disks illusion**

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

A variety of motion illusions can be elicited by static images, often requiring eye movements to generate image shifts and local motion signals. To test the physiological mechanisms involved in such motion illusions in absence of eye movements, we presented the 'spinning disks illusion' (Williams et al, 2005 *Perception* 34 Supplement, 125): concentric rings of disks filled with greylevel gradients appear to spin around the centre when the background luminance is modulated. A minimal version of this illusion is used here to investigate the underlying information processing. The analysis is based on a two-dimensional network of biologically plausible motion detectors, the 2-DMD model, which has been used to account for many aspects of motion perception. The 2-DMD model generates motion signal maps for the static disks that directly predict the perceived shifts. This response is due to displacements of the contrast profiles at the edges of the disk resulting from the lateral inhibition in the input. Based on this conclusion, novel stimuli can be generated that lead to vivid motion sensations.

SYMPOSIA & PLENARY LECTURES

CORRELATION BETWEEN VISUAL PSYCHOPHYSICS, NEUROPHYSIOLOGY AND ART—SYMPOSIUM IN HONOUR OF ADRIANA FIORENTINI AND LAMBERTO MAFFEI

◆ **The legacy of the Pisa Laboratorio di Neurofisiologia del CNR**

L Spillmann (Department of Neurology, Neurocenter, University of Freiburg, Germany; e-mail: lothar.spillmann@zfn-brain.uni-freiburg.de)

From the late sixties to the early nineties, the Pisa group led by Adriana Fiorentini and Lamberto Maffei pioneered research on the correlations between the psychophysics and neurophysiology of the visual system. Some 100 papers were published—in the very best journals—that drew international researchers from the most prestigious laboratories to Pisa. Psychophysical studies dealt with perceptual correlates of spatial interactions in the visual system, binocular depth perception, adaptation to gratings, contrast in night vision, and monocular rivalry, among others. Neurophysiological studies focused on the analysis of contrast and spatial frequency in the lateral geniculate and visual cortex, binocular depth discrimination, the unresponsive regions of receptive fields, and spatial frequency rows in the striate cortex. Some of these studies received more than 150 citations. Developmental studies investigated the spatial resolution and neural plasticity of kittens after monocular deprivation and prolonged exposure to gratings. Studies of contrast sensitivity in myopic subjects were later complemented by pharmacological studies of the effect of nerve-growth factors on visual acuity in deprived kittens and dopaminergic drugs in human amblyopes. Both psychophysical and VEP recordings were used to investigate binocular-disparity detectors, contrast perception in subjects with normal as well as astigmatic and anisometropic eyes. Furthermore, the pattern ERG was recorded in humans, cat, and monkey in response to alternating gratings. All of this work has had a broad influence in our understanding of visual perception, neurophysiology, and even art.

◆ ***Arte e Cervello: Lenticular senescence and consequences for colour perception in art and the brain***

J S Werner (Department of Ophthalmology and Vision Science, University of California Davis Medical Center, Sacramento, USA; e-mail: jswerner@purple.ucdavis.edu)

In their 1995 treatise, *Arte e Cervello* (Bologna: Zanichelli), Maffei and Fiorentini describe changes in Monet's painting that are related to the development of his cataracts, most importantly greater scatter and a reduction in short-wave light reaching the retina. The physical changes due to cataract are incontrovertible, but the consequences for painting depend more on a perceptual than a physical analysis. I review new experiments that explain why Monet's colour vision recovered so slowly following removal of his cataracts. It is shown that colour appearance, even for short-wave stimuli, is uncorrelated with lenticular density in younger and older adults. During normal aging, the visual system compensates for changes in lens opacity to maintain constancy of colour appearance. Following cataract extraction, the visual system must recalibrate itself for a change in the spectral distribution of retinal illumination, and this process has a protracted time course.

◆ **A reassessment of the role of activity in the formation of eye-specific retinogeniculate projections**

L M Chalupa (Departments of Neurobiology, Physiology & Behavior, and Ophthalmology and Vision Science, University of California Davis, Davis, USA;
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In all mammalian species the projections from the two eyes to the dorsal lateral geniculate nucleus of the thalamus terminate in separate layers or territories. This mature projection pattern is refined early in development from an initial state where the inputs of the two eyes are overlapping. I discuss the results of studies showing that the formation of segregated eye-specific retinal projections involves activity-mediated binocular competition. The major point of my talk is that while retinal activity undoubtedly is involved in this process, recent studies from my laboratory cast doubt on the prevalent notion that retinal waves of activity play an instructional role in the formation of segregated retinal projections. This will lead to a consideration of the molecular cues that may underlie the formation of eye-specific projections.

◆ **From receptive fields to perception: Surfaces, brightness, and form**

M C Morrone (Department of Psychology, Università Vita-Salute San Raffaele, Milan, Italy; e-mail: morrone.concetta@hsr.it)

The use of a quantitative mathematical approach to the analysis of responses of single neurons was the key to Maffei and Fiorentini's well-known contributions towards bridging the gap between our understanding of perception and neuronal processing. Motivated by the exciting new approach to vision introduced by the Cambridge school, Lamberto and Adriana became fascinated by the linear-system approach. Their work on the spatial-frequency selectivity of single neurons, firmly related to psychophysical phenomena, has been completely assimilated in our approach to exploring the mechanisms of perception, but were very innovative at the time. In recent times, brain-imaging techniques have provided very powerful tools by which to relate neural processing to perception. Following Maffei and Fiorentini's approach, I present recent data showing how the neuronal selectivity of primary visual cortex in humans can be used to code local features, and how subsequent stages of processing (probably related to the unresponsive region of receptive fields described by Maffei and Fiorentini in 1983) may be used to recover the form and brightness of an object. Contrast adaptation reduces and alters the coding of simple features in the human primary cortex, as Maffei and Fiorentini showed for cat cortex. However, our recent fMRI data show that adaptation to illusory brightness is a mechanism of the associative cortex. Psychophysical data also show that adaptation to form involves higher visual structures that are not welded to retinotopic space. Now, 30 years after Maffei and Fiorentini's seminal contributions to visual science, it is time to bridge the gap in understanding the neuronal circuitry of associative cortex underlying perceptual segmentation of the retinal image into meaningful objects located stably in space.

◆ **Electrophysiology of human vision**

D Spinelli (University Institute for Motor Science [IUSM], Rome, Italy;
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In the late sixties, Campbell and Maffei demonstrated that the amplitude of the steady-state VEP could predict psychophysical contrast threshold. This finding set the stage, in Pisa, for studying human vision by recording electrophysiological activity. Three lines of research were developed. The first aimed to bridge the gap between animal and human data. In human subjects, contrast sensitivity was studied by psychophysical and VEP techniques, while in cat contrast sensitivity was measured by behavioural and VEP techniques. The second used VEPs to study the development of vision in infants. The third, often associated with pattern ERG, investigated impairment of vision in special populations such as myopic, squinting, or aging. These lines of research are still active in Pisa, Florence, Milan, and Rome laboratories, sustained by new techniques, such as brain mapping and fMRI. Current development concerning the integration of VEP and fMRI techniques designed to further the understanding of the contribution of different cortical areas to VEP generation are described.

CATEGORY LEARNING IN MAN, MONKEY, AND MACHINE

◆ **Learning to recognize novel object categories from examples**

S Ullman (Weizmann Institute of Science, Rehovot, Israel;
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I describe an approach, based on recent computational modeling, which learns to recognize new object categories from image examples. Starting with a collection of images illustrating examples of a category such as 'face', 'car', 'horse', and the like, the proposed scheme constructs a

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category representation, and then uses it to identify novel members of the category. The approach is based on representing shapes within a category by a hierarchy of shared sub-structures called fragments, selected by maximizing the information delivered for categorization. The learning process automatically extracts the part-structure of the category, and during categorization, novel members of the category are recognized, and their parts are detected and localized. Fragments representing different appearances of the same object part are combined in the category representation into abstract components. This abstraction is obtained by using motion and common context cues, and it results in invariance to large changes in appearance and object transformations.

◆ **Category learning is modulated by visual similarity**

A Ishai (Institute of Neuroradiology, University of Zurich, Zurich, Switzerland; e-mail: ishai@hifo.unizh.ch)

Event-related fMRI was used to test whether matching between new exemplars and old prototypes depends on their visual similarity. Subjects memorized art paintings from six categories, and four days later performed a memory-retrieval task in the MR scanner. The old prototypes were presented with new exemplars, which were either visually similar or different from the prototypes. Behaviourally, the response to new exemplars was faster and more accurate with decreased visual similarity to the old prototypes. I found activation within a distributed cortical network, which included regions in extrastriate visual cortex, where old prototypes evoked stronger activation than new exemplars; parietal cortex where the response to new exemplars was reduced with decreased similarity to the prototypes; and prefrontal regions where new, visually different exemplars evoked stronger activation than new, similar items. The results suggest that category learning is mediated by stimulus-specific representations stored in extrastriate cortex, and activation in parietal and prefrontal regions, where new items are classified as a match or a mismatch based on their visual similarity to old prototypes.

◆ **Memory system interactions in category learning**

R A Poldrack (Department of Psychology and Brain Research Institute, University of California at Los Angeles, Los Angeles, USA; e-mail: poldrack@ucla.edu)

An important aspect of categorization involves learning to assign responses to stimulus classes in accordance with the subject's categorization strategy. Converging evidence from neuroimaging, neuropsychology, and animal studies suggests that this kind of learning may involve interactions between the declarative memory system involving the medial temporal lobe and a 'habit learning' system involving the striatum. I outline evidence that these two memory systems exhibit a negative functional relationship, and that their relative engagement can be modulated by task factors such as the presence of a distracting secondary task. I also discuss work examining the differences in the knowledge acquired by these two systems, such as its flexibility and longevity.

◆ **Visual learning and categorical decisions in the human brain**

Z Kourtzi (University of Birmingham, Birmingham, UK; e-mail: z.kourtzi@bham.ac.uk)

In everyday life we encounter a plethora of novel experiences in different social contexts that require prompt decisions for successful actions. Extracting the key features from our sensory experiences, assigning them to meaningful categories, and deciding how to interpret them is a computationally challenging task that is far from understood. The work reported here focuses on the categorization of complex movements that we encounter in the dynamic environments we inhabit and the role of learning and experience-based plasticity in shaping this process in the human brain. Combined psychophysics and human fMRI is used to show that learning shapes the processing of complex movement patterns that share biological properties with human actions (symmetrical skeleton structure, sinusoidal motion of segment joints) but with which the observers lack previous experience. In particular, training to discriminate such movements whose similarity varied parametrically along a spatio-temporal morphing continuum resulted in improved performance coupled with increased neural sensitivity in motion-related and biological motion-related areas. Furthermore, categorization of complex movements based on their prototypical structure recruits visual motion and parietal areas, whereas rule-based categorization engages primarily frontal areas known to be involved in higher executive functions. The results provide evidence for flexible neural representations of complex movements in these areas that are modulated by the stimulus dimensions relevant for categorization, and support a central role of experience-based plasticity across visual and fronto-parietal cortex in the categorization of complex dynamic patterns.

◆ **Categorical perception of faces by human and monkey observers**

G Rainer (Department of Neurophysiology, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: gregor.rainer@tuebingen.mpg.de)

When perceiving a face, we can easily decide whether it belongs to a human or non-human primate. The categorical decision of whether a face belongs to your own or a related species is of great importance for social interaction and mating. Face stimuli of humans, monkeys, and monkey–human hybrids (morphs) were used to shed light on categorization of faces into different species by humans and non-human primate subjects. Behavioral studies in both species were conducted with the goal of delineating the category boundary across the human–monkey continuum. In monkeys single unit recordings of face responsive neurons in inferior temporal cortex are currently conducted, with the goal of delineating the category boundary based on the response of these neurons to face stimuli. Preliminary findings suggest that both humans and non-human primates tend to draw the species boundary away from the centre of the continuum and that the boundary is shifted towards the category to which the observer belongs. The findings suggest differential neural mechanisms for categorization of human and monkey faces.

PLENARY LECTURE: THE RANK LECTURE

◆ **The cortical analysis of visual motion**

J A Movshon (Center for Neural Science, New York University, New York, USA; e-mail: movshon@nyu.edu)

Area MT (V5) of the extrastriate visual cortex is thought of as ‘the motion area’ because neurons there signal the true motion of complex visual patterns, a response pattern not seen in earlier visual areas. Surprisingly, this complex neuronal behavior can be accurately captured by a linear feedforward model that operates on the afferent responses of a population of nonlinear directionally selective V1 cells. This suggests that a relatively simple and experimentally tractable architecture may account for the complex transformations of visual information that take place beyond the primary visual cortex.

POSTER SESSION

BINOCULAR AND STEREOVISION

◆ **Perceptual misbinding of pattern and colour induced by visibility modulation of rivalrous stimuli**

S Abe, E Kimura, K Goryo ¶ (Graduate School of Humanities and Social Sciences, Chiba University, Chiba, Japan; ¶ Kyoto Women’s University, Kyoto, Japan; e-mail: s-abe@graduate.chiba-u.jp)

Visibility of rivalrous flashes at the onset of binocular rivalry can be modulated by monocularly presenting a stimulus prior to the flashes (visibility modulation, VM). Previously, we showed that the characteristics of the VM were different for colour and pattern stimuli [Abe et al, 2007 *Journal of Vision* 7(9), VSS07, abstract 372]. To explore how the binocular process mediating the VM integrates colour and pattern, we investigated the VM with chromatic gratings. Under the control condition where test chromatic gratings alone were presented dichoptically (an isoluminant red/gray left-tilted grating to one eye and a green/gray right-tilted grating to the other eye), the observers usually reported rivalrous percepts. However, when a chromatic grating was monocularly presented prior to the test gratings under the VM condition, the observers often reported misbinding of colour and pattern, ie they reported the percept of a red/green stripe or an isochromatic red (or green) plaid, particularly when the test duration was short. These results suggest that binocular chromatic integration can occur separately from pattern integration in the visual mechanism mediating the VM.

[Supported by JSPS grant.]

◆ **Determining size constancy after bilateral parietal damage**

M E Berryhill, R Fendrich ¶, I R Olson (Center for Cognitive Neuroscience, University of Pennsylvania, Philadelphia, USA; ¶ Dartmouth College, Hanover, USA; e-mail: berryhill@psych.upenn.edu)

The brain combines monocular and binocular distance cues with object parameters to determine size constancy. We hypothesized that the dorsal visual stream may be crucial for this process. To test this, two patients with bilateral parietal damage and simultanagnosia (patient DD: occipitoparietal damage; patient SP: midline and superior parietal damage) were tested by sequentially presenting two cubes (5, 10 cm) at several distances (28.5, 57 or 114 cm). The task was to report which cube was larger. Two conditions were compared: (i) constant retinal-size condition: retinal size was constant while physical size varied; and (ii) constant physical condition:

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retinal size was varied while physical size was constant. The results show that size constancy failed in DD in most cases. However, when retinal size was identical, DD responded correctly, possibly relying on vergence and accommodation. In contrast, SP showed intact size constancy across all manipulations. These data suggest that occipitoparietal regions are critical for combining information about size and distance for the visual guidance of action.

[Supported by NIH ROI MH071615-01 to IO.]

◆ **Binocular reference information in perception of motion in depth**

C E Grafton, H Nefs, J Harris (Department of Psychology, University of St Andrews, St Andrews, Scotland, UK; e-mail: cg33@st-andrews.ac.uk)

We explored the extent to which interocular velocity differences (IOVD), changing disparity over time (CDOT), or both binocular signals are utilized for the perception of 3-D motion in depth. We examined the relationship between reference information and detection of moving random-dot stereogram targets. In order to yield 3-D motion information, IOVD cues require temporal correlation, and CDOT cues require binocular correlation. Three types of target random-dot stereograms were generated by temporal correlation (IOVD), binocular correlation (CDOT), or both. Four types of static reference frames were also generated, applying all combinations of correlation (ie temporal and binocular; temporal only; binocular only; no correlation), but no depth modulation. Detection performance was measured as a function of signal-to-noise ratio in a 2IFC task. Results suggest that reference frames containing relevant information (ie same types of correlation) to the target type aid the perception of motion in depth. These results imply separate mechanisms at work for the different cues used.

[Funded by EPSRC.]

◆ **A 3-D model of amblyopic visual field**

A Iftime, A Thiel¶, R Sireteanu (Department of Neurophysiology, Max Planck Institute for Brain Research, Frankfurt am Main, Germany; ¶ Johann Wolfgang Goethe University, Frankfurt am Main, Germany; e-mail: adlif@yahoo.co.uk)

To achieve a better understanding of relationships between type and localization of visual misperceptions and aetiology of amblyopia, twenty-two subjects with strabismic, anisometric, or mixed amblyopia were asked to describe and sketch their percept of four artificially generated, regular geometrical patterns (gratings, checkerboard, grid), as seen with the amblyopic eye. Digital images were generated and adjusted to match their percepts. We built an algorithm that normalizes and computes Shannon entropy on the whole image and also on discrete portions of the image, arranged in a rectangular grid that covers the image. The entropy was higher in the central part of the images than in the periphery, especially in the strabismic group. We interpret the localized entropy increase as a consequence of non-overlapping receptive fields of both eyes. This is consistent with a 3-D overlapping model which shows that, for a given strabismus angle, the degree of overlapping varies with eccentricity (smaller in central areas, bigger in periphery). The overall shape of the area containing non-overlapping fields is ellipsoidal.

[Supported by grants from the Deutsche Forschungsgemeinschaft (SI 344/17-1,2) to RS.]

◆ **Effect of interocular differences in higher-order aberrations on binocular visual performance**

J R Jiménez, J Castro, C Salas, R Jiménez, R Anera (Department of Optics, University of Granada, Granada, Spain; e-mail: jrjimene@ugr.es)

We have analysed the influence of higher-order eye aberrations on binocular visual performance under mesopic conditions, measuring the aberrations in both eyes (with a Wasca aberrometer) of thirty-five emmetropic observers. Binocular visual performance was checked with two functions: binocular summation for contrast sensitivity function (CSF) and maximum disparity, a parameter that characterizes stereopsis. The results show that binocular summation and maximum disparity significantly decrease with increasing interocular differences in higher-order aberrations (total, coma, and spherical aberration). Binocular visual performance is less effective in the case of large interocular differences in higher-order eye aberrations.

[Supported by Ministerio de Educación y Ciencia (Spain) and Junta de Andalucía (Spain).]

◆ **Neuronal correlates of binocular rivalry in second-order patterns**

J Kim, C Kim¶, C-W Chung§, H R Wilson# (School of Humanities & Social Sciences, KAIST, Taejon, South Korea; ¶ New Mexico State University, Las Cruces, USA; § Chungnam University, Taejon, South Korea; # York University, Toronto, Canada; e-mail: miru@kaist.ac.kr)

It has been recently reported that there is binocular rivalry in second-order patterns with a dynamic carrier [Kim et al, 2006 *Journal of Vision* 6(6), VSS07, abstract 47a]. To find neuronal correlates of second-order binocular rivalry, we measured BOLD signal changes in early visual

cortex while subjects viewed uncorrelated dynamic random-dot fields whose contrasts were modulated at $1.5 \text{ cycles deg}^{-1}$ sine-wave with orientation of $\pm 45^\circ$. Subjects were required to press either right or left button for alternating percepts tilted rightward or leftward, respectively. We found that there is no difference of V1 activity in both hemispheres when either right or left response was made. However, there was a fluctuation of activity in V2 for alternating percepts. V2 activity increased with the right response and decreased with the left response in the left hemisphere, while the activity pattern was reversed in the right hemisphere. These results indicate that V2 area is a special site for second-order binocular processing as suggested in form and motion vision. [Supported by Korea BrainTech 21 Research Fund.]

◆ **Effects of interocular suppression on the pupillary response evoked by grating patterns**

E Kimura, S Abe, K Goryo ¶ (Department of Psychology, Chiba University, Chiba, Japan; ¶ Kyoto Women's University, Kyoto, Japan; e-mail: kimura@L.chiba-u.ac.jp)

By presenting a high-contrast grating to one eye, stable ocular dominance can be established and then a stimulus subsequently presented to the other eye would be strongly suppressed (permanent suppression). Previously, we showed that the pupillary responses to colour and luminance changes were significantly attenuated during permanent suppression [Kimura et al, 2007 *Journal of Vision* 7(9), VSS07, abstract 51]. Here, we extended our pupillometric investigation of interocular suppression into spatial domain and investigated the effects of permanent suppression on the pupillary response evoked by grating patterns. The results showed that the pupillary responses to test gratings were clearly attenuated during permanent suppression. The attenuation was observed over a wide range of test contrasts from near-threshold to well above the threshold levels. However, the magnitude of attenuation did not depend much upon the similarity in orientation between the suppressing and test gratings, although the sensitivity loss evaluated with psychophysical detection thresholds was highly selective to the orientation. These findings suggest that the mechanism that mediates the pupillary suppression may not be the same as that underlying perceptual suppression. [Supported by JSPS grant.]

◆ **Self-controlled moving system**

S K Lee, S S Lee ¶, Y T Yoon § (Department of Electrical Engineering, Jeonju University, Jeonju, South Korea; ¶ KESRI; § Seoul National University, Seoul, South Korea; e-mail: songklee@gmail.com)

A self-controlled moving robot (SCMR-I) was constructed that is tracking the object with only the image data obtained from the camera. The SCMR-I has two cameras in front. To identify the movement of the object from the images obtained by the cameras, SCMR-I uses image processing such as stereo vision, image difference, etc. Matlab is used as the image processing tool. The direction of the moving object is determined by image zone partition. The image zone partition method divides the space into several zones, and determines in which zone the moving object is located. From the two images of the stereo vision system, we can determine in which direction the object was moved. The direction calculated by the image zone partition method is transmitted to the motor controller which gives a signal to the motor to move the SCMR-I in that direction. [Supported by KESRI which is funded by MOCEI (Ministry of Commerce, Industry and Energy).]

◆ **Binocular fusion characteristics in the central part of the fovea**

Y Loginovich, A Bulatov, A Bertulis (Department of Biology, Kaunas University of Medicine, Kaunas, Lithuania; e-mail: loginovich@vision.kmu.lt)

In psychophysical experiments, the horizontal and vertical limits of binocular fusion were measured as a function of the eccentricity in the foveal region with the use of three-dot stimuli organized in right-angle patterns. The results showed a monotonous linear growth of the horizontal and vertical fusion limits. The slope ratio was approximately 2:1 and the intercept ratio about 1.4. The data are similar to the results of previous studies (Loginovich et al, 2004 *Perception* 33 Supplement, 90). The linear functions obtained were used to evaluate the extent of Panum's area in the centre of the fovea. It was approximately 10 min of arc and 7 min of arc for horizontal and vertical dimensions, respectively. Our findings are consistent with the data on the human cortical magnification factor (Grüsser, 1995 *Vision Research* 35 1125–1134) and with the assumption that the Panum area is scaled by the size of the foveal hypercolumns (Yeshurun and Schwartz, 1999 *Biological Cybernetics* 80 117–129).

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◆ **Peripheral fading of dichoptically matched and unmatched stimuli**

L Lou (Department of Psychology, Grand Valley State University, Allendale, USA;
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A peripheral stimulus disappears from awareness faster with monocular than with binocular viewing (Gonzalez et al, 2007 *Vision Research* 47 136–144). This finding may be explained in terms of interocular interactions (interocular suppression with monocular viewing and interocular facilitation with binocular fusion). A series of experiments with dichoptically matched or unmatched peripheral stimuli was conducted to test these interpretations. The main findings were: (1) the time to fade for fused dichoptic stimuli is longer than that for the corresponding monoptic stimulus, but shorter than what is predicted by a model assuming more than 50% independence of monocular adaptations; (2) the time to fade is shorter for observers with higher stereoacuity; (3) the time to fade is shorter for fused dichoptic stimuli with uncrossed, but not with crossed, disparities than for a corresponding stimulus pair with zero disparity; and (4) binocular rivalry does not affect the time to fade.

◆ **Propagation of suppression waves**

M Naber, O Carter ¶, F A J Verstraten (Department of Experimental Psychology, University of Utrecht, Utrecht, The Netherlands; ¶ Harvard University, Cambridge, USA;
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We use binocular rivalry (BR) and generalized flash suppression (GFS) to investigate the propagation of traveling suppression waves. We report several new properties of suppression waves. First, we observed a strong relationship between the speed of suppression waves and the strength of the induction stimulus. For example, increasing dot density, a measure of strength in GFS, decreased the latency of the suppression wave. In BR, we found increasing the strength (ie contrast) of the induction pulse increased the speed of the traveling wave. Second, the waves of suppression tended to decelerate as a function of distance from the inducer. Our experiments, thus far, indicate that suppression waves are similar in many respects to waves in the physical world. Moreover, we also suggest that the well-described physical properties of waves may offer important theoretical insights into the dynamic transitions in conscious vision.

◆ **Unexpected auditory and visual events speed up binocular rivalry**

A Parker, D Alais (Department of Psychology, University of Sydney, Sydney, Australia;
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Fluctuations in binocular rivalry dominance between orthogonal gratings were measured under three conditions: periodic luminance flicker, random luminance flicker, and no flicker ($N = 5$). Flicker sped up rivalry dramatically: dominance periods were 0.49 s for random flicker, 1.57 s for periodic transients, and 2.34 s for no flicker. Results were similar when luminance transients occurred in an annulus surrounding the gratings ($N = 4$; random: 0.49 s; periodic: 1.19 s; no flicker: 1.56 s), and also when auditory transients (500 Hz beeps) were used ($N = 4$; random: 0.47 s; periodic: 1.25 s; no beep: 1.98 s). Since the effect is bimodal, it suggests a process more global than visual timing, such as supramodal attention to novel events, or a distortion in a widely distributed neural timing network that may count events as part of a time estimation process. The latter possibility is supported by observers' subjective reports that alternation rates in the random condition were not perceptually faster than in normal rivalry (despite a 4-fold change), indicating a very strong dissociation between subjective time perception and physical timing.

◆ **Does stereo correspondence take account of eye position?**

G Phillipson, J C A Read ¶ (Department of Neuroinformatics DTC, Edinburgh University, Edinburgh, Scotland, UK; ¶ Newcastle University, Newcastle, UK;
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In order to fuse the images in two eyes into one, the brain has to work out which feature in the left retina is caused by the same object in space as a given feature in the right retina—this search is the stereo correspondence problem. At first sight this seems like a two-dimensional problem, as the correct match could be anywhere in the left retina. Fortunately, if eye position is known, geometry reduces this to one dimension as the correct match lies somewhere on an 'epipolar line' on the left retina. Artificial stereo systems use this constraint, updating the epipolar lines when the cameras move, in order to make the search for correspondences efficient. Surprisingly, there is currently no evidence that the brain takes account of eye position in solving the stereo correspondence problem. I describe a set of experiments designed to reveal if the brain takes account of the rotations of epipolar lines which occur when the eyes move from side to side, and present some preliminary results.

[Supported by Neuroinformatics Doctoral Training Centre (EPSRC/MRC), Royal Society, MRC.]

◆ **The disparity-gradient limit for binocular fusion is not a reflection of human vision imposing a scene surface-gradient limit**

I S Read, D Buckley, J P Frisby (Department of Psychology, University of Sheffield, Sheffield, UK; e-mail: pcp06isr@sheffield.ac.uk)

Human stereo vision is subject to a disparity gradient (DG) limit for binocular fusion, often taken as 1.0. A DG limit has been used successfully in the PMF computer stereo-algorithm to impose a scene-gradient limit, thus implementing the surface smoothness constraint. This raises the question: does the DG limit in human vision reflect a scene surface-gradient limit? If so, then individual differences in DG limit should correlate with individual differences in inter-pupillary distance (PD) because disparity from any given depth interval is scaled by PD. We found no support for this using stereograms of dipole arrays (Burt and Julesz, 1980 *Perception* 9 671–682). In a second study, we measured the fusion/diplopia scene depth-gradient limit directly using dipoles presented as real stimuli. The size of this limit correlated negatively with PD ($r_s = -0.64$, $p < 0.05$), which is predicted if scene gradient limit is the result of an underlying DG limit. These complementary studies suggest that in human vision the fusion/diplopia limit is imposed in disparity space as generally assumed.

◆ **Investigation of hemodynamic response delays on retinal-disparity data: The quest for likely connections among brain areas**

C Rondinoni, C A Galera, D B Araujo (FFCLRP—Psychology and Education, University of São Paulo, Ribeirão Preto, Brazil; e-mail: crondi@usp.br)

We aimed to localize brain areas involved in depth detection and 3-D spatial attention, and to characterize the hemodynamic properties with an fMRI examination. Data were acquired during a depth-detection task and compared with a localization-control task. Retinal disparity was produced by anaglyph glasses. Stimuli consisted of red and green anaglyphs surrounded by a zero-disparity frame. The control task consisted of alternating fingers when any figure appeared while rest blocks showed only a fixation point. The depth-detection task was to respond to crossed or uncrossed disparity. Rest condition showed zero disparity. Hemodynamic onset delay measurements were inspected from GLM-based VOIs and the relative timing among areas was estimated. Left hemisphere showed graded latencies from cingulate gyrus, through superior parietal lobe and middle occipital gyrus. The right hemisphere showed shorter latencies in the superior parietal lobe and a gradient into the middle occipital gyrus. Results are discussed in terms of a top-down attentional control, extending along the dorsal stream from paracentral areas through occipito-temporal lobes.

[Supported by FAPESP]

◆ **Paradoxical fusion of two images with a squinting eye**

S I Rychkova, V Malychev (Eye Microsurgery Clinic, Irkutsk, Russia; e-mail: rychkovasvetlana@hotmail.com)

Binocular fusion can be detected in patients with concomitant squint (one deviating, one non-deviating eye). Over 450 such patients were examined, and their deviation angle measured by the Hirschberg corneal-reflection method while they were fusing two images presented under controlled conditions with a binarimeter. In most cases, the normal eye received its image on the fovea, and the squinting eye received the other image on a peripheral area. More surprisingly, 37 patients (20 with convergent, 17 with divergent squint) experienced diplopia when viewing the test stimuli with their squinting eye alone. In addition to the foveal image, they reported the presence of a fused peripheral image. This paradoxical fusion was repeatedly observed, with classical four-point colour tests and geometric alignment tests. Lustre was also experienced monocularly with couples of images having a grey level mismatch in their central area. Knowing that each retina sends projections to both cerebral hemispheres, the locus of these unexpected and remarkable fusion effects remains to be determined.

◆ **Does emotional content influence dominance of visual percepts in binocular rivalry?**

A Sahraie, R L Bannerman, M V Milders, B de Gelder (Department of Psychology, University of Aberdeen, Aberdeen, Scotland, UK; ¶ Tilburg University, Tilburg, The Netherlands; e-mail: a.sahraie@abdn.ac.uk)

Previous research suggests that several factors including stimulus strength, context, complexity, and attention affect the dominance and suppression of visual percepts during binocular rivalry. In a series of experiments, we studied whether emotional information also impacts upon perceptual dominance in binocular rivalry. In experiment 1 we have shown that an emotional facial expression (fearful or happy) in the background of a rival display is sufficient to promote the predominance of an associated foreground stimulus. However, when emotional and neutral faces were presented dichoptically, without being associated with any other stimuli (experiment 2),

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expressive faces predominated to the extent that the neutral faces were not perceived. Response biases could not account for the results as experiment 3 examined dominance periods of fearful and neutral faces presented as face–house composites and showed that fearful faces persisted longer than neutral faces. These results indicate that emotional meaning can modulate binocular rivalry, providing further support for the preferential processing of emotional stimuli in the visual system.

◆ **Evaluation of perceived depth caused by motion parallax in the depth-fused 3-D visual illusion**

H Takada, M Date, S Suyama, A Yamori ¶, K Nakazawa (NTT Cyber Space Laboratories, Nippon Telegraph and Telephone Corporation, Tokyo, Japan; ¶ Keio University, Kanagawa, Japan; e-mail: takada.hideaki@lab.ntt.co.jp)

Using subjective tests, we evaluated the perceived depth caused by parallax produced by the motion of an observer using only a single eye when the front and rear image luminance ratio in the depth-fused 3-D (DFD) visual illusion was changed. The DFD visual illusion consists of two processes. First, two images that differ only in luminance displayed at the front and rear frontoparallel planes are perceived as a single image at one depth. Second, we can perceive a continuous depth change when the luminance ratio between the front and rear images is continuously changed according to the 3-D image depth. We have already established that depth perception in the DFD visual illusion is caused by the binocular parallax of the observer's eyes. However, we did not discuss depth perception from motion parallax. We found that perceived depth by the motion parallax changed linearly with the luminance ratio. Therefore, we conclude that the DFD visual illusion is caused not only by the binocular parallax but also by the motion parallax.

◆ **Does binocular disparity mislead stereopsis research?**

T Z Wang (Department of Automation, Wuhan University of Technology, Wuhan, China; e-mail: wtz@public.wh.hb.cn)

Since 1838 Wheatstone's invention of the stereoscope binocular disparity has been the most important type of information in stereopsis. Disparity is defined as the difference in the location of the image of an object in the two eyes. It can only be precisely measured after the location has been identified; in other words, disparity is a high-level type of visual information. However, vast results of experiments with random-dot stereograms (Julesz, 1986 *Vision Research* 26 1601–1612) demonstrate that stereopsis is a knowledge-free low-level process and precedes form perception. How a high-level type of information—disparity—can be used to depict a low-level process? In spite of Marr [1980 *Vision* (New York: W H Freeman)] the use of higher-level features, zero-crossings, as the primitive, and suggesting some additional constraints of matching, leave this problem still unresolved. In addition, the studies on Da Vinci stereopsis (eg Anderson and Nakayama, 1994 *Psychological Review* 101 414–445) show that disparity cannot be used in a half-occlusion area. All this implies that disparity may mislead stereopsis research. [Supported by NSFC No. 60275040.]

◆ **Decoding binocular-disparity processing in the human brain**

A E Welchman, S Li (School of Psychology, University of Birmingham, Birmingham, UK; e-mail: a.e.welchman@bham.ac.uk)

Sensitivity to binocular disparity is evident at multiple levels of the visual hierarchy in the primate brain. However, the relationship between this activity and key perceptual functions that exploit disparity information remains largely unknown. Here, we investigated whether we could predict selectivity for disparity-defined depth position from fMRI responses in human visual cortex. Subjects viewed random-dot stereograms (RDSs) depicting a plane closer or further than the fixation point (crossed vs uncrossed disparity). We used multivariate pattern-classification methods to predict activations across voxels in ventral and dorsal visual areas related to the different stimulus classes. We observed classification accuracies above chance across the cortical hierarchy from V1 to hMT+/V5 and LOC, with highest accuracies in V3, V3a, and LOC. However, classification accuracy was modulated when the contrast of dots presented to one eye was inverted (ie anticorrelated RDS), reducing accuracy to chance levels in V3, V3a, V4, and LOC. These findings suggest that selectivity in these human visual areas predicts the coarse depth position of disparity-defined surfaces.

[Supported by BBSRC grant to AEW.]

◆ **High-level effects in binocular rivalry**

M Wolf, S Hochstein (Department of Neurobiology, Hebrew University, Jerusalem, Israel; e-mail: michali@alice.nc.huji.ac.il)

In binocular rivalry, the brain does not fuse different images seen by the two eyes; instead, perception alternates between two views. In this study, we asked whether the content of the images

affects the dominance times, as would be expected only for high-level mechanisms. First, we compared the strength of words vs non-words. Stimuli were constructed so that one eye saw two lines of words and the other saw two lines of non-words printed orthogonally. Subjects pressed keys indicating their percept. Results show that subjects spent a longer time perceiving non-words. We then extended our study to the relative dominance of possible vs impossible figures. Participants tracked the changes in perception. We found that, with simple pictures, impossible figures were generally dominant for longer periods. These results are consistent with our hypothesis that, for higher-cortical-level mechanisms, more interesting stimuli are more salient and more dominant in binocular rivalry.

BIOLOGICAL MOTION

◆ Emotional modulation of functionally distinct neural systems by the form and motion of fearful bodies

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Ventral form processing regions are activated by fearful compared to neutral static body postures, whereas moving fearful bodies activate biological-motion-sensitive posterior superior temporal sulcus (pSTS). Yet it is unclear to which extent form and motion processing regions are differentially modulated by the relative availability of fearful body form and motion cues. We used fMRI to examine this issue by comparing activations for fearful versus neutral whole-body gestures presented in static images and in two sets of identical movement sequences differing in their form cues. Viewing fearful compared to neutral body movements in full-light displays (full form information) was associated with increased activity in fusiform and occipital gyri. Patch-light fearful movements (minimal form information) increased activity in pSTS, but did not modulate ventral occipitotemporal cortices. Thus bodily signals of fear differentially modulate regions that process the most salient aspects of the body stimuli: their biological motion and spatiotemporal form. Right dorsolateral prefrontal cortex was activated more by neutral than fearful bodies, especially in patch-light displays.

[Supported by a grant from the Department of Psychology, Durham University (APA), and the Wellcome Trust (MH and MLP).]

◆ Biological motion processing in bilateral parietal patients

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Two parietal patients were tested on flanker tasks involving biological motion (BM) stimuli and complex non-biological rotating (CR) patterns. In both tasks central target figures were presented simultaneously with two other to-be-ignored items (flankers) presented on either side of the target. Response dimensions were left/right for BM and clockwise/counter-clockwise for CR stimuli, respectively. Flankers moved in either the same direction as the target (congruent) or in the opposite direction (incongruent). Both patients performed the CR task at normal levels. In contrast, performance was severely impaired in the BM task. Specifically, they were at chance in explicitly determining the direction of motion of the central target. However, reaction times indicated that the patients still showed a dynamic congruency effect. They were much faster to respond in the congruent than in the incongruent trials. Our patients' accuracy and reaction times were normal in the CR task. Their failure to explicitly recognize the BM stimuli appears to be independent from the incidental processing and may reflect a stimulus-specific, high-level deficit.

[Supported by NEI EY15960 to LB.]

◆ Neurons in monkey pre-motor cortex (area F5) responding to filmed actions

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Mirror neurons are a class of neurons in monkey pre-motor cortex that respond both during action execution and visual perception of actions. While many studies have shown that such neurons are robustly activated under naturalistic conditions, it has been difficult to elicit single-cell responses using video stimuli. We present preliminary evidence showing that a subset of neurons in area F5 respond to filmed actions. Neuronal responses were recorded during a fixation paradigm in which a monkey was presented with filmed actions showing another monkey

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grasping either a piece of food or an object. The peak of activity of neurons responding to filmed actions—although smaller than under naturalistic conditions—clearly coincides with the moment in which the monkey's hand reaches the goal object. This observation, when compared with previous findings, confirms the role of F5 neurons in the high-level coding of observed actions. Furthermore, the use of well-controlled stimuli, such as videos, opens exciting possibilities for the quantitative investigation of their response properties.

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◆ **Rapid and efficient search of biological motion**

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Biological motion, being both dynamic and complex, is potentially interesting for visual search. However, peripheral perception of biological motion is difficult and search times are very long, compared to faces and animals. In a new paradigm, we presented biological motion as stick figures rather than as light-points to reduce peripheral grouping problems. This brought search times down to about 15 ms per item. Our experiments show that biological motion is found much faster by form than by dynamics. Our analysis provides evidence for a parallel search mechanism. Moreover, search of non-biological motion was as fast, suggesting a similar parallel process.

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◆ **Impaired perception of biological motion in children with periventricular leukomalacia**

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It has recently been suggested that children with periventricular damage show an impairment of perception of biological motion (Pavlova et al, 2003 *Brain* **126** 692–701; Pavlova et al, 2006 *Neuropsychologia* **44** 586–593), although precise thresholds have not been measured. We measured signal-to-noise thresholds for perceiving the direction of ambulation of a point-light walker, and of simple translational motion in a group of children with periventricular leukomalacia (PVL). Compared with age-matched controls, PVL thresholds were far worse for biological motion (factor of two), but only slightly worse with translational motion.

◆ **Rotating walker: Multistable perception of an ambiguous biological figure**

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Previous research has shown that biological motion stimuli lacking explicit depth cues exhibit perceptual multistability (Vanrie et al, 2004 *Perception* **33** 547–560). We demonstrate multistable perception of a rotating human figure whose form is defined from the motion of a small number of orthographically projected local dots. With periods of extended continuous viewing (300 s), observers report high rates of rapid and repeated perceptual switching; the rotating walker appears to randomly alternate between walking in clockwise and counter-clockwise directions, in some cases reversing 80 or more times over the 5 min trial. When an intermittent presentation technique is introduced (present 3 s, ISI 5 s), the viewers interpretation consistently stabilizes, an effect found previously with some well-studied multistable stimuli (Leopold et al, 2002 *Nature Neuroscience* **5** 605–609). We discuss the possible mechanisms underlying perception of this ambiguous biological figure, in addition to outlining the steps in creating the stimulus.

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◆ **Perception of three-dimensional biological motion from limited lifetime stimuli**

S Kuhlmann, M H E de Lussanet, M Lappe (Department of Psychology, Westfälische Wilhelms-Universität, Münster, Germany; e-mail: kuhlmanns@psy.uni-muenster.de)

Biological motion perception is often studied with point-light walkers seen from the side, but it excels also when point-light walkers are seen from the front or in intermediate orientations. The computational requirements are higher in the latter case because movement in depth introduces additional degrees of freedom. Biological motion perception in the profile view does not require local motion of the point-lights. However, in the case of stimuli oriented in depth the need to analyze movement in depth may recruit motion signal analysis for kinetic depth perception. Thus, motion signals that are not necessary for walkers in profile view may become important for three-dimensional walkers. We tested this with limited-lifetime biological motion stimuli. We find that three-dimensional biological motion can be perceived with point lifetimes of one frame,

ie when the points give no local motion. We further find that a discrimination between forward and backward walking relies strongly on the movement of the lower leg, and becomes difficult in the frontal view when the lower-leg movement is difficult to ascertain.

◆ **Perception of biological motion during locomotion in a virtual environment**

S Mouta, J A Santos (Institute of Education and Psychology, University of Minho, Braga, Portugal; e-mail: smouta@iep.uminho.pt)

The classical studies on the perception of biological motion (BM) use impoverished stimuli without translation for the identification of moving patterns. A previous psychophysical study demonstrated that a velocity match between translational point-light walker (PLW) was poorest and greatly biased by background contrast when compared with rigid translational motion. The current work combines two methodologies to develop the study of BM perception. A computational method considers the quality and quantity of information presented by BM stimuli. The impoverishment of PLW leads to a decrease of the body rigidity increasing the patterns complexity. The relative motion between opposing vectors in complex patterns may contribute to an impaired speed perception. We manipulated the structure of BM stimuli differentiating complexity levels through an optic flow analysis. Moreover, the visual analysis of human motion in a classical setup differs substantially from analysis under more realistic conditions. An action–perception paradigm in a virtual environment allows us to compare perceptive judgments raised by different stimuli representations during locomotion and to gather visually guided motor responses. [Supported by Foundation for Science & Technology, Portugal, Grant SFRH/BD/18265/2004.]

◆ **Ability to anticipate human action affects perceived audiovisual synchrony**

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Aymoz and Viviani (2004 *Vision Research* **44** 1547–1563) found that for biological movements the lag between perceived changes in movement and those in other visual properties was suppressed. They suggested that this effect might depend on humans' ability to anticipate the gestures by simulating the observed action. We investigated this hypothesis by measuring the audiovisual integration window of human actions. We created 42 point-light movies of a drummer performing swing groove on a drumhead (ie 3 tempos \times 2 levels of audiovisual congruence \times 7 delays). Additionally, 42 movies were created by eliminating the drumhead. Absence of the drumhead induced participants to observe the drummer movement when judging the synchrony, instead of focusing on the impact of the stick on the drumhead. Twenty repetitions of each movie were presented in two separate sessions for the two drumhead conditions, during which participants gave forced-choice judgments of audiovisual synchrony. Our preliminary results show a substantial effect of drumhead presence/absence on perceived audiovisual integration, suggesting that anticipation due to action simulation changes perceived synchrony.

[Supported by The British Academy.]

◆ **Asymmetry of emotions expressed in full-body movement**

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The left half of the human face is more emotionally expressive than the right, as has been shown using 'chimeric' pictures, with one hemiface replaced by the other's mirror image. This finding has been interpreted as supporting a 'right-hemisphere model' of emotion. Alternatively, it has been discussed that asymmetry might be reduced for positive emotions. We investigated movement and expressiveness asymmetries between left and right hemibody in emotional movement. We compared movement amplitudes and kinetic energy between left and right joint angles in emotionally expressive (angry, happy, sad, fearful) walking. 'Chimeric walkers' were created by animating an avatar with the joint movements of one body side replaced by those of the other, with appropriate temporal alignment. Observers rated the expressiveness of the original animations, and of right–right and left–left chimerae. The left side of the body exceeded the right in movement amplitude and energy for all emotions, especially in upper-extremity movement. Higher expressiveness ratings for left–left than right–right walkers indicate that bodily emotion expression is consistent with the right-hemisphere model.

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Wednesday

◆ **Look who's talking: Visual detection of speech from whole-body biological motion cues during interpersonal conversation**

D Rose, T J Clarke (Department of Psychology, University of Surrey, Guildford, UK; e-mail: d.rose@surrey.ac.uk)

We previously demonstrated that point-light displays of human whole-body motion can reveal an actor's emotional state, but social context influences this ability in that for some emotions two actors are better than one (Clarke et al, 2005 *Perception* **34** 1171–1180). Our displays showed two professional actors engaging in verbal discourse while expressing various mood states (with no soundtrack or visible intrafacial or oral motion). An interesting question remaining is the role of biological motion cues in conversation per se, since such dialogue is normally aided by non-verbal markers (such as gestures and head-nods) which guide and coordinate the exchange. We therefore showed our stimuli to a fresh group of observers and simply asked who spoke first. Significant ($p < 0.001$) identification of the speaker was obtained overall, and in particular when the expressed emotion was anger, joy, sadness, or love but not fear or disgust ($p < 0.05$). Observers can therefore often identify which of two people is speaking from their body movements alone.

◆ **Perception – action coupling in learning new skills: EEG analysis of imitation of hand movements**

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Imitation requires watching someone and transforming visual information about limb motion into motor commands. Some theories suggest this complex task is partially facilitated by information about limb movements and dynamics, which is available in the kinematics, activating motor cortex. Here we track activity in motor areas using μ -rhythm desynchronization. We investigated whether a single attempt to imitate an action influenced a second observation of the same action. We taught subjects a new complex manual action (writing Cham script letters) by watching a video of a hand demonstrating each letter. The μ rhythm was significantly more desynchronized to the second observation of an action than the first observation, relative to a condition where subjects saw the action but were instructed to write an English letter. These findings support the hypothesis that the perceptual processes involved in observation with the intention to imitate depend on previous motor experience of the action to be imitated.

◆ **Perception of biological motion in noise: No need for a specific segregation mechanism based on local-motion information**

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Perceiving a point-light walker in noise requires the ability to decide which points belong to the walker. Our aim was to investigate whether there is a specific segregation mechanism which uses local-motion signals to separate the stimulus-points from the noise-points. We therefore tested biological motion perception under different conditions for the lifetime of stimulus and noise dots. The task was either to decide about the orientation of a walker (left or right) or about the direction of walking (forward or backward). The lifetime of stimulus and noise varied independently and could be either two frames (local motion) or one frame (no local motion). We found no advantage for conditions in which lifetime of stimulus and noise differed. Thus, our results do not indicate that there is a specific segregation mechanism based on local-motion information. The results are in line with the predictions of a template-matching model, which uses a global form template and its temporal evolution for the analysis of biological motion from point-light stimuli.

CONTRAST

◆ **Luminance pedestal effects on pattern detection**

C-C Chen, S-Y Lin, Y-C Lin, S-T Kuo ¶ (Department of Psychology, National Taiwan University, Taipei, Taiwan; ¶ Taiwan TFT-LCD Association, Hsinchu, Taiwan; e-mail: c3chen@ntu.edu.tw)

We investigated the effect of local luminance change on spatial-pattern detection. The targets were Gaussian spots with scale parameter (standard deviation) ranging from 0.13 to 1 deg. The local luminance pedestal varied from 1 to 68 deg radius and mean luminance varied from 2.9 to 58 cd m^{-2} . We used a QUEST adaptive-threshold seeking procedure and 2AFC paradigm to measure the target contrast threshold at different target sizes and pedestal size and luminance.

The target threshold decreased with target size with a -0.5 slope on log-log coordinates up to 0.3 deg. There was little, if any, threshold reduction as the target size further increased. This spatial summation curve had the same shape at all pedestal luminance levels and size. The effect of the pedestal was to shift the summation curve vertically on log-log coordinates. The visibility of the target can be modeled by a function with a form $f(L, s) \times g(s_t)$ where $f(L, s)$ is a function of pedestal luminance and size and $g(s_t)$ is a function of target size.

[Supported by Taiwan TFT LCD Association.]

◆ **How does letter identification change with time and crowding?**

H K Falkenberg, P J Bex¶ (Department of Optometry and Vision Science, Buskerud University College, Kongsberg, Norway; ¶ Schepens Eye Research Institute, Boston, USA; e-mail: h.falkenberg@hibu.no)

We used an equivalent-noise paradigm to analyze the basis of letter contrast-sensitivity changes with exposure duration and under crowded conditions. Letter-contrast identification thresholds were measured at 4 deg eccentricity in a 26AFC task. Targets were presented for 27 to 430 ms on a noise background whose rms contrast was systematically varied from 0% to 40% , under crowded or uncrowded conditions. Equivalent-noise analysis of the letter-threshold versus background-contrast functions was used to estimate internal noise and sampling efficiency. Contrast sensitivity increased with duration in all conditions. In uncrowded conditions, the improvement was mostly based on an increase in sampling efficiency over time. In crowded conditions, the improvement with exposure duration was associated with a reduction in internal noise and an increase in sampling efficiency. The presence of flanks elevated internal noise, but only at brief durations, and reduced sampling efficiency at all durations. We speculate that the improved letter identification arising from efficiency increases is related to the recruitment of additional high spatial frequencies over time.

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◆ **Contrast sensitivity in the barn owl**

W M Harmening, P Nikolay, J Orłowski, H Wagner (Department of Zoology and Animal Physiology, RWTH Aachen, Aachen, Germany; e-mail: wolf@bio2.rwth-aachen.de)

Barn owls are excellent candidates for studies of orientation behaviour, both in the auditory and visual domain. One of the fundamental functional descriptions of a visual system is the contrast sensitivity function, which is surprisingly lacking in barn owl literature up to now. In this study a behavioural measure of contrast sensitivity in the barn owl is presented. Three American barn owls were trained to discriminate two discrete axes of a Gauss windowed sinusoid grating (Gabor patch), presented either in horizontal or vertical orientation. When owls reached significant performance in a 2AFC psychophysical paradigm during the training, the experimental phase began. Michelson contrast was altered randomly between 0.992 and 0.01 for every stimulus presentation (constant-stimuli design). The contrast sensitivity (CS) was calculated from the inflection point of the corresponding psychometric function for 10 individual spatial frequencies, covering 3.5 octaves of the spectrum. A peak CS of about 20 was found at 1.1 cycles deg^{-1} . The high-frequency cut-off was at 2.3 cycles deg^{-1} , the low-frequency cut-off was at 0.3 cycle deg^{-1} .

◆ **Effect of figural context on contrast-detection threshold of collinear Gabor patches**

M Kikuchi, K Masuda¶ (School of Computer Science, Tokyo University of Technology, Hachioji, Japan; ¶ ITOCHU Techno-Solutions Corporation, Chiyoda, Japan; e-mail: kikuchi@cs.teu.ac.jp)

It has been revealed that contrast-detection threshold of a Gabor patch flanked by collinear mask Gabor patches is lower than the threshold of a single Gabor patch (Polat and Sagi, 1994 *Vision Research* **34** 73–78). We investigated whether such a threshold reduction also occurs when collinear mask patches comprise a part of a figure. We used following types of stimuli. Type I stimuli included a single Gabor patch. Type II stimuli added collinear mask Gabor patches on one side of the type I patch. Type III stimuli extended type II stimuli so that the collinear mask patches in type II stimuli constituted a side of a square, by adding three sets of collinear patches forming three sides of the square. We found that the contrast-detection thresholds for types II and III stimuli were lower than for type I stimuli, but there were no significant difference between types II and III stimuli. These results suggest that the figural context of mask Gabor patches has little effect on contrast-detection threshold.

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Wednesday

◆ **Vernier position discrimination of interpolated and illusory contours: Common or separate mechanisms?**

L Minini (Department of Physiology, Anatomy and Genetics, University of Oxford, Oxford, UK; e-mail: lori.minini@dpag.ox.ac.uk)

Humans can detect displacements of luminance-defined stimuli that are much smaller than the resolving power of the visual system [Westheimer, 1981 *Progress in Sensory Neurology* (New York: Springer)]. Previous findings suggest that Kanizsa and luminance-defined contours are functionally equivalent in the hyperacuity range (Dresp and Bonnet, 1991 *Vision Research* 31 1813–1817); however it is still unclear whether these borders are localized with equal precision. This question was explored with a three-line Vernier acuity task, a range of lateral offsets, and collinear reference elements that consisted of luminance-defined lines, inducers that formed or did not form a Kanizsa contour, and crosses. Responses were mapped psychometrically and Vernier thresholds (75% correct) obtained with Probit analysis. No significant differences in thresholds were observed between stimuli with and without the illusory contour, suggesting that gap interpolation was equally accurate in these conditions. The results indicate that Kanizsa contours do not improve Vernier position discrimination, and argue for separate mechanisms mediating contour interpolation and illusory-contours perception.

◆ **Measuring the visible range of high-dynamic-range images**

A Rizzi, M Pezzetti, J J McCann¶ (Università degli Studi di Milano, Dipartimento di Tecnologie dell'Informazione, Crema, Italy; ¶McCann Imaging, Belmont, USA; e-mail: rizzi@dti.unimi.it)

We made pairs of identical film transparencies. We viewed one (single-contrast), then two superimposed in registration (double-contrast). Single-contrast images have 2.7 \log_{10} dynamic range; double-contrast ones 5.4 \log_{10} range. Observers estimated the appearance of 40 gray areas surrounded with white and black blocks of different sizes. First, the surround had equal white and black areas (average single-contrast luminance = 50.01% max; double-contrast = 50.00% max). Doubling the contrast had minimal effect on retinal glare. Magnitude estimates show nearly the same plot (appearance vs log luminance) for both contrasts in the range of 0.0 to 2.3, and no discrimination at higher optical densities. Second, with a 8% white–92% black surround appearances ranged from 0.0 to 2.7. Increasing the stimulus range had little effect on appearance. Decreasing the white area of the surround decreased veiling glare and increased the range of usable densities. These, and other experiments, measure how veiling glare controls the range of appearance in high-dynamic-range images.

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◆ **Brightness enhancement when looking through a tube**

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A surface viewed through a dark-walled tube appears strikingly brighter and of higher contrast than the same surface viewed by the unobstructed eye (the tube effect). In this experiment the left eye viewed the left half of a calibrated computer screen through a tube (4 cm diameter, 30 cm length), while the right eye looked at the right half without a tube. A series of fixed luminances for the left eye (5–40 cd m^{-2}) was matched in brightness by the right eye. The luminance required for matching the brightness viewed through the tube was found to be twice as high as the reference luminance. The effect was eliminated when a black divider separated the two hemifields. Additional observations are: (i) The tube effect develops over a few seconds. (ii) It is strongest when the tube is held close to the eye. (iii) With a translucent tube, enhanced darkness is sometimes seen. The tube effect may be largely due to simultaneous contrast elicited by the graded luminance profile at the mouth of the tube.

◆ **Contrast dependent response latency in a spiking neural network**

L C York, M Oram¶, M van Rossum (University of Edinburgh, Edinburgh, Scotland, UK; ¶University of St Andrews, St Andrews, Scotland, UK; e-mail: lcyork@yahoo.co.uk)

The onset latency of single neuron responses in the visual system depends strongly on stimulus contrast. While in V1 latency increases are tens of ms, in higher visual areas (IT) the latency can increase 200 ms at the lowest contrast (Oram et al, 2002 *Philosophical Transactions of the Royal Society B: Biological Sciences* 357 987–1001). We present a layered neural network model of noisy integrate-and-fire neurons. Crucially, the model has strong recurrent connectivity and synapses with short-term synaptic depression. With these realistic ingredients, the model reproduces the contrast-dependent latencies. The model furthermore predicts a strong dependence of

the spiking statistics on the contrast and time after stimulus onset. We analysed the response statistics predicted by the model and compared them to the data. The study shows that recurrence and short-term synaptic depression are important to explain dynamics and statistics of visually evoked responses in higher visual areas.

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LIGHTNESS AND BRIGHTNESS

◆ **Thresholds for luminosity and causality in the animated glare effect**

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This work is an extension of findings reported earlier (Zavagno and Bressanelli, 2006 *Perception* 35 Supplement, 182) concerning a peculiar case of perceptual causality in animated-glare-effect displays (AGE). We noticed that different speeds at which luminance ramps changed cyclically (maximum range: black to white in 256 luminance steps; minimum range: homogenous black) modulated the impression of perceptual causality expressed in terms of an apparent-light expanding from a central square causing shading changes in a cross configuration. In particular, slow animations (5 frames s^{-1}) showed weak causality responses, expressed in terms of a temporal scission between a first non-causal event (luminance ramps are perceived as color changes) and a second perceptual reorganization into a causal event (apparent luminosity is suddenly seen as causing actual shading), while fast animations (100 frames s^{-1}) showed always strong causality responses. Here, we investigated the correlations between luminosity thresholds in two AGEs (5 frames s^{-1} , 50 frames s^{-1}) and respective thresholds for the perception of causality. The threshold for causality was significantly higher for the slow animation, in agreement with our hypothesis of perceptual reorganization.

◆ **Single dissociation between lightness contrast effects**

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Most observers report that a gray square on a white background appears darker than the same gray placed on a black background. Relatively few studies have focused on the variability in judgments between different observers who make lightness matches for physically identical targets on different backgrounds. Here, we present data on a distinct group of functional superseers within the normal population who, even after confirmed lightness matching instructions, report lightness equivalence between targets of the classic side-by-side simultaneous lightness contrast display (SLC). Interestingly, these same observers report significant differences in lightness between the physically identical targets in White's display. We have yet to find observers with normal vision who experience the classic SLC effect and not White's effect. This single dissociation suggests a need for a re-evaluation of models which attempt to explain both effects with the same underlying mechanism or computational rule.

◆ **Global belongingness factors can give rise to White's effect**

A C G Galmonte, T A Agostini ¶, A Soranzo §, A Gherzil ¶, A Schepis # (Department of Psychology and Cultural Anthropology, University of Verona, Verona, Italy; ¶ University of Trieste, Trieste, Italy; § Teesside University, Middlesbrough, UK; # University of Macerata, Macerata, Italy; e-mail: alessandra.galmonte@univr.it)

Munker–White's illusion is an optical effect illustrating the fact that the same target luminance can elicit different perceptions of lightness in different contexts. White's effect is consistent with simultaneous contrast. Agostini and Proffitt (1993 *Perception* 22 263–272) showed that perceptual belongingness (the subsumption of some set of elements into a perceived whole) could cause simultaneous lightness contrast to be seen in configurations in which the inducing elements are not adjacent to the target. In the present work, in Agostini and Proffitt-type configurations we obtained, by means of the perceptual organisation factors of similarity and good continuation, displays in which a White effect determined by belongingness in absence of spatial contiguity is achieved. The factors we manipulated were achromatic colour (high–low reflectance) and shape (circle–square) of the inducing elements of the display, which was always placed on a mid-reflectance background. We tested also double-increments and double-decrements conditions. Even if there are no junctions at all, the classic White effect can be observed. Results are discussed within the relevant literature.

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Wednesday

◆ **Whiter than white, blacker than black—overshot in lightness perception**

J Geier, L Séra ¶, M Hudák§ (Stereo Vision Ltd, Budapest, Hungary; ¶ Kodolanyi Janos University College, Székesfehérvár, Hungary; § ELTE, Institute of Psychology, Budapest, Hungary; e-mail: janos@geier.hu)

We investigated a new illusion: while the contrast of a patch (sharp-edged disk, Gauss patch) in a homogeneous background is continuously reduced until zero and the observer is fixating a signed point, the illusory inverse of the patch is perceived at the end of that process. (In the case of a Gabor patch, an illusory displacement is perceived.) The illusion occurs even on a totally white or black background. The phenomenon cannot be considered as a classical afterimage, since it appears even with black or white patches, at short exposure (< 1 s), at low contrast ($< 10\%$), and is eliminated by eye movements. In our experiment ($N = 20$) subjects were asked to stop the computer-controlled contrast-reduction the moment they perceived the disappearance of the patch. The patch turns into illusory inverse well before its physical contrast reaches zero. We have modelled the phenomenon with a retinotopical set of PID controllers: the cause of the overshoot is the 'maladjusted' D component. Our model also provides a new explanation for the Breathing Light illusion.

◆ **Articulation: Number of shades or number of surfaces?**

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In any given scene, articulation could have either a photometric (number of shades or reflectance levels) or a geometric (number of surfaces) meaning. Although the former meaning is more common today, the latter was the original sense, introduced by Katz in 1935. The present study was conducted to distinguish between these two forms of articulation and to measure their separate contributions in a scene. Each display had a single target embedded in a larger background. The background varied along two dimensions: the range of shades and the number of surfaces. Shades spanned the full black–white range or a much narrower light gray–white range. The number of surfaces was between 2 and 20. The display was placed in the specially designed chamber with controlled illumination and viewing conditions. Observers made lightness matches using a Munsell chart. Although both photometric ($F_{1,25} = 32.638$, $p < 0.0001$) and geometric ($F_{1,25} = 5.207$, $p = 0.0313$) articulation produce effect measurable for different shades of targets ($F_{1,25} = 6387.162$, $p < 0.0001$), the photometric articulation makes a larger impact on the lightness of the surface.

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◆ **Equating the appearance of neutral density filters: Luminance dominates contrast**

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Neutral density filters (NDFs) are characterized by reflectivity (β) and inner transmittance (θ). We asked whether psychophysical observers are able to match the parameters (β and θ) of two simulated NDFs placed over backgrounds that differed in mean luminance and contrast. Subjects adjusted the two parameters of a simulated NDF in a match stimulus so that it appeared to be identical to a simulated NDF in a target stimulus. Subjects were very poor at matching the parameters of the two NDFs. However, the resulting mean luminance in the filter region of the match stimulus was well predicted by the target stimulus. Conversely, the resulting contrast in the filter region of the match stimulus was poorly predicted by the target stimulus. Very similar results were obtained when subjects adjusted luminance and contrast to make the matches. We conclude that, when subjects are able to adjust two parameters of a simulated NDF simultaneously, their settings are dominated by luminance, and contrast is set only approximately.

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◆ **Adaptation to glare restores lightness constancy**

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Failures in lightness constancy were found when an increment test on a dark surround was viewed under a transient glare condition. We check the hypothesis that these failures may be temporal and that, under steady conditions, constancy may still be achieved. We conducted an experiment in which twelve subjects compared incremental tests viewed under steady glare conditions (30 lx and 60 lx) with a Munsell scale without glare, by mean of a haploscopic arrangement. Two conditions were considered, light surround (0.5 cd m^{-2}) with tests from

0.75 cd m⁻² to 4 cd m⁻², and dark surrounds from 0.125 cd m⁻² to 0.35 cd m⁻² with a fixed test (0.5 cd m⁻²). Results from the first experiment showed rising lightness rating for stimuli in a light surround. The second experiment showed lightness rating to be constant for stimuli in dark surrounds (mean values of 4.5 and 4.8 for 30 lx and 60 lx, respectively). In addition, there was no significant difference between the results obtained for the two levels of glare.

◆ **Picture perception and scene perception: Effect of binocular-disparity and motion-parallax depth cues on lightness perception in 3-D virtual scenes**

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We investigated how available depth cues affect perception of lightness in three-dimensional rendered scenes containing strong gradients of illumination in depth. Observers viewed a virtual room (4 m width × 5 m height × 17.5 m depth) with checkerboard walls and floor. In four conditions, the room was presented with or without binocular disparity (BD) cues to depth and with or without motion parallax (MP) cues to depth. In all conditions, observers were asked to adjust the albedo of a standard surface to match the lightness of test surfaces placed at seven different depths (8.5 m–17.5 m) in the scene. We estimated lightness-versus-depth profiles in all four depth-cue conditions. Even when observers had only pictorial depth cues (no MP, no BD), they partially but significantly discounted the illumination gradient in judging lightness. Adding either MP or BD led to significantly greater discounting and both cues together produced the greatest discounting. The effects of MP and BD were approximately additive. BD had greater influence at near distances than at far distances.

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◆ **Vasarely illusion: A sensory effect might be reduced by depth cues**

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Vasarely illusion is considered as a sensory illusion and a glowing illusory cross along the diagonals of the squares is explained as a result of lateral inhibition of ganglion cells at the retina. I constructed several variants of Vasarely's pattern using depth cues, which might differentiate the squares perceptually in 3-D space. There were occlusions, attached shadows, and disparity cues. The cues were placed in display images in such a way that the brightness discrimination along the diagonals of the squares was not changed. I investigated the strength of the glowing illusory cross using a two-alternative forced-choice discrimination task. Ten naive human subjects were tested. Results showed that the strength of illusory cross was significantly weakened when the cues were brought into the scene. So, any cues starting up the process of scission might eliminate an illusory effect induced by low-level sensory mechanisms.

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◆ **Influence of spatial-frequency distribution in brightness perception of light environment**

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Brightness perception of light environment depends not only on illuminance or mean luminance value, but also on the luminance distribution of the scene. We conducted a psychophysical experiment by employing pictures of light environment as image stimuli and analyzed the data from a viewpoint of spatial-frequency information processing in order to estimate the effects of nonuniform luminance distribution in brightness perception. Still pictures of scenes in a room (reference images) were modified with a two-dimensional frequency analysis: low-pass filtering and contrast-gain operation in spatial-frequency dimension for providing test images. By adjusting the brightness of the reference images to that of the test images, equi-brightness pairs of reference and test images were derived. The results show that, even though the mean luminance value is constant, the brightness of contrast-decreased images substantially decreases and that of low-pass-filtered images slightly decreases, suggesting that all spatial-frequency channels operate for brightness perception but low-spatial-frequency components of the images are critical factors for increasing brightness.

◆ **Lightness computation in minimal images: Effects of relative and cumulative area, articulation, illumination, and dark adaptation**

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

Observers' heads were placed inside a large hemispheric dome so that their entire visual field was filled by only two gray shades. The domes varied in terms of relative area, articulation, illumination

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level, and presence/absence of dark adaptation. Each condition was viewed by a separate group of twenty observers. We found that: (i) the lighter region was always seen as white or nearly white; (ii) increase in area of the darker region could increase its lightness by 3.5 Munsell steps, but only when that region was larger than half the total area; (iii) this effect was not cumulative: it applied only when a single region was larger than half the total area, and not when the same area was presented in four separate regions; (iv) by itself, the number of elements in the dome had no effect; (v) varying the illumination by a factor of 225 had almost no effect on the lighter region and caused the darker region to change by about 1 Munsell step; (vi) dark adaptation had no effect.

[The authors thank Jennifer Faasse, Oscar Escobar, Camilo Marmolejo, and Amanda Ebokosia for their help in data collection.]

◆ **A new effect of brightness induction caused by a stepwise-expanding disk**

K Sakurai (Department of Psychology, Tohoku Gakuin University, Sendai, Japan;
e-mail: sakurai@mind.tohoku-gakuin.ac.jp)

A stepwise-expanding black disk produces brightness induction on a white background around the disk. The area around the disk is perceived brighter than the remaining background area, and it looks like a total solar eclipse. The effect caused by stepwise expansion is stronger than that caused by continuous smooth expansion. The optimal condition for the effect was investigated by changing the smoothness of the expanding motion. In movie stimuli in which a black disk expanded from 1 to 20 deg in diameter, the number of total frames of the movie and its frame rate were varied. To measure the strength of the effect, observers performed the magnitude estimation of the perceived brightness around the disk. The maximum effect was obtained when the number of total frames was 20 and the frame rate was 10 frames s⁻¹. The optimal condition is that the disk expansion in diameter is in steps of 1 deg, and the duration of each frame is 100 ms.

◆ **Visuomotor priming reveals early stages of contrast processing**

T Schmidt, S Miksch, L Bulganin (Department of General and Experimental Psychology,
University of Giessen, Giessen, Germany; e-mail: thomas.schmidt@psychol.uni-giessen.de)

We studied the effect of a brightness-contrast illusion on a visuomotor priming task. Speeded key-press responses to the arrangement of a dark and a bright luminance target were performed in the presence of preceding dark and light flanking stimuli whose apparent brightness was enhanced or attenuated by a contrast illusion. When the illusion amplified apparent flanker contrast, flanker arrangements consistent with the target arrangement speeded responses, while inconsistent flanker arrangements prolonged them. When the illusion attenuated apparent flanker contrast, this priming effect reversed, despite the fact that the more luminant flanker always appeared brighter than the less luminant one. Our data show a qualitative dissociation of contrast processing in priming and conscious vision, contradicting theories that priming is based on raw physical stimulus features. We propose that priming effects, as opposed to conscious perception, measure an early stage of lightness processing that is based on only local contrast information.

[Supported by the German Research Foundation.]

◆ **A new explanation for brightness illusions**

S Somiya (Japanese Psychological Association, Meijo University, Nagoya, Japan;
e-mail: sohmiyaseiyu@gmail.com)

Although many researchers have attempted to explain brightness illusions, no complete agreement has yet been reached. Here I report that two factors are essential for studying them and propose a new explanation based on the differences of logical interpretations for the brightness illusion displays. The factors are: (i) a possibility that our visual system unconsciously infers three light-source positions for segments in the displays (the front of the segments, the segments themselves, and the back of the segments), and (ii) a possibility that our visual system interprets a non-transparent segment in brightness-illusion displays not only as a non-transparent surface illuminated from the side, but also as a transparent segment illuminated from behind, a shade, a cast shadow, a self-luminous segment, or a space. If our visual system takes these factors into account and selects more likely solutions out of possible interpretations, it is not surprising that a physically identical gray is perceived as having a different brightness.

◆ **The role of perceptual distance in the assimilation/contrast shift phenomenon**

A Soranzo, N D Puppa, G Quinn (School of Social Science and Law, University
of Teesside, Middlesbrough, UK; e-mail: a.soranzo@tees.ac.uk)

Contrast and assimilation are opposite phenomena: in the contrast, grey targets appear darker when bordering bright surfaces (inducers) rather than dark ones; in the assimilation, the opposite occurs. The question is: what factor favours the occurrence of one phenomenon over the other?

Researchers provided two types of answers to this question, in accordance with the level of the visual process they refer to. Low-level advocates focused on the spatial frequency of the inducers; high-level supporters concentrated on the figure/ground segregation. An experiment on an IT system equipped with goggles for the stereo vision was run to compare these viewpoints. Observers were asked to evaluate the lightness of the target, by manipulating two variables: (i) the perceptual distance between inducers and target, and (ii) the inducers' intensity. Results show that, when the inducers' spatial frequencies are kept constant, the lightness of the target depends on the perceptual distance between inducers and target together with the inducers' intensity. We conclude that, when directly compared, high-level mechanisms may overcome the effects of low-level ones.

[Supported by 06 Tees Valley's Digital City.]

◆ **Breaking down the Benary Cross**

M L T Vergeer, R van Lier (Nijmegen Institute for Cognition and Information [NICI], Radboud University Nijmegen, Nijmegen, The Netherlands; e-mail: m.vergeer@nici.ru.nl)

We present large reductions of lightness differences in the Benary Cross by breaking down its global appearance and, with that, changing the perceived figure-background relations. We start with the traditional Benary configuration in which a grey triangle superimposed on a black cross appears lighter than a grey triangle juxtaposed to that cross, even though the triangles are surrounded by the same amount of black and white. In our experiment, the global shape of the cross is manipulated by creating triangular notches at corresponding positions along the contours of each bar of the cross (the local surroundings of the patches stay the same). As a result, the previously superimposed triangle now appears juxtaposed to the indented cross, revealing a reduction of lightness differences. Subsequently, local differences between both patches are nullified by shifting the notches along the contours of the cross, which leads to a further decrease of lightness differences. Finally, after rotating the resulting image by 45°, lightness differences are even reversed. Experimental data confirm the above observations.

[MV is supported by a grant from the Netherlands Organisation for Scientific Research (NWO).]

◆ **The contribution of binocular cues to gloss perception**

G Wendt, F Faul, R Mausfeld (Institut für Psychologie, Universität Kiel, Kiel, Germany; e-mail: gunwendt@psychologie.uni-kiel.de)

The visual system uses several cues to estimate the glossiness of a surface. A well-known example is local intensity peaks ('highlights'). Many of these cues are available under monocular viewing conditions and are used to render gloss in photographs or paintings. Under ecological binocular-viewing conditions, however, additional information is available. Generally, the positions of the highlights are shifted relative to corresponding surface points in the two monocular half-images. Hence, the highlights have a different disparity ('highlight-disparity') than the surfaces. We investigated whether the visual system takes this binocular information into account. In our rating and matching experiments we used complex, three-dimensional curved surfaces, which were presented on a CRT and fused by means of a mirror stereoscope. The glossiness of these computer-generated stimuli was varied by adjusting the exponent in the Phong lighting model. The highlights were presented either with or without 'highlight-disparity'. Our results indicate that the availability of binocular gloss cues enhances both the authenticity and the strength of perceived gloss.

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◆ **Segmentation and anchoring in lightness perception**

D Wollschlaeger, B Anderson¶ (Department of Psychology, University of Kiel, Kiel, Germany; ¶ University of New South Wales, Sydney, Australia; e-mail: dwoll@psychologie.uni-kiel.de)

We report results from asymmetric lightness and transmittance matching tasks with stereoscopically presented gradient stimuli that provide evidence for the importance of laminar segmentation in lightness perception. Subjects were shown stereoscopic pairs of circular achromatic gradients where either the inner or the outer luminance matched the luminance of the uniform background. The gradients contained a number of randomly distributed dots of the background luminance that carried far disparity. Under stereoscopic viewing conditions, this gradient was perceived as a uniform background surface seen through a hole cut into a uniform foreground layer, the hole being covered by a transparent filter with varying degrees of transmittance. Subjects made lightness matches using a uniform reference patch, and made transmittance matches by adjusting the center contrast of a center-surround cosine-wave grating. For decremental gradients, anchoring perfectly held, and the luminance variation was fully attributed to the changing layer transmittance. For incremental gradients, contrast polarity to the surround was not the sole determinant of lightness.

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- ◆ **Ground is stronger than figure: The perceptual lightness in figure – ground scission patterns**
Y Yamaguchi, I Dan, Y Wada, K Shiina (Sensory and Cognitive Food Science Laboratory, National Food Research Institute, Tsukuba, Japan; e-mail: yui@affrc.go.jp)

We investigated the overall lightness impression of the space surrounded by wallpaper, in which the total areas of the figure and ground were equal. We constructed 16 small rooms with different wallpaper patterns using combinations of figure–ground luminance allocation (darker-figure/lighter-ground or lighter-figure/darker-ground), luminance/size, and patterns (jagged stripe pattern or dispersed square pattern). In experiments 1 and 2, ten participants compared the overall perceptual lightness between two rooms. In experiment 3, participants compared the perceptual expanse of the figure and ground in each room. We found that the influence of the ground on perceptual lightness was stronger than that of the figure. The perceived expanse of the total area of the ground was larger than the figure in the case of the jagged pattern. This is consistent with the known phenomenon that the ground spreads behind the figure. On the other hand, the figure was perceived to be larger in the case of the square pattern, and the ground was weaker and failed to dominate the appearance of the overall lightness.

[Supported by a Grant-in-Aid for Scientific Research, JSPS for YY.]

- ◆ **Modulating brightness by means of figure – ground segmentation: The phantom illumination case**
D Zavagno, O Daneyko (Department of Psychology, Università di Milano-Bicocca, Milan, Italy; e-mail: daniele.zavagno@unimib.it)

Two experiments concerning the phantom illumination illusion (Zavagno, 2005 *Perception Psychophysics* 67 209–218) are presented with reference to figure–ground segmentation. In experiment 1, two sets of four stimuli each were presented with paired comparisons. Paper stimuli were created so that: (i) in two stimuli the target area (T) should be seen as part of the physically homogeneous black background (BG); (ii) in two stimuli T was segregated from BG by means of actual contours; (iii) in two stimuli T and BG were segregated by means of subjective contours; (iv) two stimuli were halfway between type (i) and type (iii) stimuli. Observers performed a forced-choice task indicating the darkest T in each pair. In experiment 2, the same stimuli were presented singly on a CRT and observers' task was to rate each stimulus on a $-10/+10$ scale according to the brightness of T with respect to BG. Results, discussed in reference to assimilation and contrast models, show that the illusion occurs only when T is perceived as part of BG.

[Support: Experiment 1 was carried out at NEC Laboratories America, Princeton, NJ, USA.]

- ◆ **Double illusory brightness variation in the Breathing Light Illusion**
S Gori, E Giora ¶, T Agostini (Department of Psychology, University of Trieste, Trieste, Italy; ¶ University of Padua, Padua, Italy; e-mail: simone.gori@unipd.it)

The so-called Breathing Light Illusion (BLI) consists of a blurred white spot presented on a black background. That spot appears wider and brighter when approaching it, but smaller and darker when receding from it (Gori and Stubbs, 2006 *Perception* 35 1573–1577). Here an intermediate gray disk with sharp boundary is superimposed on the centre of the BLI. The observers reported that, when approaching the stimulus, the blurred area is perceived brighter and, simultaneously, the disk darker. Vice versa, when one recedes from the stimulus, the blurred spot is perceived darker and the disk brighter. Whilst the variation of the perceived brightness for the blurred spot is probably due to afterimages (Anstis et al, 2007 *Perception* 36 791–794), this cannot be the case for the disk, because it presents a sharp boundary. An explanation based on simultaneous contrast is therefore proposed: the illusory enhancement of contrast would cause a second-order illusory process affecting the perceived brightness of the disk.

MOTION PERCEPTION

- ◆ **A synergetic model for dynamic bistable figures**
E Giora, S Gori, R Pedersini (Department of General Psychology, University of Padua, Padua, Italy; e-mail: enrico.giora@unipd.it)

We studied reversals between the percepts in two bistable figures by examining individual shifts in category boundaries as a function of continuous variation in the ratio of areas of the figure. In experiment 1 each participant observed a movie where the figure and the ground got reversed depending on the ratio of their areas. The subjects' task was to indicate subjective reversals between figure and ground. In experiment 2 each participant observed another movie where two overlapping figures appeared alternately in front of each other depending on the ratio of the area of the figures (Petter's effect). Hysteresis was observed in both experiments. We propose a general model for our results based on a non-linear system where the control parameter depends on the ratio of the areas of the figures. Following the synergetics' theoretical modelling, the switching of phenomenological perception between two alternative percepts can be formalised by means of a potential landscape with two attractors.

◆ **The role of optic flow in detecting deviations from ‘straight ahead’**

B J Andrews, M G Harris (School of Psychology, University of Birmingham, Birmingham, UK; e-mail: bja080@bham.ac.uk)

While moving through the world, particularly while driving, it is important to maintain a specific trajectory: weaving from side to side or veering in and out of marked lanes on a roadway is not only dangerous, but hampers smooth and efficient progress. Driving in a straight line requires constant steering adjustments and we have examined how drivers detect changes in the visual field that cue the need for these steering adjustments. We used partially occluded dot-flow and textured ground planes to systematically measure the amount of rotation in an optic flow field needed to elicit consistently correct deviation judgments from observers. The results suggest that performance varies across the flow field and that flow close to the horizon is most valuable for detecting rotation (and therefore deviation from a straight trajectory). In this region, the rotation component of the optic flow predominates, whereas in the foreground, the translation component predominates. A simple model is proposed that accounts for performance at a range of fixation positions and flow speeds.

[Supported by grants from the EPSRC and the University of Birmingham School of Psychology.]

◆ **Heading-perception deficit in a patient with frontal-eye-field lesion**

J Billino, D Braun, F Bremmer ¶, K Gegenfurtner (Department of Psychology, Justus Liebig University, Giessen, Germany; ¶ Philipps University, Marburg, Germany; e-mail: jutta.billino@psychol.uni-giessen.de)

Heading perception represents a highly relevant ability for navigation in space. Studies concerned with neural-processing mechanisms of heading information have focused primarily on occipital and parietal regions. However, some results suggest a specialized processing pathway that might involve brain areas beyond the classical motion-processing pathways. We studied a patient who had suffered a right frontal brain lesion including the frontal eye field (FEF). Detection thresholds for different kinds of motion information were determined. The patient showed a specific impairment of heading perception. A pronounced asymmetry of thresholds in the visual hemifields could be observed. Threshold for heading to the contralesional field was 20.5% which exceeded the upper limit of predictions derived from a control sample (17.3%). Detection of heading to the ipsilesional field was unimpaired (7.0%). The role of the FEF in vision is still a matter of debate. Our results hint at a critical contribution to heading perception. This is in line with recent findings that support a radial-motion bias in the macaque FEF.

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◆ **Feature attribution of Gabors and faces in the Ternus – Pikler display**

M Boi, T Otto, H Ogmen ¶, M Herzog (Life Science – Brain Mind Institute – Laboratory of Psychophysics [SV – BMI – LPSY], École Polytechnique Fédérale de Lausanne [EPFL], Lausanne, Switzerland; ¶ University of Houston, Houston, USA; e-mail: marco.boi@epfl.ch)

We presented a set of three squares in a first frame followed, after an ISI of 100 ms, by the same set of squares shifted one position to the right (Ternus – Pikler display). The squares are perceived to move as a group rightwards. As with Verniers (Ogmen et al, 2006 *Vision Research* 46 3234 – 3242), elements such as Gabors or faces, superimposed on the central square of the first frame are predominantly perceived at the central square of the second frame in accordance with group motion (non-retinotopic feature attribution). If a high-contrast Gabor in anti-phase is presented at the central square of the second frame, the two Gabors are perceived superimposed in temporal alternation on this square. No fusion of the Gabors occurs. However, when low-contrast Gabors or Verniers are displayed, they fuse, that is, they are integrated without being perceived as alternating. Hence, element fusion is not an automatic outcome of feature attribution since its occurrence depends on stimulus parameters.

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◆ **Evidence for an independent role for spatial frequency in perceived pattern motion direction**

L Bowns, (School of Psychology, University of Nottingham, Nottingham, UK; e-mail: lbowns@psychology.nottingham.ac.uk)

The independent role of spatial frequency on perceived pattern motion direction was investigated. Two type II plaids were presented at varying spatial frequencies. The velocity vectors of the underlying components had a constant velocity so that predicted speed and direction from the components, the intersection of constraints (IOC), the vector average, and distortion products remained constant for each of the two plaids across spatial frequency. The experiment was repeated at two durations. Perceived direction, measured by a method of adjustment, changed as a function of spatial frequency, approaching the (IOC) direction at higher spatial frequencies.

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Results were similar at short and long durations. Consequently, at low spatial frequencies the information used to compute motion direction is affected directly by spatial frequency, either at the level of component or distortion products.

◆ **Optic flow velocity profiles influence heading and speed discrimination**

J S Butler, P MacNeilage¶, J L Campos, H Bülthoff (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; ¶ University of California at Berkeley, Berkeley, USA; e-mail: john.butler@tuebingen.mpg.de)

It is usually assumed that the human visual system is most sensitive to the velocity of motion at the retina. However, two optic flow velocity profiles that specify the same peak velocity can have different durations and specify very different accelerations and displacements of the observer. We compare heading and velocity discrimination in response to constant and raised cosine optic flow velocity profiles. The experiment was divided into four separate blocks, heading discrimination and velocity discrimination, with constant and raised cosine velocity profiles. On each trial, subjects were presented with two consecutive movements (same velocity profile) through a limited lifetime 3-D star field and asked to indicate which motion was more to the right (heading discrimination) or which had a faster maximum velocity (velocity discrimination). The heading experiments show there is not a consistent preference of motion profile within the group but individual subject's thresholds are significantly different between motion profile conditions. The different profiles in the velocity experiments did not show as clear a pattern of results as those in the heading experiments.

◆ **Scale changes provide an alternative means for coarse heading perception**

F J Calabro, L M Vaina¶ (Department of Biomedical Engineering, Boston University, Boston, USA; ¶ Boston University & Harvard Medical School, Boston, USA; e-mail: fcalabro@bu.edu)

We adapted stimuli previously described by Schrater et al (2001 *Nature* **410** 816–819) for studying how changes in spatial-frequency content (scale changes) contribute to heading perception. Our stimuli consisted of five textured panels, each containing an optic flow, scale change, or speed gradient corresponding to different simulated velocities towards the observer. In a 5AFC task, eight subjects indicated towards which panel they were moving. They performed best with optic flow (95.8% correct $\pm 1.0\%$) and scored well above chance with scale changes ($69.4 \pm 1.2\%$), but were significantly worse when the only cue was a speed gradient ($26.0 \pm 2.8\%$). Results, compared to a display version where the spatial arrangement of the panels was randomized (preventing spatial integration), showed no difference in performance for motion ($p > 0.2$), scale changes ($p > 0.3$), or speed ($p > 0.2$). In an additional control experiment, looming detection from scale changes was similarly worse than detection from optic flow. Taken together, these results suggest that a scale-change detection mechanism provides an alternative means for making efficient, although coarse, heading judgments.

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◆ **Effective encoding of retinal flow**

D Calow, M Lappe (Department of Psychology, Westfälische Wilhelms-Universität Münster, Münster, Germany; e-mail: calow@psy.uni-muenster.de)

The resources of signal processing in the brain are limited and therefore the range of signals that can be processed is bounded. Statistically efficient processing schemes restrict the limited resources of a signal-processing system to the range of statistically probable signals and serve for the effective encoding of the natural distribution of signals. Relying on the statistical properties of retinal motion signals during locomotion, we propose a nonlinear processing scheme of retinal flow, which maximizes the mutual information between the input and the output signal, and spreads the processing of the input uniformly over the resources of the system. This processing scheme predicts receptive fields of motion-sensitive neurons in the velocity space. The properties of the receptive fields are tightly connected to the position in the view field and to the position of the highest response in the velocity space, and can be characterized as low-pass, high-pass, or tuned for their speed selectivity and as tuned or untuned for their direction selectivity.

◆ **Priming for motion direction with first- and second-order stimuli**

G Campana, A Pavan, C Casco (Department of General Psychology, Università degli Studi di Padova, Padua, Italy; e-mail: gianluca.campana@unipd.it)

Priming for first-order motion has been shown to rely on the functional integrity of area V5/MT (Campana et al, 2002 *Cerebral Cortex* **12** 663–669). The retinotopicity of this area would predict a reliance of direction priming on spatial position. In order to test this hypothesis, and to see whether a similar priming exists with second-order motion, we tested motion direction priming and its interaction with spatial position with both first- and second-order motion.

Indeed, mechanisms and neural substrates mediating implicit memory for these two types of motion perception are still unknown. Our results indicate that motion-direction priming occurs not only with first-order, but also with second-order motion. Priming for motion direction is position-sensitive with both types of motion, suggesting for both a locus of representation within the V5/MT complex, where retinotopicity is still maintained. Finally, cross-order motion priming also exists, but is not sensitive to spatial position, suggesting a neural locus where processings of first- and second-order motion converge in MST or beyond.

[Supported by Fondazione CARIPARO, PRIN 2005.]

◆ **Spatio-temporal grouping in perceptual rivalry**

V Conrad, Q C Vuong ¶, M O Ernst (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; ¶ Newcastle University, Newcastle upon Tyne, UK; e-mail: verena.conrad@tuebingen.mpg.de)

Perceptual rivalry occurs when stimuli have multiple interpretations which are equally probable. For example, two distributions of dots, one translating leftward and one rightward can be perceived as a 3-D cylinder rotating clockwise or counterclockwise. Repetitive presentation of an ambiguous stimulus can stabilize one perceptual interpretation. Here we examined how unambiguous spatio-temporal contexts affect stabilization of ambiguous structure-from-motion stimuli. Using an intermittent-presentation paradigm we stabilized one interpretation of the ambiguous cylinder and introduced contextual information by providing an unambiguous version of the 3-D cylinder. We manipulated spatial distance and temporal proximity between ambiguous stimulus and unambiguous context. The task was to report perceived rotation direction of the ambiguous cylinder. We found that stabilization was more likely to be disrupted by unambiguous context that had appeared in corresponding locations in preceding frames. Context simultaneously presented with the stimulus at a different spatial location had little effect. This shows that temporal contexts were weighted more than spatial contexts, and suggests that the visual system analyses recent perceptual history to interpret the present input.

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◆ **The spatio-temporal basis of the flash-lag effect: Psychophysical and computational approaches**

A M Cravo, M V Baldo (Department of Physiology and Biophysics, University of São Paulo, São Paulo, Brazil; e-mail: cravo@icb.usp.br)

A moving object appears to lead a briefly flashed object, even when the two are aligned (flash-lag effect, FLE). We manipulated the nature of the abrupt-onset stimulus (stationary or moving) and also its spatio-temporal value: when moving, the abrupt-onset stimulus can act as a spatial and temporal marker, but it can also serve as a temporal marker only, provided another stimulus provides the spatial reference. Simulations performed in a simple neural network (Baldo and Caticha, 2005 *Vision Research* **45** 2620–2630) predicted that the FLE could emerge from two moving stimuli. Additionally, the model predicted that the magnitude of the FLE should be similar to the standard FLE if the abrupt-onset moving stimulus was used either as a temporal marker only or as both temporal and spatial markers in trajectories orthogonal to the continuously moving trajectory of the stimulus, but should increase if the trajectories were antiparallel to each other. Psychophysical experiments confirmed such predictions, making it possible to explore the relationship between spatial and temporal components of the FLE.

[Supported by FAPESP.]

◆ **Dynamic shift of visual receptive fields in the motion-detection hierarchy**

A Daneshmand, A Ezzati (School of Cognitive Sciences, Institute of Physics and Mathematics, Tehran, Iran; e-mail: alidaneshmand1984@gmail.com)

We measured potential effects of first- and second-order motion on the spatial position of receptive fields (RF) in motion-detection hierarchy. After adaptation with first- or second-order motion for 30 s, a dynamic counter-phase grating (first-order adaptor) or a bistable stimulus composed of two identical superimposed sinusoidal gratings with opposite motion direction (second-order adaptor) was presented as the test stimulus for 30 s. After adaptation, a perceptual bias occurred in detection of motion direction (classical motion aftereffect). Test stimuli were shown randomly in 8 different positions aligned with the adaptor. Subjects' task was to report perceived direction of motion. The fraction of time in which MAE was perceived in the expected direction was used as a measure of MAE strength in each area. We found MAE strength greater in the areas toward the direction of adaptation, both in the area of adaptation ($p < 0.05$) and outside it ($p < 0.05$). This is congruent with the idea that adaptation results in skewness of neuronal RFs toward the direction of motion.

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◆ **Multiple object tracking in amblyopia**

P Domsa, J Kórtvélyes, V Gál, Z Vidnyánszky ¶ (Department of Information Technology, Péter Pázmány Catholic University, Budapest, Hungary; ¶ Hungarian Academy of Sciences, Budapest, Hungary; e-mail: patriciadomsa@gmail.com)

We investigated the efficacy of visual attentional selection in amblyopia using the multiple object tracking (MOT) task, which requires selection and tracking of a subset of visual objects in a visual display containing moving identical objects. Fifteen adult patients with unilateral amblyopia and fifteen controls were tested monocularly on the MOT task (three conditions, which differed in the speed of the moving objects). We found that amblyopic patients performed better with their fellow eyes than with their amblyopic eyes at all three speed levels tested. Surprisingly, at the highest speed, performance of the control group was also better when the dominant eye was tested as compared to the non-dominant eye. We also found that amblyopic patients performed worse with their amblyopic eye than controls with their non-dominant eye. The results provide evidence that in amblyopic patients attentional tracking is less efficient in the case of visual information conveyed by the amblyopic eye as compared to that originating from the fellow eye.

◆ **Optimal speed estimation for ocular following responses in humans are based on natural-scene statistics**

J Drewes, F V Barthelemy, G S Masson (INCM – CNRS Marseille, Marseille, France; e-mail: Jan.Drewes@incm.cnrs-mrs.fr)

It is commonly assumed that the visual system is optimized to process naturalistic inputs for both low- and high-level processing. Here, we search for an advantageous effect of natural-scene statistics when estimating motion. Ocular following responses (OFRs) are reflexive eye movements known to reflect many properties of low-level motion processing. Using the scleral search coil technique, we recorded OFRs to drifting ultra-narrow bandpass noise images. As previously shown, OFRs are best elicited with low-spatial-frequency stimuli (< 1 cycle deg^{-1}) moving at optimal speed (20 deg s^{-1}). However, when mixing two bandpass noises, we found evidence that the normalized sum of two frequencies can create stronger OFRs than a single frequency, and the weighting of the frequencies (mix ratio) influences the response gain. The optimum weighting with multiple bandpass noises was similar to the spectral shape of natural scenes ($1/f$). These results provide a first behavioral evidence that speed is best estimated by combining information across different channels, with weighting based on natural-scene statistics.

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◆ **Within-modality cue combination: Localising contours defined by speed and direction**

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Localising contours in the visual scene provides important information about object boundaries. Motion contours—defined by sharp differences in motion signals across space—are readily detected by the human visual system. In previous work we systematically varied the direction difference whilst keeping the speed difference fixed, and found that ability to localise the resulting motion contour was not dependent on the distance between velocity vectors. There was also no clear improvement for combining speed and direction differences. We repeated this experiment with different pairings of speeds and also extended it by varying speed difference whilst keeping direction difference fixed. This fuller exploration of the parameter space allowed us to find that at certain points there is improvement with combination. We found that simple velocity-vector-based difference does not predict the results well, by underestimating performance on direction-difference-only tasks and overestimating performance on speed-difference-only tasks. We consider the combined localisation improvement with respect to possible cue combination between speed and direction.

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◆ **Pure phi movement**

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The classical two-element apparent motion stimuli originally studied by Wertheimer can give rise to a host of qualitatively different motion percepts. A particularly interesting one is that of pure phi, which refers to the percept of the two stimulus elements being stationary, while something else appears to move in front of them. This percept (also referred to as ‘omega’, ‘shadow’ or ‘afterimage’ motion in the literature) has occasionally been observed when the two stimulus elements are presented in a strictly alternating sequence (zero interstimulus interval, ISI), and occurs at stimulus onset asynchronies (SOAs) briefer than those necessary for optimal (beta) motion. We investigated how the occurrence of pure phi depends on SOA and ISI. SOAs between

35 and 120 ms were found to be most effective in producing pure phi. At all SOA levels where pure phi was observed, it occurred mainly at negative interstimulus intervals, ie in cases where the two stimulus elements were simultaneously visible for some time during the animation cycle.

◆ **Spiking MT model: Dynamics and motion patterns**

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We propose a bio-inspired spiking MT model and study some of its dynamic properties. To do so, a V1 layer is first modelled by an array of motion-energy-direction-selective complex cells tuned for different speeds and directions. Then, we define the MT layer connecting MT cells to V1 cells with suitable associations of velocity and orientations in a neighborhood, including inhibitions and feedbacks. Our model encodes several kinds of information. At the cell level, it reproduces motion integration dynamics of real V1 and MT cells (eg Smith et al, 2005 *Nature Neuroscience* 8 220–228). At the global level, we show how the MT layer activity defines motion-pattern-encoding biological-motion information. The relevance of this motion pattern is shown by applying the same framework as in Escobar et al (2006 *NeuroComp*) to various classes of motion.

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◆ **Topographic map of motion aftereffect after saccade**

A Ezzati, A Golzar, S R Afraz (School of Cognitive Sciences Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran; e-mail: ezzati@ipm.ir)

How does information from successive fixations due to saccadic eye movements amalgamate into a single percept? Here, we report that visual motion aftereffect (MAE) transfers across separate fixations when adaptor and test are presented in the same spatial position. After adaptation with coherently moving random-dot stimuli embedded in a 4×4 grid, subjects changed their fixation to a newly presented fixation point. A neutral test method was employed to measure MAE strength. Test stimulus was a small moving random-dot pattern filling one of the randomly selected grid holes in a 5×6 grid. Test-stimulus area corresponded to three different regions with regard to adaptor: the same retinal region, the same external spatial coordinates, and none. We found that MAE strength was significantly ($p < 0.05$) greater in the same spatial position in comparison with non-adapted areas. Interestingly, the highest MAE strength was found in the center of spatial coordinates and not at the edge. We suggest that motion-selective area MT and far extrastriate visual areas are responsible for spatial MAE.

◆ **Electrophysiological correlates of motion priming: A combined ERP/TMS study**

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Priming of motion direction is related to the intertrial storage of the previously presented direction of motion. This effect depends upon the functional integrity of extrastriate cortex V5/MT (Campana et al, 2006 *Cerebral Cortex* 16 1766–1770). The aim of the present combined rTMS/ERP study was to gain insight into the neural correlates of the time course of the perceptual stages that subservise motion discrimination. The results showed a disruption of priming when TMS was delivered over area V5/MT, accompanied by enhanced amplitude of both the N1 and N2 components only for the priming condition. We interpret the increased N1 to reflect the greater resources necessary to process visual stimuli to overcome the effects of TMS when a stimulus shares the same direction as the previous one. The TMS-dependent enhancement of N2 may be associated with an impairment of cortical mechanisms that are specific for priming and related to an automatic search in visual memory for previously seen stimulus.

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◆ **Investigation of local motion antagonism with transcranial magnetic stimulation**

J O Garcia, A Pouya, E Grossman (Department of Cognitive Sciences, University of California at Irvine, Irvine, USA; e-mail: jogarcia@uci.edu)

Previous research has shown perceptual cancellation of transparency in displays with locally balanced opponent motion, thought to be the consequence of the centre–surround antagonism in MT (Qian et al, 1994 *Journal of Neuroscience* 14 7357–7366). Focal transcranial magnetic stimulation (TMS) over MT disrupts underlying receptive fields (RFs) such that direction discrimination is impaired (Hotson et al, 1994 *Vision Research* 34 2115–2123). Our experiments assessed the consequence of altering these directional receptive fields (via TMS) on local motion antagonism in MT. Subjects made angle discriminations on random-dot displays that varied the

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local proximity of balanced motion. We found a spatial extension of antagonistic regions resulting in perceptually cancelled motion with TMS over MT as compared to TMS over V1 or no TMS. These experiments provide a novel method to manipulate and measure the spatial extent of MT RFs with TM stimulation over early visual brain regions.

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◆ **Flashes and abrupt onsets of moving stimuli as probe stimuli in the flash-lag effect**

A Gauch, D Kerzel (Department of Psychology, University of Geneva, Geneva, Switzerland; e-mail: angelique.gauch@pse.unige.ch)

In the flash-lag effect illusion, a flash that is displayed at the same physical position as a moving object is perceived to lag behind the moving object. We asked our subjects to indicate the position of a moving bar relative to the onset position of another bar that appeared unpredictably along the trajectory and immediately started to move in the opposite direction (moving-probe stimulus). Motion extrapolation predicts a lag effect twice as large with the moving probe because both objects' trajectories are extrapolated. Differential latencies predict no lag effect with the moving probe because the continuously visible moving object and the moving probe have the same latencies. Our results showed that the size of the lag effect was the same when a moving probe was presented instead of a flash. This suggests a common mechanism implied in the comparison between successive positions of a moving object and the onset position of a flash or a moving object. Subsequent experiments excluded the Froehlich illusion as an explanation for the effect. [Supported by the Swiss National Foundation 10011-107768/1.]

◆ **Two-stroke movement illusion created by a luminance-modulated stationary pattern**

J Allik (Department of Psychology, University of Tartu, Tartu, Estonia; e-mail: juri.allik@ut.ee)

A new version of the two-stroke movement illusion (Mather, 2006 *Vision Research* **46** 2015–2018) was created by a stationary pattern the elements of which do not change their relative spatial positions. Like other forms of luminance-modulated random-dot patterns (Allik, 1992 *Vision Research* **32** 157–165), the motion impression was produced by luminance increments added to continuously visible and static elements. Because it is impossible to see the contrast-reversed afterimage in the incessantly visible patterns, the proposal that the reversed phi motion could serve as an explanation of the two-stroke or four-stroke motion is untenable. It is more likely that the decision about the perceived movement direction is made on the basis of vector summation of potential jumps of elements in the spatiotemporal distribution of luminance.

◆ **Perception of social attribution in Heider – and – Simmel-like animations**

M Guerreschi, A N Sokolov¶, C Casco, M A Pavlova§ (Department of General Psychology, University of Padua, Padua, Italy; ¶Ulm University Medical School, Ulm, Germany; §Children's Hospital, University of Tübingen, Tübingen, Germany; e-mail: michele.guerreschi@unipd.it)

Heider – and – Simmel (HS)-like animations of geometric shapes have been an indispensable tool for investigation of the social perception revealed through motion. We examined how parametric transformations of movement affect social attribution. Healthy adults were presented with: (i) HS-like animations; (ii) nonlinear (random) movement of the same geometric shapes; and (iii) linear movement of the same shapes. Participants judged the intensity of social attribution (emotionality, interactivity) expressed in the movies. The findings indicate that the intensity of perceptual impression of social attribution strongly corresponds to movement transformations: HS-like movies were estimated as most social, linear transformations as most non-social interactions. Nonlinear transformations hold an intermediate position, and were judged as significantly less social than HS-like animations, but more social than linear transformations. For the first time, this study rigorously demonstrates that parametric motion transformations modulate visual perception of social attribution in HS-like animations. This work opens a window for controlled study of social attribution and underlying brain mechanisms in normalcy and pathology, in patients with periventricular leukomalacia or autistic individuals.

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◆ **Using visual motion adaptation to test models of braking control**

M G Harris (School of Psychology, University of Birmingham, Birmingham, UK; e-mail: harris@bham.ac.uk)

Adapting to a moving stimulus reduces perceived velocity and suggests a way to distinguish between models of braking control based upon \dot{v} (the rate of decline of time-to-contact, which depends on velocity), and models based on D_i (the ideal deceleration needed to stop at a visual

target, which depends upon velocity squared; Rock et al, 2006 *Journal of Experimental Psychology: Human Perception and Performance* **32** 1479–1484). After adapting to forward movement over a textured ground plane, subjects (i) braked to stop at a visual target in a simple visual simulator, and (ii) matched the perceived speed of the ground plane to an unadapted sky plane. Adaptation reduced perceived speed and produced later, heavier braking. Unadapted braking patterns were best fitted by a model based upon the rate of change of D_i , and this model needed only a change in gain to fit the adapted data. Models based on $\dot{\tau}$ provided a poor fit to the unadapted data and needed large and implausible changes in all parameters to fit the adapted data.

◆ **Similar adaptation effects on detection and localization of optic flow patterns**

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Many models of optic flow processing (eg Perrone and Stone, 1998 *Journal of Neuroscience* **18** 5958–5975) suppose that common neural mechanisms are used to detect optic flow patterns and localize their centres. However, recent neuropsychological (Beardsley and Vaina, 2005 *Journal of Computational Neuroscience* **18** 55–66) and neuroimaging evidence (Koyama et al, 2005 *Current Biology* **15** 2027–2032) suggests a separate cortical area specialized for localizing the centre of flow patterns, possibly important for monitoring self-motion. This is consistent with our findings (Harvey and Braddick, 2006 *Perception* **35** Supplement, 238) that spatial integration properties for detecting and localizing are quite different. We examined the relation between detection and localization by adapting subjects to rotating, expanding, or contracting motions, and measuring effects on coherence thresholds for both detection and localization tasks. When adaptation and test directions were opposite (eg expansion vs contraction, clockwise vs anticlockwise rotation), thresholds were elevated far more for rotating than for contracting test patterns. Overall, adaptation had similar effects on detection and localization tasks, suggesting that both depend on a common processing stage where adaptation effects occur.

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◆ **A coupled network of motion cells responds to noise: jitter aftereffect and D_{\max} data**

T J Hine (School of Psychology, Griffith University, Nathan, Australia; e-mail: t.hine@griffith.edu.au)

Adaptation to rapidly changing textured region(s) within the visual field produces the jitter aftereffect (JAE) of illusory relative motion. In adapting stimulation, black-and-white elements of 0.1 deg from 8% to 93% contrast were displaced rigidly 32 times a second in random directions at random amplitudes $< D_{\max}$ (overall 'Brownian' motion). This was compared to uncorrelated noise of an equivalent 'energy' level. The noise always produced a stronger JAE and the spatial density of this noise was also varied. Even sparse noise produced strong JAE and this strength was not linearly related to the amount of adaptation stimulation. In a separate 2AFC discrimination experiment, the transition from a motion to a noise percept in a textured field of varying density undergoing Brownian motion of varying displacements was investigated. Discrimination thresholds depended on density and displacement size. All these results are better explained by a coupled network of motion cells responding to noise rather than their linear summed output.

◆ **Predictive and postdictive visual interactions on the path of apparent motion**

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A target moving in discrete steps can appear to move continuously even along sections of the path in which no stimulus is presented. We investigated whether this representation is constructed predictively, along the expected trajectory of the target, or postdictively, after the appearance of the next target. Observers viewed an unambiguous apparent-motion display, which either occasionally reversed direction or moved continuously. Observers carried out a speeded 2AFC discrimination task on probes presented between the possible target locations. In the continuous condition, observers' reaction times to detect a probe change were longer when it occurred ahead of the disc than when it occurred elsewhere on the motion path. Conversely, when the disc reversed direction, significantly less interference was observed ahead of the disc (along the predicted motion path), and significantly more interference was observed behind the disc (along the updated motion path). We conclude that the representation of a moving object in an apparent-motion display is constructed postdictively, after the predicted motion path is confirmed.

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◆ **Temporal response dynamics of motion processing in human vision: Modulation depth and speed**

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We measured reaction times for discriminating the drift direction of first-order and second-order motion. Reaction times were measured as a function of modulation depth (expressed as multiple of direction-discrimination threshold) for 1 cycle deg^{-1} , first-order (luminance-modulated) and second-order (contrast-, polarity-, orientation-, length-modulated) patterns moving at 1 deg s^{-1} . Reaction times were fastest for first-order motion but decreased at the same rate as modulation depth increased for all patterns, except length where the decrease was steeper. Reaction times were also measured for first-order (luminance) and second-order (contrast) motion over a range of speeds. At 1 deg s^{-1} , reaction times were faster for first-order motion but as speed increased, reaction times for second-order motion decreased much more rapidly becoming similar to, and sometimes faster than, those for first-order motion at high speeds ($\sim 8 \text{ deg s}^{-1}$). These findings show that the time to encode different motion types is not invariant. That reaction times can be faster for second-order motion under some conditions suggests that second-order motion is not necessarily delayed compared to first-order motion.

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◆ **Video content classification: The use of object- and region-segmentation methods in the detection and analysis of moving objects in multimedia videos**

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The development of network-based technologies and multimedia services led to a considerable growth of video content within the communication networks. To make video content more accessible to the users we need a classification method based on content analysis. This implies the use of semantic analysis methods. Most of the analysis methods rely on video segmentation. We evaluate here the performances of classical methods based on region and objects segmentation, and present a new method that combines object segmentation with region segmentation. The proposed algorithm works in two stages. First, we extract the moving objects from the background using a statistical change detector. This implies the use of object segmentation and region segmentation. Then, by comparison between an object partition and a region partition, the extracted moving objects are tracked along different frames. The simulation shows good results for the classical object-based and region-based segmentation methods for simple videos. The proposed combined segmentation method has good results even for videos with complex motion and many different interacting objects.

◆ **The fMRI correlates of visually induced self-motion in depth**

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Optic-flow fields are able to generate the conscious illusion of self-motion in a stationary observer. Here we used fMRI to reveal the differential processing of self-motion and object-motion in the human brain. Subjects were presented an expanding optic-flow stimulus, composed of disparate red–blue dots, viewed through red–blue glasses. We compared the activity obtained during periods of self-motion with periods of object-motion percept. We found, that the left MT+ and precuneus, as well as areas bilaterally along the dorsal part of the intraparietal, and along the left posterior intraparietal sulci were more active during self-motion than during object-motion perception. Additional signal increases were located at the depth of the left superior frontal sulcus, over the ventral part of the left anterior cingulate, in the depth of the right central sulcus. Our results suggest that the illusory percept of self-motion is correlated with the activation of a network of areas, ranging from motion-specific areas to regions, involved in visuo-vestibular integration, visual imagery, decision making, and introspection.

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◆ The effect of background motion on the detection of motion onset

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The dependence of motion detection on background motion was investigated using a sinusoidal grating as a stimulus and by varying the gap between the target area and background grating. Target velocities were 0.4, 0.6, 0.8, 1.0, and 1.6 deg s⁻¹ to the right, and background velocities 0.4, 0.8, 1.6, and 3 deg s⁻¹ to the left or right. Gap between the target and the background was either 2 or 100 pixels. Velocity of the target, and velocity and direction of the background both had significant effect on the reaction times to target motion onset. It was confirmed that reaction times decrease with the increase of target velocity and that background moving in the same direction than the target prolongs the reaction to target motion onset. We also found that the effect of the gap was significant ($p < 0.05$) only at target velocities under 1 deg s⁻¹, showing that with the increase of velocity adjacent background was as influential as distant one in slowing down the reactions.

◆ Perceptual combination of rotational and translational motions

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The circumstances under which the visual system combines two translational motion components have been studied extensively (eg two superimposed gratings). Here, we investigate the interactions between rotation and translation using ellipses. Ellipses rotated around their centres, which were constrained to translate along the horizontal. Observers had to indicate if they perceived separate motions (rotation and translation) or a combination in the form of a single (possibly curved) trajectory. A single trajectory was reported whenever the orientation of the major axis of the ellipse stayed within 20° of the horizontal. Rotation and translation were perceived for orientations of 90°, and either percept could be seen for 45°. Measuring the perceived direction of motion for different points along perceptually curved trajectories, we found directions close to the orientation of the major axis of the ellipse. Our results show a striking illusion: rotating objects can be perceived to travel on a curved path when they actually translate linearly. The visual system wrongly combines two motions (translation and rotation) into a single percept (curved trajectory).

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◆ The effect of spatial layout on motion transparency

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It remains unclear how the visual system uses speed cues to segment images. Verghese and Stone (1997 *Vision Research* 37 397–406) showed that speed discrimination increases for segmented stimuli, suggesting that each discrete entity provides independent estimates of speed, which are combined across space. We present here evidence that motion transparency is constrained by spatial layout in the same direction as that reported by Verghese and Stone. We performed an experiment in which subjects had to discriminate between two stimuli, one containing two speeds (transparent) and the other containing five speeds. We measured the minimum speed difference as a function of the four layouts of Verghese and Stone. Stimuli were random-dot patterns displayed on circular patches located 9° away from the fixation point. We found that the smallest threshold was obtained for the maximally separated patch configuration and the threshold increased as the patches were brought closer. Results suggest that the effect of parsing the image into entities on speed discrimination facilitates the segmentation of layers in motion transparency.

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◆ **Perception of physical causality in an animal model**

E Mascialzoni, L Regolin, R Actis-Grosso ¶ (Department of General Psychology, University of Padua, Padua, Italy; ¶ University of Milano-Bicocca, Milan, Italy; e-mail: elena.mascialzoni@unipd.it)

Identifying causal relations ought to be fundamental for the survival of animals. This knowledge could be either implicit or the outcome of some learning process. So far, it has been shown that toddlers as young as 24 weeks are able to understand Michotte's causality (Leslie, 1982 *Perception* **11** 173–186). Such capability is shared by humans and other primates, such as tamarins (Hauser, 1998 *Developmental Science* **1** 31–37) and rhesus macaques (Flombaum et al, 2004 *Psychological Science* **15** 795–800). We investigated this ability in a highly visual species, the domestic chicken. Newborn visually naive chicks were tested for their spontaneous preference for a Michotte's launching effect and a non-causal stimulus (a moving object passing behind a stationary one). Chicks did not seem to discriminate physical causality. Further investigation is certainly warranted exploring, for example, spontaneous preferences between a traditional Michotte's effect and a similar stimulus producing, in human subjects, the perception of intentional movement (ie escape).

◆ **Combining phase information across channels in perceived motion transparency: A computational approach**

A I Meso, J Zanker (Department of Psychology, Royal Holloway University of London, Egham, UK; e-mail: a.i.meso@rhul.ac.uk)

Motion transparency can be perceived when two or more types of motion occupy the same region of visual field. We investigated the signal-detection task necessary for this perceptual separation using computed simulations to characterise some of the mechanisms that can account for human performance. Correlation-type motion-detector arrays with multiple spatial channels were used for local detection. Responses to transparently moving stimuli in space–time representations have been shown to include regions of informative signals from individual components and ambiguous signals from overlap regions. In global distributions, informative signals form separate peaks necessary for transparency, but are masked by the ambiguous signals. To increase the performance of the simulated separation, we reduced the contribution of the ambiguous signals by (i) combining local detector signals across channels, (ii) using nonlinearities that exploit phase relationships during the combination, and (iii) pooling the resulting phase-locked responses into an output distribution. We conclude that phase sensitivity is important in motion-transparency perception and discuss the advantages of alternative combination nonlinearities over linear pooling mechanisms.

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◆ **Profound deficits in global-motion perception in binocularly deprived or dark-reared kittens**

D E Mitchell, D Kung, J Kennie (Department of Psychology, Dalhousie University, Halifax, Canada; e-mail: d.e.mitchell@dal.ca)

Greater deficits of global-motion perception have been reported following treatment of humans with binocular as opposed to monocular congenital cataracts. We examined global-motion perception of kittens deprived from near birth of form vision to 6, 8, 10, or 12 weeks of age by eyelid suture in one ($N = 1$) or both eyes ($N = 2$), as well as of kittens reared from birth in total darkness until they were 6 or 10 weeks old ($N = 3$). Coherent motion thresholds made with random-dot kinematograms were only slightly elevated from those of normal animals in either eye of the monocularly deprived kitten, but were elevated to close to 100% in the binocularly deprived or dark-reared kittens. Despite recovery of normal grating acuity, the deficits were equally profound in the animals dark-reared to 6 weeks of age suggesting that the critical period during which the cortical regions involved in the integration of global-motion signals in cats requires normal input from at least one eye is very short (< 6 weeks of age).

[Supported by NSERC grant 7660.]

◆ **Embodied perception of gravity when bouncing a ball**

A H P Morice, R Baures, M-A Amorim, I Siegler, N Benguigui (Laboratoire 'Contrôle moteur et perception', Université Paris XI, Orsay, France; e-mail: antoine.morice@u-psud.fr)

There is some evidence that, while observing moving objects, kinematics conveys information about the dynamics of movement. Whether this perception is direct or based on heuristics is still under debate. Here, we provide evidence that interacting with objects and observing the visual consequences of action improves perception of dynamical invariants such as gravity eigenvalue

(9.81 m s^{-2}). During the physical session, participants were asked to bounce a virtual table tennis ball at a target height by manually controlling a virtual racket. During the playback session, they passively observed previously recorded physical bounces. In both sessions, participants compared the acceleration of the ball to the terrestrial gravity acceleration. Gravity fields varied from 1 to 18 m s^{-2} by a staircase method. Results show that perception of gravity is more accurate and less variable during the physical than during the playback session. Moreover, when exposed to abnormal gravity values, participants quickly learned how to perform the suitable action. These results are discussed in light of the literature about the influence of action on perception.

◆ **Speed overestimation in intentional reaction**

G Parovel, C Casco¶, M Sinico§ (Department of Communication Sciences, University of Siena, Siena, Italy; ¶University of Padua, Padua, Italy; §University IUAV of Venice, Venice, Italy; e-mail: parovel@unisi.it)

When an object (A) moves up to and makes contact with another object (B), which then moves off, its motion appears passive if A is faster (launching) and active if A is slower (triggering). We showed (Parovel and Casco, 2006 *Vision Research* **46** 4134–4142) an overestimation of B speed, proportional to A speed in launching and constant in triggering. We asked whether this speed overestimation applies not only to mechanical causality but also to intentional reaction, in which B motion is faster, starts before the arrival of A, and is perceived to intentionally escape from A. In both intentional reaction and triggering, conditions where B is perceived as self-propelled, we found overestimation (25% vs 20% respectively) independent of A speed. These results suggest that both mechanical causality and social causality phenomena are related to precise rules applied by the visual system at a low level of motion integration.

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◆ **Motion integration by MT pattern neurons: An explanation for pattern-to-component effects**

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It remains unknown how local ‘component’ motion signals are integrated into ‘pattern’ motion signals. Majaj et al (2007 *Journal of Neuroscience* **27** 366–370) tested MT pattern neurons with small grating patches applied to localized sub-regions of the receptive field. Plaid patches produced ‘pattern’ tuning when applied to a single sub-region, but produced ‘component’ tuning when the two plaid components were presented separately to different sub-regions (ie MT integration appears to be local). We have now explored the possible mechanisms underlying these results using a model of MT neurons that can be tested with image sequences (Perrone, 2004 *Vision Research* **44** 1733–1755). The model uses subunits consisting of speed-tuned ‘direction clusters’ distributed across the receptive field (3×3 array). The original model applied opponent direction inhibition after the 9 cluster responses were integrated. We altered this feature and applied the inhibition locally (within a cluster) prior to integration. This new version of the model is sensitive to the stimulus patch location and can replicate Majaj et al’s recent physiological results.

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◆ **Some observations on the perceived relations between sound and visual motion**

A Sakai (Department of Psychology, Meisei University, Hino, Japan; e-mail: a_sakai@psy.meisei-u.ac.jp)

A black square was presented at the centre of a white screen on a computer display. After standing still for 4000 ms, the square moved horizontally to the right. One of six sounds was presented at one of four temporal positions: 3000 ms or 500 ms before the onset, or synchronized with the onset, or with the termination of motion. The sounds contained four pitches with two non-steady state sounds—a whiz and a knock. Though sounds accompanied with the visual motion were selected arbitrarily and artificially, observers reported some relations between them. When the sounds preceded the motion, they were attributed to external factors other than motion—they were perceived as ‘alarms’ or ‘cues’ or ‘warning guns’. When the sounds were synchronized with the motion, they were perceived as mechanical noises. When the sounds were synchronized with the termination of motion, observers described their experiences as ‘the square ringed the doorbell’ or ‘the object declared to get a goal’—sound and motion were unified into a single event.

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◆ **Implicit knowledge of writing movements facilitates printed-cursive-letter recognition**

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In a previous work (Scocchia et al, 2006 *Perception* 35 Supplement, 81) it has been shown that recognizing a capital letter could be primed by the coincidence between fixation point and the typical starting point of handwriting. Here, we attempted to replicate that result with cursive, lower-case letters. After a writing pre-test subjects performed a letter-recognition task. Stimuli were standardized cursive printed letters 'A', and 'O' (5°) which were flashed nearby to a fixation point. The position of the fixation point with respect to the letter could be (i) the starting point of the letter handwriting, (ii) the last point of the letter handwriting, (iii) the highest point of the letter handwriting, or (iv) the lowest point of the letter handwriting. If implicit motor knowledge facilitates letter recognition, greater accuracy and faster RTs would be expected in the first condition. Analysis on accuracy and reaction times confirmed our predictions.

◆ **A spatio-temporal interaction on the apparent motion trace**

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In several human brain imaging studies activity was found in V1 along the apparent motion trace. This activity has been related to a representation of a moving object token. Here, we investigated whether perceptual interferences along the apparent-motion trace vary with the time and position of the token. We varied the positions and the timing of a low-contrast target that was presented on the apparent-motion trace. Targets which were presented in time with the presumed movement of the apparent-motion token were detected significantly more often than targets which appeared out of time. This spatiotemporal pattern of motion masking is consistent with the hypothesised time course of the apparent-motion token. We relate this finding to an attentional process involved in the perception of motion or to a time-specific prediction of visual events along the apparent-motion trace. This time-varying effect might be the result of temporally specific feedback activity from higher visual areas onto V1.

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◆ **Hyperbolic velocity for straight-line motion seems constant**

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A mathematical model is proposed using differential geometry that was to predict velocity estimates of a moving object. It considers a stationary observer and a single object that moves smoothly on a homogeneous background in the frontoparallel plane. If the object is moving along a straight line in the frontoparallel plane at constant speed, then according to the Runeson effect it seems to be moving more slowly as it gets farther from the frontal position of the observer. The model identifies and quantifies this bias in terms of distance and viewing angle. This is true for any velocity profile, not only constant speed. The model also accounts for underestimation of speed for translational versus rotational motion. One of the consequence of this model is a differential equation giving the velocity profile that would be perceived as constant speed. The solution to this equation is a hyperbolic cosine (cosh) function depending on the frontal viewing distance and scaled by a constant coefficient k . Experiments with 'time to contact' simulation and analysis of the data strongly support this fact.

◆ **Motion direction causes anisotropic flash-lag and flash-mislocalization effects**

Z Shi, R Nijhawan¶ (Department of Psychology, Ludwig Maximilians University, Munich, Germany; ¶ University of Sussex, Brighton, UK; e-mail: strongway@psy.uni-muenchen.de)

Motion towards fovea causes greater flash-lag effect (FLE) than motion away from fovea. Previous research suggested that the anisotropy was due to differential latency (Mateeff and Hohnsbein, 1988 *Vision Research* 28 711–719). Recent studies also showed that motion can cause the positional shift of the nearby stationary flash. To examine the factors that contribute to the direction-based anisotropic flash-lag effect, we conducted three experiments to measure motion-based flash-mislocalization effect, movement-mislocalization effect, as well as classic FLE. The results indicate that the motion-direction-based anisotropy in the flash-lag effect is due to anisotropies observed both in the flash-mislocalization and the movement-mislocalization effects. Differential latency cannot fully explain the anisotropy. In foveopetal motion condition, the large FLE is mainly due to a combination of the large movement-mislocalization and an anti-flash-mislocalization effect. In foveofugal motion condition the small FLE is due to the small

movement-mislocalization and similar magnitude of flash-mislocalization. The difference of flash-mislocalization contributes around 25% to the general anisotropy in the FLE.
[Supported by Deutsche Forschungsgemeinschaft grant EL248/1.]

◆ **Differential development of radial and rotational motions in early infancy**

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Our previous studies have indicated that sensitivities to radial (Shirai et al, 2005 *Perception* 34 Supplement, 226) and rotational (Shirai et al, 2006 *Journal of Vision* 6 290s) motion increase between 2 and 3 months of age. We expanded our previous results and directly compared the sensitivities to radial motion (expansion and contraction) and rotational motion (clockwise and counterclockwise) in infants aged 2 and 3 months. Eighty 2- and 3-month-old infants were tested. We presented a pair of optic flow patterns (radiation vs translation or rotation vs translation) to the infants. We measured the infants preference for radial (or rotational) motion over translations by the preferential looking method. Sensitivity to radial expansion was higher than for the other three motions both in the 2- and 3-month-olds, and the expansion bias was greater in the 3-month-olds than in the 2-month-olds. The relation between the expansion bias and development of some cortical systems is discussed.

[Supported by Japan Science and Technology Agency (to MKY), and Japan Society for the Promotion of Science (to NS).]

◆ **New Moon illusion: Observing an occurrence of the Rosenbach phenomenon in the natural world**

L Sugano (Department of Human Science, Takachiho University, Suginami-ku, Japan; e-mail: sugano@takachiho.ac.jp)

I discuss here a phenomenon that occurs only during a full moon when an altocumulus cloud is in the background. Though it appears in Turner's painting *Fishermen at Sea*, this illusion has not yet been described in the field of perception. When a fast-moving altocumulus cloud forms at the same time as a full moon is rising on the horizon, three types of optical illusions occur. The first occurs when the moon is especially bright. The perception in this case is that the altocumulus cloud is actually passing behind rather than in front of the moon. The second illusion occurs as the cloud passes in front of the full moon: the perception is as if the cloud is actually wrapping around the moon. Simultaneously, the surface of the full moon appears to be slowly rotating in a direction opposite to the movement of the altocumulus cloud formation. The third illusion is that the perception of two-dimensionality changes to three-dimensionality as the cloud passes the moon.

◆ **Perceived autonomy in the motion of objects**

T Suzuki (Department of Psychology, Meisei University, Hino, Japan; e-mail: mofu-mofu@excite.co.jp)

When we observe the motion of two objects shifting horizontally to the right on the computer display, depending on the pattern of motion, an impression of autonomy is ascribed to the first or the second object. We often describe such events as one object chasing the other or one object leaving the other alone. The purpose of this study was to define the characteristic pattern of motion that produces such impressions. Participants, ten students aged 22 to 27 years, were presented with 18 patterns of motion on the screen and asked to describe the impressions of motion freely. As a result of classification of the descriptions, some characteristic patterns of motion were found. For example, when the speed of the second object was faster than that of the first, the second object was perceived as chasing the first autonomically. When the first object converted the direction of motion, it was perceived as running away autonomically.

◆ **Halt and recovery of illusory motion perception from a peripherally viewed static image**

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Some static images cause illusory motion perception in peripheral vision. We investigated the halt and the recovery of the illusory motion. Subjects saw the image for 10 s with steady fixation, and typically experienced disappearance of the illusory motion. After various ISI durations, the image was presented again in the same location. The magnitude of the illusory motion from the second image presentation increased as the ISI became longer. By contrast, when the second image was presented in a different retinal location than in the first presentation, the perceived motion duration recovered almost completely, even when the stimulus was presented with no ISI. Presenting the stimulus in a different retinal position thus facilitates the perception of illusory

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motion, when stimulus presentation at the original location becomes ineffective. The results indicate that an adaptation system depending on retinal position affects the halt of illusory motion in the static image, supporting the idea that local adaptation plays an important role in producing this illusory motion.

- ◆ **Direction of motion in depth: Dissociation of perception of self-motion and object motion**
L M Vaina, L Sassi¶, E Leung, S Squatrito¶, K Petet (University of Boston, Boston, USA; ¶ University of Bologna, Bologna, Italy; e-mail: vaina@bu.edu)

Accurately estimating direction of self-motion through the environment (heading) and detecting possibility of collision with a moving or static object (collision detection) are fundamental tasks of visually guided navigation. Here, we use psychophysical data from two patients and normal controls to investigate whether performance on these tasks can be dissociated and to speculate on the basic computations required by each. fMRI showed that both patients suffered an occipital lobe infarct involving V1, V2d, and V3. In psychophysical motion tasks, both patients were impaired in direction discrimination and 2-D form from relative motion, but performed normally on higher-level tasks, including complex pattern motion discrimination (radial, translational, circular) and heading perception. They failed to detect objects moving on a collision trajectory with the observer; their performance remained at chance when we varied speed, number, or trajectory of non-target objects. The results suggest that impairment in collision detection may be due to deficits in lower-level mechanisms of isolating objects and object trajectories, which are not required in defining heading from flow.

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- ◆ **Deformation sensors might play a key role in stereokinetic phenomena**
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Form-from-motion networks need to contain deformation (def) sensors, because only def carries form information. For the classical stereokinetic phenomena of Benussi and Musatti we only need one type of global def sensor. It should be tuned to expansion in one and simultaneous contraction in the perpendicular direction. A smart network of these def sensors can be tuned to minimal global def interpretations. Such a minimalisation process optimizes overall perceptual rigidity by estimating global slant, but requires no reasoning-like assumptions or inferences. For a slowly rotating square no global def minimalisation can eliminate the local def components near the corners. Hence we see these local deformations despite the fact that we look at a rotating flat rigid object. Psychophysical results obtained by Lothar Spillmann and me, on the speed limits of stereokinetic effects, suggest that the postulated def sensors only get input from low-speed motion sensors. This might be a general characteristic of deformation analysis.

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- ◆ **Tests for monocular flow-parsing in large field-of-view stimuli**
P A Warren, S K Rushton (School of Psychology, Cardiff University, Cardiff, UK; e-mail: warrenpa@cardiff.ac.uk)

Using retinal flow-fields containing stereo disparity, we have recently suggested that optic flow can be 'parsed' from the retinal image to obtain an estimate of scene-relative object movement during self movement (eg Rushton and Warren, 2005 *Current Biology* **15** R542–543). Here, we explore whether stereo disparity is necessary for flow-parsing or whether other sources of information, which could theoretically constrain flow-field interpretation, are sufficient. In this study we test the impact of stimulus field of view (FOV) on flow-parsing behaviour. Using back-projection apparatus with a horizontal field of view of up to 70 deg, stationary observers viewed (monocularly) an array of cubes at different depths in the scene. The cubes moved in a manner consistent with observer translation or rotation. Simultaneously, observers viewed a probe (in stereo) at different depths in the scene and assessed its trajectory. In the largest FOV condition, perceived trajectory was inconsistent with flow-parsing behaviour. Consequently, the additional information provided by increasing stimulus FOV may not be sufficient for monocular flow-parsing.

OBJECT RECOGNITION

- ◆ **Identity-selective aftereffect in natural objects**
R Azadi, S-R Afraz¶ (Ahwaz Jondishapour University, Tehran, Iran; ¶ Harvard University, Somerville, USA; e-mail: r.azadi@yahoo.com)

Recent evidence reveals high-level identity/category-selective aftereffects for faces. Here we questioned whether an identity-selective aftereffect occurs only for faces, or adaptation to other complex shapes can lead to this type of aftereffects? Using a 2-D morphing paradigm, we made

shape average of pictures of four fish types and spanned a whole morphing space from each fish identity to the averaged fish. Extending each identity axis to negative values provided anti-fish images. Fish identification for each fish identity was facilitated after 5 s of adaptation to its graphically opposite identity (the anti-fish). In a control experiment, to rule out possible contribution of lower level visual aftereffects, an eye movement of 4° was applied after adaptation and before test phase of the experiment. Results showed a smaller but significant aftereffect following the eye movement. The results suggest that high-level aftereffects can take place for object categories other than faces; however, more quantitative studies are required to compare the strength of these aftereffects with the face aftereffects.

◆ **Spatial-frequency efficiency for object discrimination**

S Buffat, C Roumes, J Lorenceau ¶ (Cognitive Sciences, IMASSA, Brétigny sur Orge, France; ¶ LENA, Lidy, Paris, France; e-mail: sbuffat@imassa.fr)

We used natural images of objects seen from various viewpoints to assess the relative relevance of information across spatial scales. We measured human and ideal signal : noise ratio in a same – different task. Test images were an adaptative combination of object images, filtered along three spatial-frequency bands or full spectrum, and various noises (white or band-pass). We also varied the viewing distance. The recorded psychometric functions were fitted by a bootstrap method. Human-observers' thresholds were computed for all pairs of test images. An ideal observer, using an independent observation decision rule, provided ideal thresholds. We then computed efficiency as the ratio between the thresholds. Results show that thresholds are nearly the same for full-spectrum images and medium-spatial-frequency images, suggesting that the latter provide the relevant information needed for discriminating objects. Object discrimination in natural images, at one angular size, but at various viewpoints, could be mainly mediated by a medium-spatial-frequency band.

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◆ **Contour images recognition**

V N Chikhman, V Bondarko, M Danilova, A Goluzina, S Solnushkin (Department of Information Technology, Pavlov Institute of Physiology, St Petersburg, Russia; e-mail: niv@pavlov.infran.ru)

We run a set of psychophysical experiments to study recognition of contour images of well-known objects. Backward and direct masking was used in an attempt to understand which mechanisms underlie such recognition. Three different types of masks were employed: random textures, superposition of all the images, and superposition of the same, but fragmented images. Three sizes of the images and masks were used (4, 8, 12 deg); the contour width was scaled with the size. The results of the experiments are presented as confusion matrices. The masks formed by superposition of the whole images were more effective: they resulted in longer stimulus duration. The other two types of masks required the same duration, but provided different types of errors. Higher percentage of correct responses was obtained for medium sizes, but it depended on the type of mask. The experimental confusion matrices were compared with the results of modeling using spatial-frequency analysis of images and taking into account spatial-frequency sensitivity of the visual system.

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◆ **High-level aftereffects in visual processing of complex images**

V Daelli, N van Rijsbergen, A Treves (Cognitive Neuroscience Sector, SISSA, Trieste, Italy; e-mail: daelli@sissa.it)

In recent studies an adaptation-aftereffect paradigm has been applied to the investigation of the perception of facial categories, with morphed images creating a continuum between two extremes. Given the particular status of faces, it is not clear whether adaptation aftereffects are present in the perception of other classes of items; adaptation to simple geometrical shapes has been described, but this paradigm was never applied to complex natural images. We investigated whether the adaptation aftereffects can be extended to the perception and categorization of objects. We morphed images of objects, creating continua of within-category (eg cat – cat) and between-category (eg cat – rabbit) stimuli, and measured the similarity between the extremes of the continua on the dimensions of shape, texture, and meaning. We found significant aftereffects in perceptual discrimination of the morphed images after adaptation to the extremes of the continuum, modulated by the type of similarity rating performed before the adaptation task, suggesting a role of attention to particular features of the images in aftereffects.

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◆ **Properties of gamma oscillations in visual discrimination tasks**

A K Harauzov, Y Shelepin, J Noskov, T Selchenkova (Laboratory of Vision Physiology, Pavlov Institute of Physiology, St Petersburg, Russia; e-mail: haral@infran.ru)

It is generally believed that neuronal oscillations in the gamma band underlie a possible mechanism for the visual perception. We investigated the properties of evoked gamma band activity in visual discrimination tasks of different complexity. Stimuli were rectangular matrices composed of Gabor patches. Matrices differed by the number of Gabor patches with vertical or horizontal orientation relative to other orientations. The task was to identify the dominant orientation. Complexity of the task was inversely proportional to the number of equally oriented Gabor patches in the matrix. All subjects showed a significantly phase-locked EEG component of 40 Hz peaking at 90 ms after stimulus onset and maximally prominent at electrodes placed over extrastriate cortex. We observed a slight decrease of the frequency in the gamma range with the number of equally oriented Gabor patches in the matrix, whereas the energy of gamma response did not significantly vary with stimulation type. Therefore our data reveal plastic properties of gamma oscillations: their frequency increases with complexity of the task.

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◆ **Representing object orientation in the absence of attention**

I M Harris, C T Benito, P E Dux ¶ (School of Psychology, University of Sydney, Sydney, Australia; ¶ Vanderbilt University, Nashville, USA; e-mail: irina@psych.usyd.edu.au)

We investigated whether object processing in the absence of attention is orientation-invariant or orientation-dependent, by looking at priming effects from ignored stimuli. Subjects performed an RSVP dual-target task in which they reported two upright red target objects (T1 and T2) embedded within streams of either upright or rotated black distractors. On half the trials, one of the early distractors in the stream had the same identity as T2. We found that a rotated distractor facilitated T2 report (ie reduced the attentional blink suffered by this object), but an upright distractor (ie the identical image of T2) reduced T2 report. These results are only partly consistent with previous findings of orientation-invariant processing in the absence of attention and awareness (eg Harris and Dux, 2005 *Cognition* **395** 73–93; Dux and Harris, 2007 *Cognition* **104** 47–58). Rather, they suggest that multiple levels of representation become activated for ignored stimuli and have opposite effects when the same object is later selected for report. More abstract, object-centred, representations facilitate subsequent identification, while image-based representations seem to inhibit it.

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◆ **Frequency-based categorization of complex visual objects**

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How do we come to group visual objects into discrete categories? We tested whether stimulus frequency could drive category formation for high-level visual objects. We presented complex visual stimuli from a two-dimensional continuum following a bimodal frequency distribution: two regions of the stimulus space were shown with high frequency ('peaks'), while intermediate stimuli were shown less often. When asked to categorize the stimuli, subjects closely followed the frequency distribution. Frequency-based categorization was best at the extremes of the spectrum and emerged within less than 50 trials. In a second experiment, subjects passively viewed the same frequency distribution and subsequently guessed the category membership of each stimulus. Again judgments closely followed the frequency distribution. These results suggest that (i) stimulus frequency can strongly influence the categorization of complex visual objects, (ii) this influence is independent of physical dimensions and may be based on the establishment of a frequency-based category axis, (iii) learning of frequency information is extremely fast, and (iv) passive exposure is sufficient for frequency to influence categorization.

◆ **Depth information contained in the representation of moving 3-D objects in apparent-motion perception**

S Hidaka, Y Kawachi, J Gyoba (Department of Psychology, Tohoku University, Sendai, Japan; e-mail: hidaka@sal.tohoku.ac.jp)

We investigated depth information contained in the representation of apparently moving 3-D objects. In three experiments, we measured the magnitude of representational momentum (RM) as an index of the consistency of object representation (Kelly and Freyd, 1987 *Cognitive Psychology* **19** 369–401). Experiment 1A revealed that the RM magnitude was greater when shaded convex moving objects shifted to a flat circle than when they shifted to a shaded concave hemisphere. The difference diminished when the moving objects were concave (experiment 1B). Experiment 2

confirmed, with luminance-polarized circles, that these results were not obtained from luminance information of the shaded hemispheres. Moreover, experiment 3 showed that, in terms of low-pass filters, the RM magnitude was greater when the convex moving objects shifted to blurred convex hemispheres than when they shifted to concave hemispheres. These results suggest that the internal object representations in apparent motion contain incomplete depth information, intermediate between those of 2-D and 3-D objects, particularly convexity information with low-spatial-frequency components.

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◆ **Recollection, familiarity, and visual similarity**

A Ishai, M Wiesmann (Institute of Neuroradiology, University of Zurich, Zurich, Switzerland; e-mail: ishai@hifo.uzh.ch)

We used art compositions to test whether recognition memory depends on the visual similarity between new and old pictures. We predicted faster and more accurate responses to new, visually different paintings than to new, visually similar paintings. Subjects memorized 90 paintings and three days later performed a ‘remember/know/new’ memory retrieval task. The old prototypes were randomly presented with new paintings, which were either visually similar to the prototypes, somewhat similar (ambiguous), or visually different. Consistent with our hypothesis, subjects correctly recognized more new, visually different items and the response latency was significantly shorter than that to the new, similar, or ambiguous paintings. The number of “know” responses to the new, similar items was significantly higher than the number of “know” responses to the ambiguous and different paintings. Our results suggest that recognition memory of newly learned pictures is modulated by visual similarity. False alarms—mistaking new pictures for old ones—are associated with feelings of familiarity, not recollection.

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◆ **Temporal window of colour-motion binding in the stream/bounce event perception**

Y Kawachi, T Kawabe¶, J Gyoba (Department of Psychology, Tohoku University, Sendai, Japan; ¶User Science Institute, Kyushu University, Fukuoka, Japan; e-mail: kawachi@sal.tohoku.ac.jp)

Two identical visual objects moving across each other in a two-dimensional display can be perceived as streaming through or bouncing off each other at the position of their coincidence. In general, the former perception is more frequent than the latter. In our preliminary observation, a switch of the object colour between the two objects biased perception towards bouncing. Using this phenomenon, we examined the spatiotemporal window within which the integration of colour and the motion of objects can affect the stream/bounce event perception. We varied the presentation duration (0–350 ms) of the moving objects after the colour switch at the coincidence. The results revealed that a critical duration (approximately 150 ms) was required for the observers to stably utilize the colour change in determining the stream/bounce event. Furthermore, we found that the critical duration was invariant across several motion speeds of the objects. These results suggest that colour-motion binding within the temporal window of approximately 150 ms is utilized to alter visual event perception.

◆ **A new algorithm for image segmentation by using colour, intensity, and scale**

S A Kondra, W Vanzella, R Daliri, V Torre (Department of Neurobiology, SISSA, Trieste, Italy; e-mail: kondra@sissa.it)

We present a new method for image segmentation based on a watershed algorithm that uses edges (colour + intensity + scale) and a novel region-merging procedure. The merging procedure uses a χ^2 distance over three feature vectors: one for colour representation, one for the scale map, and one describing the output of rotational filters. Edges are detected by means of the algorithm developed by Pellegrino et al (Pellegrino et al, 2004 *IEEE Transactions on Systems, Man, and Cybernetics* **34** 1500–1518). A visual representation of texture, similar to a Texton map is obtained with a modified Lindeberg scale (Lindeberg, 1998 *International Journal of Computer Vision* **30** 117–156). This scale map is also used for eliminating edges in the region of fine scales. Performance of the method is evaluated on images from the Berkeley database. The proposed algorithm provides better results for the global-consistency error (GCE) than those previously reported for the same set of images [Micusik et al, 2006, in *Computer Vision—ECCV 2006* Eds A Leonardis, H Bischof, A Pinz (Berlin: Springer) pp 468–480].

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◆ **Achieving visual object constancy across variation in illumination**

R Lawson (School of Psychology, University of Liverpool, Liverpool, UK;
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Three object-naming and change-detection studies were carried out to test whether altering the illumination of an object influenced its identification. Stimuli were pictures of isolated, computer-generated models of familiar objects and photographs of everyday objects in natural scenes for which lighting varied due to the sun's position relative to the viewer. People were largely insensitive to variation in lighting and to contrast reversal. Decrements in performance were found only for objects depicted under extreme lighting conditions. In contrast, when the view depicted of the object models altered from the initial to subsequent presentations, there was a substantial reduction in priming relative to same-view conditions. Furthermore, detection of changes to the viewpoint of the everyday objects was quite accurate, unlike the detection of lighting changes. These results suggest that there is usually minimal cost to compensating across the changes in lighting that occur under normal viewing conditions for familiar objects. In contrast, performance is typically disrupted if constancy must be achieved across even modest depth rotations of the same objects.

◆ **Substitution masking of a local target induced by a global mask**

I Luiga, T Bachmann (University of Tartu, Tartu, Estonia; e-mail: iluiga@hotmail.com)

We probed local and global object processing in substitution masking. If substitution masking is taking place on object-representation level, a large global object compared to a small local object may also lead to substitution masking. In our study, a global mask outlined by small objects on the contours gave rise to the masking effect. Enhanced perception of a target presented in the corner of the mask and reduction of substitution masking was observed compared to when a target was presented at the edge. Mask shapes with corners produced stronger masking with mask delays shorter than 180 ms than ring-shaped masks. Targets with corners were perceived better also. Therefore, corners of an object may draw more attention, leading to the reduction of substitution masking. As hypothesized, a global object mask produced substitution masking comparable to a local object mask. Reduction of substitution masking due to the reinforcing influence of processing of a congruent global pattern was not observed.

◆ **Time course of the sensitivity of the visual system to phase information**

G A Rousselet, P J Bennett ¶, A B Sekuler ¶ (Department of Psychology, University of Glasgow, Glasgow, Scotland, UK; ¶ McMaster University, Hamilton, Canada;
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We examined the phase-tuning function of ERP signals evoked by complex objects. Stimulus phase was systematically manipulated in a parametric design, with 11 steps of phase information, ranging from 0% (noise), to 100% (original stimulus). Contrast and amplitude spectrum were maintained constant across noise levels. Subjects had to discriminate between two faces, a task orthogonal to the stimulus manipulation. Sharp monotonic changes in the ERPs occurred between 100 and 150 ms after stimulus onset and peaked around the latency of the N170. Those changes had a topography very similar to the one of early visual evoked responses. Phase sensitivity in the ERP was not affected by the task, as very similar patterns were observed when subjects performed a face-detection task. The onset of phase sensitivity was overall delayed for house stimuli. Controlled experiments with different types of noise textures suggest that part of the response evoked by faces and houses might correspond to the processing of higher-order image statistics like skewness and kurtosis.

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◆ **Hemispheric processing for categorical and metric properties in object recognition: A behavioural and fMRI study**

A Saneyoshi, T Kaminga, C Michimata ¶ (Teikyo University, Tokyo, Japan; ¶ Sophia University, Tokyo, Japan; e-mail: a-sane@nifty.com)

Participants performed two kinds of sequential matching tasks. Stimuli were novel, unnameable, multi-part objects. In the categorical task, two objects differed in categorical relation of the components. In the metric task, two objects differed in metric relation. Experiment 1 (visual half-field study) indicated a right visual-field (left hemisphere) and left visual-field (right hemisphere) advantage for the categorical and metric tasks, respectively. Experiment 2 (fMRI study) suggested that the activations of the right parietal and right temporal lobes are correlated with each other in the metric task but not in the categorical task. These results suggest that the categorical and metric properties are processed by different neural substrates. The right-hemisphere advantage

for the processing of metric properties might be related to the connectivity of the right parietal and temporal lobes.

◆ **Two decision centers for visual pattern recognition in the human brain**

A V Sevostyanov, Y Shelepin ¶, V Fokin, G Trufanov, A Harauzov ¶ (Medical Military Academy, St Petersburg, Russia; ¶ Pavlov Institute of Physiology, St Petersburg, Russia; e-mail: asevnov@mail.wplus.net)

Perceptual decision could finalize processing of visual signals provided by dorsal and ventral streams. The dorsal pathway is responsible for perception and interpretation of spatial relationships of the visual scene, and the ventral one for the meaning, including emotional meaning, and 'economic' value of objects in the scene. We applied a classical boxcar paradigm looking for differences in BOLD signal with the help of fast echo planar imaging (EPI) covering the whole brain in 3 s. The purpose of study was to localize cortical areas of the human brain involved in visual pattern recognition for Gabor gratings of different complexity and meaning. Our results show that both streams, dorsal (BA7 bilaterally) and ventral (BA37 bilaterally), were involved in visual processing. Equally, dorsal and ventral parts of the prefrontal cortex participated in decision-making: dorsolateral prefrontal cortex (DPC) was activated when the decision was evident and straightforward and ventromedial prefrontal cortex (VPC)—when the verdict was ambiguous. The latter activity in VPC could also reflect the work of the error-detecting mechanism. [Supported by Russian Foundation for Basic Research grant N 05-04-49032.]

◆ **Human and machine limits in CAPTCHA recognition**

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Many websites today offer online services, such as web searches or electronic mail. However, some people insist on scanning search-engine results, or registering many accounts for e-mail or message boards, in order to transmit spam. This increases the system's load and users find that the system runs more slowly and message boards fill with spam. That is why many services now ask the user to fill in a form using numbers shown in an image (a 'CAPTCHA'). Because spammers have created special tools, based on text-recognition programs, CAPTCHAs have noise backgrounds and the characters are transformed. This transformation should allow human recognition but should not be recognised by conventional pattern-recognition programs. Using linear transformations of letters and noise backgrounds, we compared the recognition performance of human observers and commercial text-recognition programs. Measurements of the human limits of pattern recognition in multiplicative noise and for nonlinear transformations allow us to propose an optimal type of transformation.

◆ **Combined effects of perceptual-grouping cues on object representations revealed by motion-induced blindness**

M Shibata, Y Kawachi, J Gyoba (Department of Psychology, Tohoku University, Sendai, Japan; e-mail: shibatam@sal.tohoku.ac.jp)

Salient visual objects perceptually disappear when they are surrounded by a rotating distractor (motion-induced blindness: MIB). In order to investigate the combined effects of perceptual-grouping cues on the representation of an object with a hierarchical structure, we analysed the disappearance patterns of stimuli in which an inner target was embedded in an outer target. Participants were asked to report whether either or both of the targets disappeared during 60 s of the MIB stimulus presentation. The results showed that when the targets were presented with a separation of less than 0.5 deg (high proximity), both targets disappeared simultaneously as a single object; however, they did not do so when the contour of the outer target was not closed. Additionally, the results indicated that when both targets had high similarity in shape, the targets disappeared simultaneously, even when they were presented with a separation greater than 0.5 deg (low proximity). These results indicate that the visual system forms a whole-object representation by utilizing multiple perceptual-grouping cues in combination.

◆ **Decoupling implicit and explicit processes in the recognition of objects from unusual viewpoints: Does a failure to name necessarily imply failed recognition?**

Z Terpening, I Harris, J Watson ¶ (School of Psychology, University of Sydney, Sydney, Australia; ¶ Sydney Adventist Hospital, University of Sydney, Wahroonga, Australia; e-mail: zoeterps@gmail.com)

This study follows a strong trend in the visual perception literature attempting to decouple implicit and explicit processes by investigating whether an inability to name an object necessarily implies failed recognition. In particular, we investigated whether a failure to explicitly name a non-canonical object, necessarily implies that the object has not been recognized (at least implicitly). In the first experiment, healthy subjects ($N = 24$) completed visual implicit priming

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tasks to determine whether canonical and non-canonical objects presented briefly (thus precluding explicit recognition) could produce priming effects. Evidence of priming would suggest that non-canonical objects can be recognized implicitly without explicit recognition (ie naming). Preliminary findings from a second experiment, repeating this paradigm with a group of unusual-views patients ($N = 5$), a rare subset of clinical patients (usually with right parietal lesions) who have difficulty naming objects presented from unusual or non-canonical viewpoints but retain the ability to name objects from their canonical view, are also presented. Does a failure to name objects in these patients necessarily imply failed recognition?

◆ **Lateralized EEG alpha oscillations in the preparation for global and local processing**

G Volberg, K Kliegl, M W Greenlee (Department of Experimental Psychology, University of Regensburg, Regensburg, Germany; e-mail: gregor.volberg@psychologie.uni-regensburg.de)
Although it has been suggested that hemispheric differences in global/local processing already occur in response to pre-cues that direct attention to one level, in a recent ERP experiment we found no such effects. However, it is possible that induced differences between hemispheres were overlooked in the applied waveform analysis. Moreover, the interval between cue and target stimulus was long which might be an unfavorable factor. In order to account for these objections, cue stimuli were presented with varying stimulus-onset-asynchronies (0–900 ms), and desynchronization of the EEG alpha-band was used as an index of hemispheric excitation. 200–400 ms after cue onset, the data showed larger alpha desynchronization for the local compared to the global condition at left posterior electrodes, and the reversed pattern occurred in the right hemisphere. This effect was restricted to the 600 ms stimulus-onset-asynchrony. It is concluded that global/local cue information can produce differences in hemispheric excitability, and such pre-adjustment is not made if the time up to target stimulus presentation is too short or too long.

SHAPE PERCEPTION

◆ **Where do you draw the lines?**

E Adelson, T Judd, F Durand (Computer Science and Artificial Intelligence Laboratory [CSAIL], MIT, Cambridge, USA; e-mail: adelson@csail.mit.edu)

Line drawings are efficient and effective in conveying a 3-D shape with a 2-D image. But where should you draw the lines? One proposal: find points on the surface that are 'special' in terms of the intrinsic geometry of the surface, such as the extrema of curvature along ridges and valleys. Unfortunately, these lines often look wrong. Better results are obtained with the view-dependent 'suggestive contours' described by Decarlo and colleagues; these are drawn at points where the surface is nearly parallel to the line of sight. We propose a new approach: draw lines at points where the rate of change of the surface normal is maximal (measured in image coordinates, not object coordinates). A more intuitive version, almost equivalent, is: draw lines at points where the luminance will tend to change quickly, independently of illumination or reflectance. This single rule produces all the lines you want, such as occluding contours, dihedrals, and view-dependent ridges and valleys. The resulting line drawings look correct.

◆ **Underestimation of the distance between line segments across the blind spot occurs in the blind spot**

Y Araragi (Department of Visual Communication Design, Faculty of Design, Kyushu University, Fukuoka, Japan; e-mail: araragiy@design.kyushu-u.ac.jp)

Previous studies have shown an underestimation of the space across the blind spot. I examined whether the underestimation occurred in and/or around the blind spot. Test line segments were presented across the blind spot or on the peripheral region at the same eccentricity as the blind spot. Comparison line segments were presented on the temporal retina. The method of limits was used to estimate the perceived distance between the line segments in four distance conditions. The observer's task was to adjust the distance between the comparison line segments so that it appeared equal to that between the test line segments. The results showed that the amount of underestimation across the blind spot did not significantly change with the distance between the line segments. The results suggest that the underestimation across the blind spot occurs in the blind spot.

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◆ **Perceiving illusory contour figures and knowing their shape: One process or two?**

A Barlasov Ioffe, S Hochstein (Department of Neurobiology, Hebrew University, Jerusalem, Israel; e-mail: barlasov@pob.huji.ac.il)

Investigating the relationship between illusory-figure detection and discrimination of its shape, we ask if these depend on a single, two separate, or two sequential processes. In a simultaneous detection–discrimination experiment, we presented subjects with brief, backward-masked

Kanizsa-type patterns. For each trial, subjects reported whether they perceived an illusory figure (detection) and which shape they saw (discrimination), guessing the shape even when it was not explicitly perceived. Average detection and discrimination psychometric curves were similar with significantly better-than-chance detection and discrimination beginning at ~ 100 ms. Nevertheless, we found three patterns of performance, representing different detection–discrimination relationships. There were significant detection–discrimination differences, suggesting these may be separate processes. Detection was not always followed by correct discrimination, especially for more naive subjects. Interestingly, sometimes discrimination was accurate, even without detection—a kind of blindsight in seeing individuals. Moreover, only with explicit detection did shape discrimination use local features. We suggest that illusory-figure detection and shape discrimination are separate tasks, with a relationship determined by the experience of individual subjects with these stimuli.

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◆ **Combining specular and diffuse lighting to recover 3-D shape**

S Bouzit, A Wendy, G Erich (Department of Psychology, University of Southampton, Southampton, UK; e-mail: sbouzit@soton.ac.uk)

Observers use the assumption of a single, overhead light source to recover shape from ambiguous shading. Here we examine (i) the effect of adding specular highlights on convex/concave judgments, and (ii) how specularities and diffuse shading are combined when they are consistent with different lighting directions. Observers viewed shaded disks with convex/concave ambiguity under diffuse and specular lighting. The stereoscopic depth of specular highlights reliably specifies curvature. However, under the monocular viewing used in our experiments, specularities should not provide additional information to disambiguate shape. In two experiments, lighting direction was varied and observers made shape judgments of matte and shiny objects. The addition of specular highlights increased the range of lighting directions that produced convex responses. When all objects in the scene were shiny, observers violated the assumption of a single light source, perceiving opposite shading-gradient orientations simultaneously as convex. When differences between the lighting directions of specular and diffuse sources were introduced, observers combined these in a robust manner to recover shape.

[SB and WJA are supported by EPSRC grant EP/D039916/1.]

◆ **Modification of the convexity prior but not the light-from-above prior in visual search with shaded objects**

R A Champion, W J Adams (School of Psychology, University of Southampton, Southampton, UK; e-mail: champion@cardiff.ac.uk)

Visual-search studies with shaded stimuli typically demonstrate better performance for: (i) stimuli with vertical compared to horizontal shading gradients, and (ii) vertically shaded stimuli with top-light (convex) distractors compared to bottom-light (concave) distractors. These findings suggest that preferences or prior assumptions for both overhead lighting and convexity are reflected in preattentive processing. We attempted to modify shape perception and search behaviour by providing visual–haptic training in an environment inconsistent with these two priors. In the training environment, convex and concave objects were equally prevalent and lighting direction was shifted relative to the observer's baseline light-prior. Following training, observer's asymmetry between visual-search performance with convex and concave distractors was reduced, suggesting a modification of the convexity prior. In addition, observer's shape judgments reflected a shift in the light-from-above prior. However, this shift did not affect visual-search behaviour. We conclude that experience can modify the preattentive convexity prior, but that the light-from-above prior may only be modified at a higher level.

[Supported by a Leverhulme Trust early career fellowship (RAC) and an EPSRC project grant (WJA).]

◆ **A shape illusion: Orientation, not position, drives global shape perception**

M Day, G Loffler (Department of Vision Sciences, Glasgow Caledonian University, Glasgow, Scotland, UK; e-mail: m.day@gcal.ac.uk)

Research has focused on details of local stimulus features that combine to produce global shape. We contrasted positional versus orientation information and report a new illusion. Gabor patches positioned on a circle, with orientations sampled from non-circular shapes [radial frequency (RF) patterns with varying number of lobes and amplitudes], are seen as the shape from which their orientations were sampled. For low amplitudes, points of subjective equality (PSEs) between test (continuous or sampled RFs with position and orientation consistent with the shape) and reference shapes are closely matched, irrespective of the type of test and largely independent of shape ($RF = 2 - 15$). PSEs show linear dependence on amplitudes up to 5% of

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the shape's radius with a reduction for higher amplitudes. Over a range of shapes, the visual system uses local orientations to produce global percepts, overwriting positional information. We attribute this to global shape mechanisms since it is diminished when information is restricted to a fraction of the contour or when elements are positioned on a line.

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◆ **Local 3-D curvature affects perceived rigidity and shininess of rotating specular ellipsoids**

K Doerschner, D Kersten (Department of Psychology, University of Minnesota, Minneapolis, USA; e-mail: doers003@umn.edu)

Specular flow provides constraints on 3-D shape; however, sometimes specular flow patterns lead to non-rigid shape percepts. Previously we found that global shape affects perceived rigidity of rotating specular objects; here we measure how local 3-D curvature affects both perceived rigidity and perceived shininess. Stimuli were specular ellipsoids illuminated by a $1/f$ amplitude spectrum noise environment map. Local 3-D curvature was varied along two dimensions: frequency and amplitude. This was accomplished by perturbing surface normals. Observers viewed movie clips of rotating ellipsoids and subsequently rated rigidity (experiment A) and shininess (experiment B) of the object on a scale from 1 (least) to 5 (most rigid/shiny). Note that ellipsoids, when shown to observers as static images, usually appeared to be matte. Results show that larger amplitudes of local shape perturbations resulted in ellipsoids appearing more rigid and more shiny. Low-frequency-modulated ellipsoids tended to be perceived less rigid and shiny than high-frequency-modulated ones. Overall, perceived shininess was positively correlated with perceived rigidity.

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◆ **Form misorientation in limiting cases of amodal completion**

C Fantoni, W Gerbino, S Rigutti (Department of Psychology, University of Trieste, Trieste, Italy; e-mail: fantoni@psico.units.it)

Growing evidence suggests that amodal completion is mediated by approximation rather than interpolation. Visual approximation is a process maximizing stimulus conformity and minimizing the complexity of perceived forms. In the Gerbino illusion a regular hexagon is misperceived when its angles are asymmetrically occluded by triangles that locally cover one side but not the other. Here, we demonstrate that the illusion involves the perceived orientation of the occluded form. When the occluding triangles disappear, the hexagon apparently rotates in a direction consistent with approximation: clockwise or counterclockwise, depending on whether the triangles are occluding the right or left side, respectively. We measured the apparent rotation using the method of constant stimuli and partially occluded hexagons with different types of occlusion angles (asymmetric vs symmetric), followed by an unoccluded hexagon. Observers were asked to judge in which direction the hexagon appeared to rotate. Accuracy was biased when the occlusion angles were asymmetric but not when they were symmetric. In limiting cases of occlusion, spatial integration of visually approximated portions leads to a phenomenally misoriented form.

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◆ **The perceptual salience of the Golden Section**

V Graci, B F Marino ¶, M G Cicchini ¶, N Stucchi § (Department of Optometry, University of Bradford, Bradford, UK; ¶ Università Vita-Salute San Raffaele, Milan, Italy; § Università degli Studi di Milano-Bicocca, Milan, Italy; e-mail: vgraci@brad.ac.uk)

Since Fechner in 1876, the aesthetic preference for the Golden Section (the ratio $\phi = 1.618$ between a whole segment and part of it) was largely studied without any definitive outcome. Besides, a perceptual salience of ϕ would be a premise for its aesthetic preference; nevertheless nobody tried to investigate it. Here, we tested the perceptual salience of ϕ . Standard stimuli consisted in 15 different bisections of a horizontal line by a vertical one. Two of these sections corresponded to ϕ . Subjects were asked to match the position of the vertical line of the adjustable stimulus to the position of that in the standard stimulus. In experiment 1 the standard stimulus and the adjustable stimulus were presented in sequence, separated by a mask; in experiment 2 they were both available. The point ϕ features the highest constant error which bounds two regions of smaller constant error, one with more central sections and the other with more eccentric ones. This finding suggests that ϕ is the equilibrium point between the centre and the bounds.

◆ **Selective mechanisms for simple contours revealed by a contour aftereffect**

S Hancock, J W Peirce (School of Psychology, University of Nottingham, Nottingham, UK; e-mail: sarah.hancock@nottingham.ac.uk)

A straight test stimulus can appear concave after exposure to a convex adapting stimulus. However, studies have been unable to determine whether this effect reflects a 'curvature aftereffect'

or simply combines effects of local tilt aftereffects (TAEs) (Stromeyer and Riggs, 1974 *Science* **184** 1199–1201). Here, we adapted one patch of visual field to two adjacent gratings presented simultaneously as an obtuse contour (compound adapter), and another patch to the same component gratings presented alternately (component adapter). Each grating generates an individual TAE so that straight, vertical probe stimuli appear tilted in the opposite direction to the adapting stimulus. These should produce equivalent TAEs in both adapting patches. However, the perceived concavity of a vertical probe was greater in the compound-adapter patch. This difference was considerably reduced (although not completely abolished) by increasing the spatial separation of the components. The findings suggest that the TAE was accentuated in the compound patch by a contour aftereffect, above and beyond local TAEs—a result consistent with the existence of ‘curvature detectors’.

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◆ **Evolving the Golden Ratio: A new method for an old question of aesthetic perception**

T P Holmes, J Zanker (Department of Psychology, Royal Holloway University of London, Egham, UK; e-mail: t.holmes@rhul.ac.uk)

Investigation of the Golden Ratio (1:1.62) as a measure of perceived beauty has a long history in psychological research. There is mixed evidence for the preference of this ratio in rectangles. Evolutionary Algorithms present a new opportunity for researching this preference by enabling participants to drive the real-time evolution of their preferred rectangle, whilst addressing many of the criticisms of previous studies. Populations of 9 portrait or landscape rectangles of fixed areas were presented on a screen and participants selected their preferred rectangle, from which a new generation of rectangles was evolved by mutation. This process was repeated over a number of generations. Preferred ratios can vary considerably between individuals, with group-level results differing significantly from the Golden Ratio. Strong orientation effects were found, while the method was invulnerable to the range of ratios presented. These results are discussed, along with an assessment of the Evolutionary Algorithm as a effective method for use in future research.

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◆ **Concavities count for less in symmetry**

J Hulleman, C N L Olivers[¶] (Department of Psychology, University of Hull, Hull, UK; [¶]Department of Cognitive Psychology, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; e-mail: j.hulleman@hull.ac.uk)

We investigated the relative importance of convexities (protrusions) and concavities (indentations) for the perception of shape. On the one hand, it has been suggested that convexities determine the shape of an object, whereas concavities merely act as ‘perceptual glue’ between the convexities. On the other hand, it has been argued that concavities are more salient than convexities. We show that participants find it easier to detect asymmetry in a 2-D silhouette when there is a mismatch between the shapes of convexities on either side of the axis of symmetry, than when there is a mismatch between the shapes of concavities. This is the case even when the concavities are closest to the axis of symmetry, and despite the usual bias towards this axis in symmetry perception. We suggest that the actual shape of concavities is less important in symmetry perception, because their main role is to act as part-boundaries in the representation of the shape of objects.

◆ **Perceptual transformation of a circle and its afterimage**

H Ito (Department of Visual Communication Design, Kyushu University, Fukuoka, Japan; e-mail: ito@design.kyushu-u.ac.jp)

When a circle is viewed in peripheral vision, it perceptually changes its shape into a polygon, typically a hexagon. The circle begins to change its perceptual shape after 3 s of presentation. After 7 s, in almost all trials, observers perceive a polygon from the physical circle. After disappearance of the circle, they perceive a negative afterimage with a polygon shape. The perceived polygon becomes clearer in the afterimage. Although the afterimage soon disappears, it sometimes reappears, keeping the polygon shape. On the other hand, a hexagon viewed in peripheral vision does not change perceptually into a circle during presentation. However, its negative afterimage rapidly transforms into a circle. This is not because the spatial resolution of afterimages in peripheral vision is not high enough to perceive corners. As noted above, the afterimage of a circle keeps its polygon shape. The illusion yields phenomenal evidence showing that corner detection and curvature detection are opponent processes in human vision.

[Supported by the 21st Century COE Program.]

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◆ **The effect of subjective contours in the Ebbinghaus illusions**

W H Jung, H S Kim (Center for Cognitive Science, Yonsei University, Seoul, South Korea; e-mail: com4man@gmail.com)

Three experiments were conducted to examine whether a subjective contour can affect the magnitude of the Ebbinghaus illusion. In experiment 1, two stimulus conditions—non-subjective contour (NSC) and subjective contour (SC)—were compared. The difference between the two conditions was whether the inducing elements made a subjective contour or not. In experiment 2, the difference between two additional conditions—vivid subjective contour (VSC) and real contour (RC)—was examined. In the VSC, three lines were added to the inducing elements to make the subjective contour clearer. The experimental conditions in experiment 3 were identical to those in experiment 1 except for the shape of the inner figures. The inner figure in experiment 3 was a lozenge, which was similar to figures in the subjective contour. The results showed that the magnitude of the Ebbinghaus illusion in the SC condition is smaller than in the NSC condition regardless of the shape of inner figures, and smaller in the VSC condition than in the RC condition. These results imply that a subjective contour can affect the perception of the Ebbinghaus illusion.

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◆ **Amodal completion behind multiple occluders: A temporal analysis**

O Parlangeli, S Guidi, S Palmer ¶ (Department of Communication Sciences, University of Siena, Siena, Italy; ¶ University of California at Berkeley, Berkeley, USA; e-mail: guidi14@unisi.it)

We report on a series of experiments designed to test if the time needed to complete an occluded figure depends on the number of occluding layers, and whether, in situations of multiple occlusion, there is a principled order in which the figures are completed. In the experiments we manipulated the number of layers occluding a target shape in a visual-search task, keeping constant both the total number of figures and the extent to which the target was occluded. Response times were significantly smaller in conditions where the target was occluded by just one layer than in those where there were two or more occluding layers, but no significant differences were found between RTs in these conditions of multiple occlusion. This suggests that, although completion seems to proceed from front to back, the process is not strictly serial, and that surfaces of an object immediately behind a visible occluder may be given a preferential treatment over the ones of all the other objects behind.

◆ **Does closure stabilize contour integration?**

M Persike, G Meinhardt (Department of Psychology, Johannes Gutenberg University, Mainz, Germany; e-mail: persike@uni-mainz.de)

The integration of local oriented band-pass elements into global contours has been studied for backgrounds randomly varying in element orientation and carrier spatial frequency. In spatial arrangements controlled for eccentricity, spatial certainty, and density cues, we measured contour-detection performance as a function of the degree of orientation jitter along the contour for various degrees of spatial-frequency jitter in background and contour. Contour-detection performance declined with increasing spatial-frequency jitter. Closed contours exhibited a clear detection advantage compared to open contours, with the same detection performance achieved at larger degrees of orientation jitter at all spatial-frequency jitter levels. Psychometric-curve analysis revealed that slopes did not vary systematically with the background-jitter level, but remained constant over a wide range until the highest background-jitter levels, where slopes decreased considerably. Our results show that closed contours are easier to detect, but there is no evidence that detection of closed contours is more efficient in external noise, suggesting that no particularly efficient detection routines are associated with closure.

◆ **Humans assume a mixture of diffuse and point-source lighting when viewing sinusoidal shading patterns**

A J Schofield, P B Rock, M A Georgeson ¶, T A Yates ¶ (School of Psychology, University of Birmingham, Birmingham, UK; ¶ Aston University, Birmingham, UK; e-mail: a.j.schofield@bham.ac.uk)

Observers perceive sinusoidal shading patterns as being due to sinusoidally corrugated surfaces, and perceive surface peaks to be offset from luminance maxima by between zero and $\frac{1}{4}$ wavelength. This offset varies with grating orientation. Physically, the shading profile of a sinusoidal surface will be approximately sinusoidal, with the same spatial frequency as the surface, only when: (A) it is lit suitably obliquely by a point source, or (B) the light source is diffuse and hemispherical—the ‘dark is deep’ rule applies. For A, surface peaks will be offset by $\frac{1}{4}$ wavelength from the luminance maxima; for B, this offset will be zero. As the sum of two same-frequency sinusoids with different

phases is a sinusoid of intermediate phase, our results suggest that observers assume a mixture of two light sources whose relative strength varies with grating orientation. The perceived surface offsets imply that gratings close to horizontal are taken to be lit by a point source; those close to vertical by a diffuse source.

[Supported by EPSRC grants to AJS and MAG.]

◆ **The influence of discontinuous side on regularity of shape**

M Sinico, G Parovel¶ (Department of Arts and Industrial Design, University IUAV of Venice, Venice, Italy; ¶ University of Siena, Siena, Italy; e-mail: sinico@iuav.it)

When a side of an equilateral triangle is interrupted by a spatial gap, an apparent irregularity of the shape is perceived. In order to explain this optical-geometrical illusion we carried out three experiments. The task of participants was to evaluate the regularity of the figures by two different methods of measurement. In experiment 1 we measured the influence of position and relative size of the discontinuity on the regularity of equilateral triangles. Experiment 2 was designed to evaluate the effect of the discontinuity on the apparent length of the side, in terms of the Oппel–Kundt illusion, comparing figures with and without discontinuity. Experiment 3 verified the influence of the discontinuity on the apparent inclination in depth of the adjacent side. The results show that position and size of the discontinuity are functionally related to the magnitude of the illusion. Moreover, this illusion is not traceable back to the Oппel–Kundt illusion, but we conclude that the apparent inclination in depth of a side is a crucial factor in providing a comprehensive account of the illusion.

[Supported by grants from the School for Advanced Studies in Venice Foundation (SSAV).]

◆ **Effect of contextual cues on motion-surface labeling in structure from motion**

T Yoshizawa, M Nakade, T Kawahara, K Maeda¶ (Human Information System Laboratory, Kanazawa Institute of Technology, Hakusana, Japan; ¶ Konan University, Kobe, Japan; e-mail: tyoshi@his.kanazawa-it.ac.jp)

The motion of surfaces in 'structure from motion' paradigms must be disambiguated with some feature or salience of moving dots (Yoshizawa et al, 2006 *Perception* **35** Supplement, 36). This finding shows the percept of unambiguous rotating cylinders in the target stimulus per se. Here, we focus on other aspects of ambiguity in the structure from motion. To investigate whether contextual cues solve the ambiguity, we examined the perceived direction of an ambiguous and an unambiguous rotating cylinder that was sandwiched between two rotating cylinders. We presented three groups of moving dots, each of which was perceived as a single rotating cylinder within a vertically aligned group of cylinders. We found that an unambiguous rotating cylinder induced a rotation direction in the ambiguous rotating cylinder and that the three perceived rotating cylinders were perceived as one vertically elongated rotating cylinder, indicating that the contextual cue can also solve the ambiguity.

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THURSDAY

ORAL PRESENTATIONS

IMAGING

◆ **Topography of fMRI response for spatial frequency**

S Vanni, L Henriksson¶, L Nurminen§, A Hyvärinen§ (Brain Research Unit, Low-Temperature Laboratory [LTL], Helsinki University of Technology, Espoo, Finland; ¶also AMI Centre, Espoo, Finland; §University of Helsinki, Helsinki, Finland; e-mail: vanni@neuro.hut.fi)

We characterized the BOLD signal strength as a function of spatial frequency (SF) and eccentricity for human visual cortex. Constant eccentricity with variable SF was achieved with ‘sinring’ stimuli (Mullen et al, 2005 *Perception* **34** 951–959). Experiments with quadrant and full-ring achromatic drifting gratings comprised altogether five eccentricities. Cortical surface reconstruction and retinotopic mapping allowed identification of the retinotopic areas. Areas V1, V2, V3/VP, V4v, and V3A/B showed band-pass tuning for spatial frequency. The anatomical hierarchy appeared to correlate with a steeper fall of the optimal SF as a function of eccentricity, which may be related to representation of different spatial scales in different areas. Whereas earlier animal data (Movshon et al, 1978 *Journal of Physiology* **283** 101–120; Foster et al, 1985 *Journal of Physiology* **365** 331–363) demonstrate that the SF tuning in V1 is at about three times higher frequency than in V2 (area 18), our results emphasise that in humans the slopes of the SF-band vs eccentricity vary in the distinct areas.

[Supported by Academy of Finland Centre of Excellence program, grants #105628, 111817, Finnish Graduate School of Neuroscience.]

◆ **Speed tuning in human visual cortex: An fMRI adaptation study**

H Ashida, A Lingnau¶, M Wall§, A T Smith§ (Graduate School of Letters, Kyoto University, Kyoto, Japan; ¶Centre for Mind/Brain Sciences, Trento University, Rovereto, Italy; §Royal Holloway University of London, Egham, UK; e-mail: ashida@bun.kyoto-u.ac.jp)

We used fMRI adaptation to examine speed encoding in human visual cortex. The stimuli were sequences of Gabor patches with drifting carriers; a 3 s adapter (S1) was followed, after a short gap, by a probe (S2). Either speed or temporal frequency was the same for S1 and S2 while spatial frequency always differed. When S1 and S2 both had high contrast, we observed weaker (adapted) responses for the same speed than for the same temporal frequency across all visual areas studied, including V1 and MT, revealing speed coding in all these areas. The results were mixed when S2 had lower contrasts, but a control experiment with stimuli matched for perceived speed suggested speed coding even at a low S2 contrast. The conventional view is that initial motion sensors are tuned in terms of local spatio-temporal frequency and speed is subsequently computed from the outputs. This may be true, but our results revealed that speed information is available already in V1, which is consistent with recent results of macaque physiology.

[Supported by a TMR grant from the European Commission to ATS and JSPS grant-in-aid (A18203036) to HA.]

◆ **The fate of unseen faces: An fMRI investigation of awareness in the face perception network**

M-E Large, C Cavina-Pratesi¶, T Vilis§, J Culham§ (Department of Psychology, University of Hull, Hull, UK; ¶University of Durham, Durham, UK; §University of Western Ontario, London, Canada; e-mail: M.Large@hull.ac.uk)

A common view is that visual processing within the ventral visual stream is modulated by attention and awareness. We used fMRI adaptation to investigate whether activation in a network of brain regions involved with face recognition—the fusiform face area (FFA), occipital face area (OFA), and right superior temporal sulcus (rSTS)—was modulated by physical changes to face stimuli or by observers’ awareness of the changes. We sequentially presented two matrices of four faces. In two-thirds of the trials one of the faces changed. We compared activations generated in three conditions (i) change-detected trials, (ii) change-blind trials, and (iii) no-change trials. We found that FFA and rSTS recovered from adaptation when subjects were aware of changes; whereas OFA was modulated by the physical changes to a face but not to awareness. These results suggest that, within the face network, OFA is involved in representing information that has not yet entered awareness and that consciousness is not an all-or-none phenomenon throughout the ventral stream.

[Supported by NSERC (Culham) and CIHR (Vilis).]

◆ **Anticipatory responses in human visual cortex to predictable stimuli: An EEG source-imaging study**

A M Norcia, A R Wade, V Y Vildavski, M W Pettet, L G Appelbaum ¶ (Smith-Kettlewell Eye Research Institute, San Francisco, USA; ¶ Duke University, Durham, USA; e-mail: amn@ski.org)

Detecting temporal and spatial regularities in the environment is a fundamental aspect of visual perception. Here, we show evidence of anticipatory responding cued by temporal regularity using a combination of EEG source-imaging and fMRI techniques. We observed anticipatory responding in a texture-segmentation experiment, in which texture-defined disks were introduced and then withdrawn from an otherwise uniform background at 1 Hz. The figure-appearance response deviated from baseline well before the actual onset of the disks. At this time both prefrontal and occipital cortices were active. Our results are consistent with top-down modulation of occipital cortex by prefrontal areas. Just as attention can be directed to points in space, periodic stimuli may also allow attention to be allocated to points in time, in this case to time points in the future of sequences that are temporally predictable. The primary targets of this modulatory effect appear to be the areas of lateral occipital cortex that will later on process the figural aspects of the stimulus. [Supported by EY06579 and the Pacific Vision Foundation.]

◆ **Investigations of brain activation predictive for natural-scene recognition in single presentations**

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We investigated the trial-by-trial predictability of a person's scene-recognition performance from brain activity. Brain activity was recorded with magnetoencephalography (MEG) during the initial 600 ms of encoding of a briefly presented natural-scene photograph and used to predict later recognition success in single presentations. Classification performance of support vector machines was tested with different data representations (time series, wavelet decomposition). Highly predictive brain activations were extracted from the classifier. The time series allowed for correct predictions in 78.8% of the trials (mean over seven participants; range 70.2% to 84.1%). Classification performance was similar when a wavelet pyramid representation of the data was used (mean 78.3%; range: 70.5% to 83%). Bootstrap tests showed that the obtained performance was better than guessing. The most predictive clusters of brain activity were found around 150 ms, 300 ms, and 500 ms after scene onset. However, spatio-temporal patterns varied between subjects. Our results indicate that MEG single-trial time series and their wavelet representation are highly predictive of a person's scene-recognition success.

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◆ **Are spatial patterns in the lateral occipital complex position-invariant?**

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Classification analyses of fMRI data can reveal the information present in spatial patterns of response across the cortex. We recently demonstrated that activation patterns in the lateral occipital complex (LOC) not only contain information about object category, but are related to behavioral performance in shape discrimination tasks (Williams et al, in press *Nature Neuroscience*). The object perception system needs to be able to cope with objects presented in different locations, sizes, and orientations. Here we ask whether the spatial patterns in LOC associated with different object categories are position-invariant. Novel objects (three categories) were used to eliminate confounds associated with familiarity. Two exemplars of a category were presented simultaneously within diagonally opposite visual quadrants. Participants responded whether the two objects were the same or different. Analysis of the activation patterns in the LOC revealed consistent spatial profiles within each of the three categories across the two diagonal location pairs. This result suggests that the activation pattern in LOC is position-invariant.

[Supported by NHMRC (C J Martin Fellowship) to MAW and by the NIH (NGK: grant 13455).]

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TEMPORAL PROCESSES◆ **The perception of temporal regularity is disrupted by interleaved irregularity**

S Quinn, R Goutcher, R J Watt (Department of Psychology, University of Stirling, Stirling, UK; e-mail: s.c.m.quinn@stir.ac.uk)

We report a series of studies of the ability to discriminate temporally regular from irregular patterns. Participants were asked to judge which of two intervals, each showing a sequence of briefly flashed gratings, contained a temporally regular pattern. In the target interval, gratings were regularly spaced in time. The other interval contained a sequence of the same duration, but with irregular intervals between gratings. Both patterns were then interleaved with a further irregular sequence of gratings. Discrimination was possible when the regular pattern was presented alone, but became impossible when the interleaved, irregular pattern was also presented. We examined the effects of varying the contrast, spatial frequency, and position of the elements of the interleaved, irregular pattern on the discrimination of temporal regularity. The finding that interleaved regular and irregular patterns, containing elements with the same physical characteristics, do not reveal the underlying temporal regularity suggests that such judgments can only be made on the basis of the onsets of adjacent events.

[RG is supported by RCUK Fellowship No. EP/E500722/1.]

◆ **Spatio-temporal distortions of visual perception during saccades**P Binda, D C Burr[¶], M C Morrone (Department of Psychology, Università Vita-Salute San Raffaele, Milan, Italy; [¶]Università degli Studi di Firenze, Florence, Italy; e-mail: p.binda1@studenti.hsr.it)

Both space and time are grossly distorted during saccades (Morrone et al, 2005 *Nature Neuroscience* **8** 950–954). In this study, we measured simultaneously perisaccadic spatial and temporal distortions (always studied separately in previous experiments), by asking subjects to report both the perceived spatial location of a perisaccadic vertical bar (relative to a remembered ruler), and its perceived timing (relative to a couple of sounds, ISI = 200 ms, straddling the visual presentation by variable delays). During fixation, and well before or after a saccade, bars were localized veridically in space and in time with high precision. Perisaccadically, however, bars were spatially mislocalized toward the saccadic target (as previously observed), and temporally mislocalized some 80 ms later than their actual presentation. Importantly, the magnitude of the perceived delay varied with the physical and the perceived location of the bar. These results reinforce previous evidence for the spatial selectivity of event-timing mechanisms (Johnston et al, 2006 *Current Biology* **16** 472–479), and suggest that perisaccadic spatial and temporal distortions are strongly interrelated.

[Supported by the European Commission Sixth Framework Program (grant MEMORY).]

◆ **Detecting correlations between auditory and visual signals**C A Levitan[¶], P Ko, M S Banks (University of California at Berkeley, Berkeley, USA; [¶]also Department of Experimental Psychology, University of Oxford, Oxford, UK; e-mail: levitan@gmail.com)

To combine sensory information from multiple sources, the brain must solve the correspondence problem. We examined the ability to detect correlations between auditory and visual stimuli by presenting amplitude-modulated stimulus pairs that contained correlated and uncorrelated changes over time. The visual and auditory stimuli were modulated in size and loudness, respectively. Two stimuli were presented on each trial, one uncorrelated and one partially corrected, and subjects indicated the partially correlated interval. In one experiment, we varied the temporal frequency of the amplitude modulation. Correlation thresholds were low from 0.5 to 2 Hz and rose steadily at higher frequencies. This suggests that the mechanisms involved in detecting auditory–visual correlations are sluggish. In another experiment, we varied the temporal lag between the auditory and visual stimuli. Threshold was roughly constant for lags of ± 100 ms and elevated for greater lags. Thus, the mechanisms involved in detecting auditory–visual correlations tolerate fairly large offsets in time.

◆ **Spatio-temporal interpolation is achieved within individual, rather than across multiple slits**

F I Kandil, M Lappe (Psychological Institute II, Westfälische Wilhelms-Universität Münster, Münster, Germany; e-mail: kandil@uni-muenster.de)

Spatio-temporal interpolation describes the ability of the visual system to perceive shapes as whole figures even if they move behind a stationary slit mask and only a series of narrow views meets the observer's eye. Two models, retinal painting and spatio-temporal receptive fields (ie motion detectors), have been proposed as mechanisms underlying interpolation. While retinal painting allows subjects to perceive even complex stimuli veridically, we show here that, under restricted eye movements, only strongly condensed views of the stimuli can be perceived (which,

however, suffice for Vernier identification). Further, subjects did not succeed in interpolating stimuli that were presented in a patchwork of small spatially distributed apertures, whereas in another experiment, perception of temporal Verniers in one attended slit was not affected by the presentation of ambivalent or even contrasting Verniers in neighboring slits. Our results demonstrate that interpolation does not emerge from receptive fields covering two or more slits, but rather that locally highly confined mechanisms convert temporal offsets into spatial ones within each slit.

◆ **Shifts in spatial attention affect the perceived duration of events**

G M Cicchini, M C Morrone (Faculty of Psychology, Università Vita-Salute San Raffaele, Milan, Italy; e-mail: cicchini.guidomarco@hsr.it)

We investigated the relationship between attention and perceived duration of visual events with a double-task paradigm. The primary task was to discriminate the direction of motion of a horizontal bar presented 10° left, right, above, or below fixation; the secondary task was to judge the temporal separation (from 133 ms to 633 ms) of two horizontal bars (10 deg × 2 deg) briefly flashed 8° above and below fixation. The SOA between primary and secondary task ranged from -1300 ms to +1000 ms. The intervals between the peripheral events were underestimated by up to 40%, with a maximum effect at 100 ms SOA. However, there was no underestimation when the bars were flashed at the same spatial location. The temporal compression during the double-task seems to result from the shift in spatial attention required to monitor two visual events at different positions (similar to that caused by saccades) reinforcing recent suggestions of independent timing mechanisms across visual space.

[Supported by European Commission Sixth Framework Program (New and Emerging Science and Technology grant 'MEMORY').]

◆ **Sound drives visual apparent motion**

E D Freeman, J S Driver (Institute of Cognitive Neuroscience, University College London, London, UK; e-mail: elliot.freeman@ucl.ac.uk)

We introduce a new phenomenon of visual apparent motion driven by audio-visual asynchrony. Regularly alternating flashing bars on left and right hemifields were each paired with asynchronous beeps from a central fixed sound source, with one temporally leading and the other lagging its respective visual onset. The beeps induced a reliable shift in reported leftward versus rightward motion direction, even though they themselves contained no intrinsic information relevant to this judgment. Critically, adaptation to the audio-visual sequence resulted in a negative apparent-motion aftereffect for a subsequent silent visual-only sequence. This persistent negative aftereffect rules out decision-level explanations of the subjective reports. Strikingly, an adapting sequence comprising only visual events with the same temporal pattern as the auditory inducers also produced an aftereffect of the same magnitude as the audio-visual adaptor. Perception of apparent-motion direction can thus be driven by auditory timing as much as by visual timing; furthermore, adaptation to sound-driven apparent motion results in persistent shifts in the baseline state of visual mechanisms encoding long-range motion.

[Supported by BBSRC.]

VISUAL SEARCH

◆ **Learning to discount backgrounds with varying complexity during visual search**

M P Eckstein, B T Pham, C K Abbey (Department of Psychology, University of California at Santa Barbara, Santa Barbara, USA; e-mail: eckstein@psych.ucsb.edu)

Random variability in the environment limits search performance. However, many environments consist of target-like background structures that, albeit containing some random components, are highly predictable. Thus, in theory, unlike pure noise, these target-like occurrences in the backgrounds could be discounted if humans learned to recognize and classify them as part of the environment. We measured the performance of four observers localizing Gaussian targets embedded in white noise and a randomly spatially shifted background composed of a fixed pattern of varying numbers of randomly configured target-like structures. Human performance improved by over 25% across 1200 trials. Human efficiency relative to a newly proposed ideal observer that uses knowledge of the background to mitigate its detrimental effects on performance decreased with background complexity from 20% to 7%. Spatial distribution of errors confirms that observers are learning to avoid the background. Thus, background learning can be an important mechanism to quickly adapt to the visual environment and maximize the probability of successful target search. Yet, human efficiency diminishes with background complexity.

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◆ **Distributed spatial information fails to efficiently guide visual search**

J M Wolfe, M J Van Wert (Visual Attention Laboratory, Brigham and Women's Hospital, Harvard Medical School, Cambridge, USA; e-mail: wolfe@search.bwh.harvard.edu)

In visual search, knowledge about some basic properties of targets is used to efficiently guide attention to those targets. Thus, if you know targets are red, your attention will be guided to red items. If you know that targets are on the left side of a display, you will guide attention to the left. Suppose that you know that targets (like your coffee mug or your keys) rest on a horizontal surface. There may be multiple candidate surfaces in a scene. Can you guide attention to those surfaces? Our observers searched for Ts among Ls. Letters were attached to the surfaces of an unchanging pyramid of cubes. Each cube had three visible surfaces: the top and two sides. Top surfaces were not coplanar. In some blocks, colour guided search (a T, if present, will be red). In other blocks, surface cues guided search (a T, if present, will be on top of a cube). Compared to colour, this distributed spatial information was a very ineffective source of guidance.

[Supported by NIH MH56020, AFOSR.]

◆ **Do all visual-search tasks, even pop-out tasks, require attention?**

P Poiese, T M Spalek ¶, V Di Lollo ¶ (Department of Cognitive Science and Education, University of Trento, Rovereto, Italy; ¶ Simon Fraser University, Burnaby, Canada; e-mail: paola@poiese.com)

In feature integration theory, pop-out visual search was said to be done preattentively, a viewpoint that has been seriously questioned by later evidence which was obtained exclusively with dual-task paradigms. Using single-task paradigms, we showed that (a) enumeration within the subitizing range requires attention, (b) detection of a pop-out orientation target is impaired by a salient task-irrelevant colour distractor, and (c) that detection of a pop-out target is facilitated by a spatial cue. Collectively, these outcomes are inconsistent with a preattentive view and point to the necessity for attentional involvement in all visual-search tasks, including pop-out searches.

[Supported by the Natural Sciences and Engineering Research Council of Canada.]

◆ **Detection of part-boundaries requires attention: Evidence from visual search**

L Boutsen, J Hulleman ¶ (School of Life and Health Sciences, Aston University, Birmingham, UK; ¶ University of Hull, Hull, UK; e-mail: l.boutsen@aston.ac.uk)

The computation of part-boundaries of two-dimensional shapes is a critical stage in shape processing and relies on the detection of minima of curvature (concavities) in contours. Detecting concavities is a preattentive process. However, not every concavity signals a part-boundary, and the perception of part-structure may therefore not be preattentive. To investigate the role of attention in the detection of part-structure, observers performed visual search tasks with minimally segmented shapes. Targets and distractors contained the same number of concavities and only differed in the symmetrical alignment of concavities, which created either salient (aligned concavities) or poor (misaligned concavities) part-boundaries. Targets also could be defined by the number of part-boundaries. Search for a target containing a good part-boundary among distractors containing a poor part-boundary, or the reverse, was inefficient and required attention. Search was also unaffected by the number of part-boundaries. These results suggest that the detection of part-structure is an attentional process, rather than preattentive.

◆ **Efficient search for discrepant shadows in upright but not inverted images of natural objects**

P G Lovell, I Gilchrist, D Tolhurst ¶, T Troscianko (Department of Experimental Psychology, University of Bristol, Bristol, UK; ¶ University of Cambridge, Cambridge, UK; e-mail: p.g.lovell@bris.ac.uk)

Evidence from schematic stimuli (Rensink and Cavanagh, 2004 *Perception* 33 1339–1358) suggests that search for discrepant shadows is slower for upright than inverted images—hypothetically owing to the discounting of shadows. We investigated search for shadows cast by real objects. Pebbles were photographed with and without cast shadows. The visual difference between all pebbles (without shadows) was estimated with the aid of a visual difference predictor (Lovell et al, 2006 *ACM Transactions on Applied Perception* 3 155), to allow manipulation of stimulus heterogeneity. The orientation of the target shadows was varied between 30° and 180°. Stimuli were presented upright (light-from-above) or inverted (light-from-below). Search slopes became steeper with increased heterogeneity, but this effect was much weaker for upright images. RTs were generally faster for upright images. However, at 30° they were slower, perhaps owing to the handover of processing from a relatively coarse-scaled shadow-system to other general-purpose visual routines. The results are consistent with a spatially coarse shadow module, activated when light appears to come from above, and uninvolved in any suppressive function.

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ATTENTION◆ **A general computational theory of the distribution of visual spatial attention**

G Sperling, I Scofield, A Hsu (Department of Cognitive Sciences, University of California at Irvine, Irvine, USA; e-mail: sperling@uci.edu)

We derive a computational theory of the distribution of visual attention using a linear-systems approach. First, we measure an observer's ability to distribute attention sinusoidally along rows or columns in a 12×12 array that contains 1 target (a large disk) on one of 72 attended locations, 10 false targets among 72 unattended locations (to force the observer to ignore unattended locations), and distractors (small disks) elsewhere (Gobell et al, 2004 *Vision Research* **44** 1273–1296). The basic sinusoidal data then enable the theory to make accurate, completely parameter-free predictions of the same observer's ability to distribute spatial attention in response to arbitrarily complex 72-square requested patterns of attention distributions. The theory contains (i) a spatial acuity function that describes the decline of visual processing capacity with retinal eccentricity, (ii) an attention modulation-transfer function that describes the decline of attentional conformability with increasing spatial frequency, (iii) multiplicative combination of (i) and (ii), (iv) random decision noise, and (v) a decision process that selects the most likely target location. [Supported by US Air Force Office of Scientific Research, Life Sciences Program.]

◆ **Static objects in dynamic environments grab attention**

Y Pinto, C N L Olivers, J Theeuwes (Department of Cognitive Psychology, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; e-mail: y.pinto@psy.vu.nl)

We know from everyday experience as well as from laboratory experiments that dynamic stimuli are good at grabbing our attention. The reverse situation is harder to appreciate: what is the fate of static items when everything around them is dynamic? We investigated this question using visual search tasks in which observers were instructed to look for a static target among dynamic distractors. This research yielded several important conclusions. First, static items can be efficiently detected among both blinking and moving distractors. Second, detection among blinking distractors is generally easier, despite the fact that these should be stronger candidates for attentional capture. Third, efficient attentional guidance towards a static item appears to be involuntary. Our findings support a salience account of attention in dynamic scenes: allocation of attention is determined by the relative difference in dynamics, not by dynamic items per se.

◆ **Perceptual and neural mechanisms of visual attentional suppression**

V Gál, L R Kozák ¶, I Kóbor, É Bankó, J Serences§, Z Vidnyánszky (Faculty of Information Technology, Peter Pazmany Catholic University, Budapest, Hungary; ¶ Semmelweis University, Budapest, Hungary; § University of California at Irvine, Irvine, USA; e-mail: gviktor@digitus.itk.ppke.hu)

Our goal was to isolate and characterize the perceptual and neural mechanisms of attentional suppression using psychophysics and fMRI in human observers. We designed a visual-learning experiment, which enabled us to investigate the learning-induced plasticity of the inhibitory mechanisms of attentional selection. Observers were trained on a speed-discrimination task using a transparent motion display, consisting of a task-relevant and a task-irrelevant motion component. Perceptual sensitivity and BOLD responses to the two trained subjects and a control motion direction were measured before and after training. We found that perceptual sensitivity for the task-irrelevant motion direction is decreased as a result of training. Learning also affected the BOLD responses to the motion direction that was ignored during training: in early visual cortical areas (including MT+) BOLD responses were significantly weaker to the task-irrelevant motion direction as compared to the task-relevant direction after training. These results provide evidence for the mechanisms of direct attentional suppression of task-irrelevant visual information, the efficacy of which can be improved with learning.

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◆ **The blinking spotlight of attention**

R VanRullen, T Carlson ¶, P Cavanagh ¶ (Centre de Recherche Cerveau et Cognition, CNRS, Toulouse, France; ¶ Harvard University, Cambridge, USA; e-mail: rufin@klab.caltech.edu)

Increasing evidence suggests that attention can concurrently select multiple locations; yet it is not clear whether this ability relies on continuous allocation of attention to the different targets (a 'parallel' strategy), or whether attention switches rapidly between the targets (a temporal 'sampling' strategy). The human psychometric function for detection of a single target as a function of its duration can be used to predict the corresponding function for two or more attended targets. Importantly, the predicted curves differ depending on whether a parallel or sampling strategy is assumed. This provides us with a novel way of teasing apart the two alternatives. For a challenging detection task, we found that human performance was best reflected by a sampling

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model, indicating that multiple items of interest are, sometimes, processed in series at a rate of about 7 items per second. Surprisingly, the data suggested that attention operated in this periodic regime, even when it was focused on a single target. In other words, attention might well be an intrinsically periodic process.

◆ **On the interaction of sustained and transient attention: A speed–accuracy trade-off analysis**

M Carrasco, A M Giordano (Department of Psychology and Neural Science, New York University, New York, USA; e-mail: mc5@nyu.edu)

Covert attention improves discriminability and accelerates processing speed. To examine how sustained (endogenous) and transient (exogenous) attention interact/work together or against each other we used the speed–accuracy trade-off (SAT) procedure to get conjoint measures of discriminability and processing speed while manipulating both types of attention within each trial. Observers performed an orientation discrimination conjunction task. There were trials in which both cues were neutral, both valid, and one was valid while the other was neutral or invalid. The target (a low-frequency tilted Gabor) and distractors (high-frequency tilted and low-frequency vertical Gabors) appeared at iso-eccentric locations. A response tone prompted observers to respond after various lags (40–1500 ms). The maximum benefit in both discriminability and speed of processing occurs when both sustained and transient cues are valid. In trials where one cue is valid and the other is either invalid or neutral, for some observers the transient cue dominates—a valid sustained cue cannot overcome the cost of an invalid transient cue which yields slower processing than in the neutral condition—for others the sustained cue dominates. [Supported by NIH 1 R01 EY016200-01A2.]

◆ **Reflexive attention improves change detection (but only briefly)**

D T Smith, T Schenk (Durham University, Durham, UK; e-mail: daniel.smith2@durham.ac.uk)

Humans are remarkably insensitive to changes in a visual display if the change occurs at the same time as a secondary visual event. A widely held view is that this change blindness occurs because the visual transient produced by the secondary event swamps that produced by the change, which prevents the change from capturing the attention of the observer. Although there is evidence that top–down attentional processes can facilitate change detection, the evidence regarding the effect of bottom–up attentional capture on change blindness is less conclusive. Here we compare the effects of attentional capture on change detection with participants performance on a well-established attentional paradigm (the cue–target detection task). We observed the same pattern of results in both tasks. Specifically, peripheral pre-cues facilitated performance at short (150 ms) latencies but not at longer (480 ms) latencies. These data provide clear evidence that change detection can be modulated by bottom–up attentional processes, and are consistent with the view that change blindness occurs when a change fails to capture attention.

NEURAL MECHANISMS

◆ **Non-perceived stimuli elicit local but not large-scale neural synchrony**

L Melloni, E Rodriguez¶ (Department of Neurology, Brain Imaging Center and Johann Wolfgang Goethe University, Frankfurt am Main, Germany; ¶ Max Planck Institute for Brain Research, Frankfurt am Main, Germany; e-mail: lmelloni@gmail.com)

When studying conscious perception, visible stimuli are usually associated with more extensive processing or better performance than invisible ones, intermixing the variables visibility and amount of processing. Thus, it could be argued that some of the already found neural correlates of awareness are in fact correlates of the depth of processing. One of such putative neural correlates is neural synchrony. Here, we directly study this by independently controlling visibility and depth of processing in an unconscious semantic priming paradigm, while measuring neural synchrony in an EEG-study. Congruent trials were faster than incongruent trials, enabling us to conclude that the prime, though invisible, was processed up to semantic levels. Prime-present trials were compared with prime-absent trials, which allowed us to assess the neural impact of the highly processed unconscious prime. Prime-present trials showed increased gamma power between 130–230 ms after prime presentation without concomitant phase-synchrony augmentation. In contrast, the visible target-words showed increased gamma power and phase synchrony suggesting that long-distance synchronization correlates with perceptual awareness and not with extension of processing.

◆ **Adaptive coding of visual information in neural populations**

V Dragoi, D Gutnisky (Department of Neurobiology and Anatomy, University of Texas-Houston Medical School, Houston, USA; e-mail: v.dragoi@uth.tmc.edu)

Our perception of the environment relies on the capacity of neuronal networks to rapidly adapt to changes in incoming stimuli. Understanding how rapid adaptation changes information processing by cortical networks is essential for understanding the relationship between sensory coding and behavior. However, despite the importance of this issue, whether and how adaptation impacts the properties of the population code is unknown. Here, we examine how brief adaptation (on the time scale of visual fixation) influences the structure of interneuronal correlations and the accuracy of population coding in macaque primary visual cortex. We find that brief adaptation to a stimulus of fixed structure reorganizes the distribution of correlations across the entire network by selectively reducing their mean and variability. The post-adaptation changes in neuronal correlations are associated with specific, stimulus-dependent, changes in the efficiency of the population code, and are consistent with changes in perceptual performance after adaptation. Our results indicate that brief adaptation improves population-coding accuracy to optimize neuronal performance during natural viewing.

[Supported by Pew Scholars Program, James S McDonnell Foundation.]

◆ **Dynamics of population activity in cat primary visual cortex**

A Benucci, R A Frazor, M Carandini (Smith-Kettlewell Eye Research Institute, San Francisco, USA; e-mail: andrea@ski.org)

An oriented stimulus causes activity in a population of neurons in primary visual cortex (V1). A sudden shift in orientation changes this population activity. Understanding the dynamics of this change can shed light on the underlying computations. We measured population activity with voltage-sensitive dye imaging in area V1 of anesthetized, paralyzed cats (Grinvald and Hildesheim, 2004 *Nature Reviews Neuroscience* 5 874–885). Stimuli were sequences of flashed gratings of random orientation (Ringach et al, 1997 *Nature* 387 281–284). Population activity could be explained (correlation $r = 0.997 \pm 0.002$) by a simple linear model, ie by convolving the stimulus with an elemental response, the average response to a single orientation. The linear model, however, underestimated (by tens of milliseconds) the duration of the response when a stimulus was followed by a blank screen. We conclude that the dynamics of population responses to changes in orientation reflect a simple linear computation. However, the brief maintenance of cortical activity can only be explained by a nonlinear mechanism. This maintenance may underlie perceptual phenomena of visual persistence.

[Supported by the National Eye Institute and by the McKnight Endowment Fund for Neuroscience.]

◆ **Distinct causal influences of parietal versus frontal brain areas on human visual cortex**

C C Ruff, F Blankenburg, S Bestmann, O Bjoertomt, N Weiskopf, J Driver (University College London, London, UK; e-mail: c.ruff@ucl.ac.uk)

Regions of parietal and/or frontal cortex may modulate activity in visual areas, for example during selective attention or saccade preparation. However, direct evidence for such causal claims is missing in human studies, and it remains unclear whether the putative roles of parietal and frontal regions in modulating visual cortex may differ. Here we show with concurrent TMS–fMRI that stimulating right human intra-parietal-sulcus (IPS) elicits activity changes in visual cortex that strongly depend on current visual context. Increased intensity of IPS–TMS affected BOLD signal in V5/MT+ only when moving stimuli were present to drive this visual region, whereas TMS-elicited BOLD signal changes were observed in areas V1–V4 only during the absence of visual input. These influences of IPS–TMS upon visual cortex differed significantly from corresponding effects of frontal (eye field) TMS, in their dependence on current visual input and their spatial topography for retinotopic areas V1–V4. Our results show directly that parietal and frontal regions can indeed have distinct patterns of causal influence upon activity in human visual cortex.

[Supported by the Wellcome Trust.]

◆ **Pulvinar pathway for modulation of cortical visual processing**

R A Berman, R Wurtz (Laboratory of Sensorimotor Research, National Eye Institute, NIH, Bethesda, USA; e-mail: bermanr@nei.nih.gov)

The pulvinar has long been considered a possible path for the transmission of signals from the retina to extrastriate cortex, but its function remains poorly understood. We examined the response properties of pulvinar neurons connected to the superior colliculus (SC) and to the extrastriate motion area (MT). We used orthodromic and antidromic stimulation techniques to identify three classes of pulvinar neurons in the awake, behaving macaque: (i) neurons that received input from the SC, (ii) neurons that projected to MT, and (iii) neurons that received input from MT. We found that these three classes were largely intermingled within the visual

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pulvinar, but had distinctive functional profiles. Neurons with SC input resembled neurons in superficial SC, with visual responses but no presaccadic activity. Neurons projecting to MT resembled SC-input neurons, and exhibited little directional selectivity. By contrast, neurons receiving input from MT were likely to exhibit directional tuning. These findings shed light on the functional role of the thalamus in this putative tectocortical path.

[Supported by the National Eye Institute.]

◆ **Neural activation during delayed discrimination of spatial frequency for gratings with different orientations**

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Using 3 T fMRI we examined the pattern of neural activation evoked when subjects discriminated the spatial frequency (SF) of Gabors presented with the same or orthogonal orientation (Magnussen et al, 1998 *Journal of Experimental Psychology: Human Perception and Performance* 24 707–718). On each trial, subjects viewed a $\pm 45^\circ$ Gabor followed by a delay period (8 s) and a test Gabor with either the same or orthogonal orientation. They responded whether the SF of test and reference were the same or different. RTs were shorter for Gabors sharing the same orientation. fMRI revealed elevated activity in V2 and V3 for orthogonal gratings. On trials with a different SF, the right DLPFC, right IPL, and also visual areas (V2, V3) were significantly more active. Changes in the task-relevant stimulus dimension (SF) evoked pronounced BOLD activation in right DLPFC and IPL, whereas task-irrelevant changes (orientation) had no effect. Repetition of task-irrelevant dimensions led to lower responses in V2/V3 (priming). This supports a model of working memory where task-relevant information is extracted from low-level resources. Accessing different stores requires time and has metabolic costs.

[Supported by BMBF Project Visuospatial Cognition and Norwegian Research Council.]

VISUAL DEFICITS AND VISUAL NEUROPSYCHOLOGY

◆ **Probing schizophrenia with a contour-integration task**

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We present results on the task of finding a contour in a field of Gabor patches, where the position of the contour may be signalled by timing differences. The patches making up the contour may appear 0, 20, 40, or 100 ms before or after other distractor patches. When the separation between the patches in the contour is sufficient, performance on a 2AFC task is chance at synchrony, rising to near-perfect at 40 ms, with symmetrical performance either side of zero. We found no evidence of synergy between the timing signal and contour detection. However, it is possible to distinguish an aligned contour from an unaligned one given an asynchrony of about 40 ms from the distractor patches. Tests on schizophrenic patients with the basic detection task indicate an increased threshold, over 100 ms for some individuals. Amongst the student population tested, poor performance on the task was related to high scores on schizotypy and autistic quotient scales.

◆ **Extended perceptual learning results in improved position acuity and highly efficient perceptive fields in adult amblyopia**

D M Levi, R W Li (School of Optometry, University of California at Berkeley, Berkeley, USA; e-mail: dlevi@berkeley.edu)

Practicing position discrimination for roughly 20 h improves position acuity by about 20%–30% in adults with amblyopia. The present study was aimed at investigating the limits, time course, and mechanisms of perceptual learning over extended periods of practice (50–100 h). Adults with amblyopia practiced a position-discrimination task until stable performance was maintained for 10–20 sessions. We used an efficient 10-pass paradigm combined with reverse correlation to track changes in the observers' perceptive fields (classification images) and internal noise across sessions. We found that the amount of practice needed to reach plateau depends on the degree of amblyopia. Deep amblyopes (20/50–20/125) required more than 40 sessions (40 kilo trials) to reach plateau, and the threshold improvement was as much as 50%–80%. In contrast, mild amblyopes (20/25–20/40) required fewer practice trials (~10 sessions) to obtain stable improvement (20%–50%). We document, for the first time, a dramatic optimization of perceptive fields coupled with a marked increase in sampling efficiency and a substantial reduction in internal spatial distortion following practice.

[Supported by grant ROIEY01728 from the NEI.]

◆ **‘Automatic pilot’ and hemispatial neglect: Fast online corrections to perturbed targets in two patients**

M Harvey, S Rossit, S Butler ¶, R Macintosh§ (Department of Psychology, University of Glasgow, Glasgow, Scotland, UK; ¶ University of Strathclyde, Glasgow, Scotland, UK; § University of Edinburgh, Edinburgh, Scotland, UK; e-mail: M.Harvey@psy.gla.ac.uk)

We examined if neglect patients could either adapt their pointing trajectories or interrupt the movement in response to a rightward or leftward target shift. Spatial and temporal analyses of the movement trajectories indicated that the patients were very accurate when performing online corrections to target shifts, even when the shift occurred in the leftward direction. However, when asked to stop the movement ‘in flight’ in response to a target jump, their performance was considerably impaired, both in terms of timing and number of correct stop-responses. Fast, online corrections to target jumps are thought to be mediated by the visual dorsal stream, while stop responses require an intentional reprogramming which is thought to be dependent upon the conscious perception mediated by the ventral stream. Our findings indicate that the deficits present in hemispatial neglect are more closely related to damaged ventral areas of visual processing and further agree with previous neuropsychological evidence regarding the dissociability of these pathways for fast, automatic movements versus slow, intentional motor control.

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◆ **Occipital grey-matter changes associated with retinal visual-field defects in humans**

F W Cornelissen, C Boucard, R Maguire, B Quinn ¶, B Fischl ¶, N Jansonius, J Roerdink, J Hooymans (Laboratory for Experimental Ophthalmology, University Medical Center Groningen, Groningen, The Netherlands; ¶ Harvard Medical School, Charlestown, USA; e-mail: f.w.cornelissen@rug.nl)

While developmental ocular disorders are known to affect the structure of visual cortex, surprisingly little is known about the effects of acquired retinal disorders. We investigated whether prolonged cortical deprivation, due to retinal field defects acquired later in life, leads to structural cortical changes in the adult brain. Magnetic resonance images were obtained in subjects with glaucoma, age-related macular degeneration, and controls. Grey-matter density was compared with voxel-based morphometry. In order to better understand the origin of this change, cortical thickness was measured with a surface-based method analysis as well. In glaucoma, we found a reduced grey-matter density as well as cortical thinning in anterior visual cortex, in accordance with the large peripheral field defects in this group. On the contrary, the field defects present in age-related macular degeneration were not associated with detectable cortical changes in grey-matter density or thickness. Our results indicate that visual-field defects can lead to structural changes in visual cortex.

◆ **Dyslexia and the failure to form perceptual anchors**

M Ahissar, T Biron (Department of Psychology, Hebrew University, Jerusalem, Israel; e-mail: msmerava@mssc.huji.ac.il)

Most dyslexics display poor visual and auditory performance in a broad range of tasks. It has been previously shown that dyslexics have difficulties in retaining and comparing visual stimuli across intervals, though not when stimuli are presented concurrently. Dyslexics have similar difficulties in the auditory domain. Their 2-tone frequency comparison is impaired. This deficit is found when the frequency of one of the tones is fixed and serves as a reference. In the general population, this reference is used as a ‘perceptual anchor’ that substantially sharpens discrimination compared to a ‘no-reference’ condition. Dyslexics, however, do not benefit from reference repetition. Comparing the visual and auditory conditions that challenge dyslexics suggests that auditory references are anchored to their temporal position, whereas visual references are anchored to their spatial position. The hypothesis of impaired implicit formation of perceptual anchors accounts for a broad range of reported visual deficits in dyslexia. Moreover, it accounts for the phonological deficits that characterize dyslexia, which are mainly revealed when stimulus-specific short-term phonological memory is taxed.

[Supported by the Israeli Institute for Psychobiology.]

◆ **Neural noise and autism spectrum disorders**

D R Simmons, L McKay, P McAleer, E Toal, A Robertson, F E Pollick (Department of Psychology, University of Glasgow, Glasgow, Scotland, UK; e-mail: david@psy.gla.ac.uk)

A curious aspect of the sensory symptoms of autism spectrum disorders (ASDs), not explained by current neural theories, is the combination of hypersensitivity and hyposensitivity to sensory signals (Baranek et al, 2006 *Journal of Child Psychology and Psychiatry* 47 591–601). Could increased levels of neural noise be the underlying neural symptom of this? Normally the addition of noise to a signal will result in masking, but, if both signal and noise amplitudes are relatively low, stochastic resonance phenomena can amplify the signal, resulting in better-than-expected

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detectability. The developmental consequences of the presence of this noise from early life provide a neat explanation of many of the social and non-social symptoms of ASDs and their spectrum nature (ie high functioning individuals would have relatively lower levels of neural noise, especially in adulthood). This theory suggests that the best way to examine visual performance in ASDs is to use paradigms based on detecting or discriminating signals in noisy backgrounds. Our preliminary results with such paradigms are encouraging.

[Supported by ESRC/MRC; Autism Speaks; The Wellcome Trust; Nuffield Foundation; University of Glasgow Chancellors' Fund.]

SYMPOSIA & WORKSHOPS

WHERE PERCEPTION MEETS MEMORY: VISUAL PRIMING

◆ **A distinctive short-term implicit memory system**

K Nakayama, Á Kristjánsson¶ (Department of Psychology, Harvard University, Cambridge, USA; ¶ Department of Psychology, University of Iceland, Reykjavik, Iceland; e-mail: ken@wjh.harvard.edu)

While it is generally accepted that focal attention is required for fine perceptual discriminations, it is also required for eye movements and manual pointing. Priming of the deployment of focal attention thus aids in all of these processes. Our results show such priming to reflect a short-term memory process that is feature-based (colour, position, shape), graded, cumulative, and efficacious. It easily and automatically links separable features of items to the act of attentional deployment. Yet, the memory system is very limited insofar as it cannot link focal attentional deployment to conjoined features. The effects of this short-term memory cannot be overridden by higher-level knowledge, yet is itself organized in an object-centered coordinate frame. We further ask whether this specific form of temporary learning is likely to be more general, not confined to the rapid deployment of focal attention but to a range of perceptual, cognitive, and motor processes.

◆ **The cortical basis of repetition priming**

A Cowey (Department of Experimental Psychology, University of Oxford, Oxford, UK; e-mail: alan.cowey@psy.ox.ac.uk)

Repetition priming is an example of sensory memory. It is the consciously unappreciated effect of a stimulus on the reaction time to its subsequent presentation. Is the record of the sensory event contained in the principal cortical area dealing with the stimulus qualities of that event, eg area MT for motion, the colour area for colour, or the frontal eye fields for spatial position? Disruptive TMS is used to show that priming of motion direction depends on MT, whereas priming of spatial position of that same stimulus depends on the frontal eye fields. And in a visual pop-out task TMS of frontal eye fields had no effect on visual feature priming (eg its colour) but impaired the perception of the spatial position of the feature. Priming of a different kind occurs when the prime, never consciously registered, is presented within a visual field defect caused by destruction of V1. How this affects the reaction time to the same or different stimulus then presented in the normal field is still mysterious.

◆ **Remembering visual motion: Contribution of neurons in area MT and in prefrontal cortex**

T Pasternak (Departments of Neurobiology & Anatomy, Brain & Cognitive Science, and Center for Visual Science, University of Rochester, Rochester, USA; e-mail: tania@cvs.rochester.edu)

The activity of MT neurons, associated with motion processing, and of prefrontal cortex (PFC) neurons, linked to sensory storage and executive control during a task that placed demands on both sets of neurons was examined. The monkeys compared the direction of two random-dot stimuli, sample and test, separated by a memory delay. Many PFC neurons showed robust direction-selective (DS) responses to behaviorally relevant motion, most likely originating in MT. Although during the memory delay there were reliable DS signals in both areas, their properties suggest a limited role in maintenance. In both areas, responses to the test reflected access to the preceding sample direction. This activity arose earlier in MT, suggesting a role in the comparison to the remembered direction. Only in PFC this effect was predictive of the forthcoming decision. These results show the unique contribution of MT and PFC to the task. PFC neurons reflect task-related information about visual motion, and represent decisions that may be based, in part, on MT's comparison between the remembered sample and test.

◆ **Neural correlates of object priming: An fMRI study**

M Stylianou-Korsnes, S Magnussen¶ (Department of Psychology, Stanford University, Stanford, USA; ¶ University of Oslo, Oslo, Norway; e-mail: m.s.korsnes@psykologi.uio.no)

We used fMRI to investigate the neural pathways involved in repetition priming and episodic memory in two tasks: an object-decision task where the subjects decided if the stimuli represented

a real or a non-real object, and an old/new decision task where the subjects decided if the stimulus had been presented before or not. The stimuli were line drawings of real and non-real objects presented in a mixed event-related design. The behavioural results showed faster responses to old than to new stimuli. fMRI results showed increased activation due to repetition priming in regions that were particular to explicit memory in group analyses, suggesting that repetition priming evokes explicit (episodic) memory functions. The fMRI results reveal functional differences between repetition priming and explicit memory tasks both in terms of the brain regions involved and in the direction of repeated – novel activations. Activation concerned with performance monitoring seems to be the most prominent explicit function overlapping activation between the two tasks.

◆ **Repetition effects in attention**

A P Hillstrom (Department of Psychology, University of Portsmouth, Portsmouth, UK;
e-mail: anne.hillstrom@port.ac.uk)

A salient target pops out when the observer knows the target will be salient and has practice searching for it. This priming of pop-out has been attributed to repetition effects. My experiments have shown that even search for non-salient targets can benefit from repetition, and suggests that repetition plays a role in top–down guidance of search as well as bottom–up guidance of search. It does not change the distinctiveness of targets relative to non-targets, and has characteristics akin to episodic memory effects.

3-D CUE INTEGRATION: PUTTING THE PIECES TOGETHER

◆ **Are perceptual judgments of different surface attributes based on the same relative weighting of depth cues?**

J T Todd (Department of Psychology, Ohio State University, Columbus, USA;
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Numerous theoretical analyses have shown that an individual source of visual information can adequately specify some aspects of 3-D structure but not others. For example, the optical velocity field of a rotating object can uniquely specify the local tilt or shape index of a surface, but it cannot unambiguously specify the local slant or curvedness. To what extent does this influence the relative weighting of cues when multiple sources of information are available? To address this question, observers adjusted the two independent curvatures of a quadric surface patch defined by multiple consistent cues to match the apparent 3-D structure of a second surface for which the individual cues specified different shapes. The results reveal that cue weights can vary significantly between different components of curvature in a manner that is consistent with the relative ambiguities of the individual cues. These findings indicate that the apparent shape of a surface defined by multiple cues cannot be based on any combination process that relies on a single weight for each cue.

◆ **Representational constraints in surface perception: Why the prior for coplanar reflectance change must be zero**

D Vishwanath (Department of Psychology, Rochester Institute of Technology, Rochester, USA; e-mail: dxvgss@rit.edu)

Standard computational approaches to surface perception posit that surface inference involves the recovery of two properties: geometry and pattern of reflectance. Empirical evidence has shown that perceived metrics of surface geometry (eg slant) represent an optimal combination of individual visual cues (eg disparity and texture), and are well described by a Bayesian maximum likelihood model. An ongoing puzzle is whether the perception of 3-D shape from 2-D surface reflectance patterns (a picture) arises from a similar optimal combination of cues. Though many effects in picture perception can be adequately explained under a Bayesian model, empirical evidence suggests that the perception of 3-D shape from a 2-D picture surface cannot. A Bayesian explanation requires the prior for coplanar surface reflectance patterns to be zero. This implies that reflectance change is not a property of perceptual surfaces but may be intrinsic to the identity of surfaces. It might also explain the so-called dual nature of pictures.

◆ **Robust Bayesian cue integration: The role of priors in nonlinear cue integration and learning**

D Knill (Center for Visual Science, University of Rochester, Rochester, USA;
e-mail: knill@cvs.rochester.edu)

A Bayesian model for nonlinear cue integration is described that makes rational inferences about scenes across the full range of possible cue conflicts. The model incorporates the knowledge that depth cues can be interpreted with the aid of any of a hierarchy of possible prior assumptions about objects. Integrating visual cues, therefore, results in a perceptual depth estimate that is a mixture of interpretations suggested by each prior—with the mixture proportions determined

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in part by the size of cue conflict. The model gives rise to robust behaviors like down-weighting or vetoing some cues. I describe psychophysical data on human integration of foreshortening and stereoscopic information about surface slant that is well-fit by the model. I also describe learning results in which exposure to more random environments leads subjects to downweight a pictorial cue to surface slant (foreshortening). The results are consistent with a Bayesian learning model that uses the results of combining foreshortening and stereoscopic slant information to adapt the priors that it uses to interpret the foreshortening cue.

◆ **Combining information to perceive 3-D layout**

M Banks (Visual Space Perception Laboratory, University of California at Berkeley, Berkeley, USA; e-mail: martybanks@berkeley.edu)

A fundamental problem faced by the visual system is providing information about the 3-D environment from the 2-D retinal images. Several sources of information—usually called depth cues—are used in this inference process. The means by which various cues are used to infer 3-D structure have been examined. The combination of disparity and texture cues to a surface's slant is well modeled by weighted summation. The combination approaches statistical optimality and thereby minimizes the uncertainty of the slant estimate. We have also examined the combination of disparity and figure-ground cues. Figure-ground information provides more than ordinal depth information and the combination of disparity and figure-ground approaches optimality considering the natural statistics of the environment.

◆ **A novel approach to the problem of cue integration**

F Domini, C Caudek ¶ (Department of Cognitive and Linguistic Sciences, Brown University, Providence, USA; ¶ University of Florence, Florence, Italy; e-mail: Fulvio_Domini@brown.edu)

The current approach to the problem of cue integration in the perception of 3-D shape postulates that the outputs of (fairly) independent depth-processing modules are combined in a statistically optimal fashion. An alternative to the modular architecture of the Modified Weak Fusion Model has been proposed by Domini and Caudek (2006 *Vision Research* 46 1707–1723) by hypothesizing that the visual system combines the information provided by different image signals (eg velocities, disparities, texture gradients ...) prior to the extraction of depth information. Such approach has been termed the Intrinsic Constraint Model. The aim of this presentation is twofold. First, we will carry out an ideal observer analysis showing that the IC model yields optimal performance for the recovery of the affine structure. Second, we will discuss novel empirical findings showing that, in recovering 3-D information from the retinal images, the visual system relies on the mutual constraints among image signals. Such findings are consistent with the predictions of the IC model.

WORKSHOP ON LIGHTING AND VISION

◆ **Lighting and vision in real environments**

E Colombo (Department of Lighting, Light and Vision, National University of Tucumán, San Miguel de Tucumán, Argentina; e-mail: ecolombo@herrera.unt.edu.ar)

At the present time architects, lighting engineers, and, more generally, lighting designers form a broad community dealing with new problems as well as researching new ways of looking at some old problems. With this in mind, researchers from the visual sciences could help with new results. First of all, it is necessary to carry out realistic experiments, with greater range of different variables and their interactions, diverse kind of measurements, more complex frameworks, and global situations. Our recent research has been concerned with fundamental aspects of vision by addressing the following issues: the effect of glare on visual functions, temporal modulation sensitivity, color as information, motion mechanisms, influence of natural light, lighting and ageing, and visual perception of real sites. All this work was done in such a way that it could be readily transferred to firms, educational institutions, practitioners, and private and governmental officers. [Supported by the National Research Board (CONICET), the Research Board of the University of Tucumán (CIUNT), the National Agency of Science and Technology (ANPCYT), and various national and international firms and institutions.]

◆ **The assessment of visual performance in the mesopic range**

J Barbur, H Walkey, G Walker (Applied Vision Research Centre, Henry Wellcome Laboratories for Vision Sciences, City University, London, UK; e-mail: johnb@city.ac.uk)

Visual performance in the mesopic range is affected by changes in the spatial and temporal properties of the retina and/or changes in the quality of the retinal image as a result of increased aberrations and scattered light. The aim of this study was to establish the extent to which retinal and/or optical factors set the limits of visual performance at low light levels. Pupil size, ocular aberrations, chromatic sensitivity, and functional contrast were measured as at a number of

discrete retinal illuminances over a range of light levels that covered the mesopic range. The results show that the pupil size affects contrast acuity thresholds, significantly, in at least two different ways. For stimulus conditions that generate a large pupil size, but where vision is still dominated by cone photoreceptors signals, increased aberrations and scattered light can cause a significant loss of contrast acuity. The largest increase and inter-subject variability are, however, observed in the low mesopic and scotopic ranges when vision is dominated by rods.

◆ **High dynamic range displays**

M Bloj (Bradford Optometry Colour and Lighting Lab, School of Life Sciences, University of Bradford, UK; e-mail: m.bloj@brad.ac.uk)

New high dynamic range (HDR) displays have the potential for moving human visual psychophysical research and computer simulations away from the limited luminance ranges found in traditional CRTs and into luminance ranges that are closer to those experienced by us in the real world. Before this novel technology becomes an accepted tool for psychophysical research and visualisation, a thorough characterisation of the device is needed. I present recent research from the Bradford Optometry Colour and Lighting Lab that focuses on establishing the pixel independence, channel constancy, channel independence, and spatial homogeneity of a 37 flat-panel Brightside DP37 HDR display. In this type of displays the colour transforms are underdetermined, which means that the number of colorimetric dimensions is smaller than the number of device channels, so we have developed a method for accurately presenting a desired luminance and chromaticity output that is also presented along with an estimate of the true display gamut available. [Supported by a joint EPSRC/dstl Grant No. EP/D032008/1.]

◆ **Electronic ballasts, lighting temporal modulation and visual performance**

M Jaén (Department of Lighting, Light and Vision, National University of Tucumán, San Miguel de Tucumán, Argentina; e-mail: MJaen@herrera.unt.edu.ar)

It is well known that temporal modulation of lighting (flicker) can be unhealthy. Since fluorescent lamps activated with magnetic ballasts (MB) began to be massively used, office workers' complaints associated with lighting became frequent. The use of electronic ballasts (EB) in the circuit, which raises the main frequency of light modulation from 100 Hz to 50–60 kHz, diminishes eye strain and headache symptoms in individuals; however, this solution may require a large investment and is not always available. Therefore, the early detection of individuals who have high sensitivity to this effect becomes very important. We developed a simple psychophysical method to assess the efficiency of a visual-search task under both lighting situations (MB and EB). We performed the experiment with a sample of fifty subjects aged between 20 and 22 years, all with normal or corrected-to-normal vision. Results showed statistically significant differences between the efficiency attained in these two lighting situations. The method allowed us to discriminate, by using a thresholding criterion, two sub-samples of individuals: one with low and the other with high sensitivity to temporal modulation of lighting. Our results are comparable to those obtained with classical discrimination methods, such as Landolt's rings tests.

◆ **Straylight in the human eye. Population variation and psychophysical assessment**

T J T P van den Berg (Netherlands Institute of Neuroscience, Royal Academy of the Netherlands, Amsterdam, The Netherlands; e-mail: t.j.vandenberg@nin.knaw.nl)

Retinal straylight is the cause of important visual disturbances such as glare hindrance and contrast loss. It results from light scattering in the optical media over angles of 1° to 90° . A forced-choice psychophysical assessment technique was developed ('compensation comparison'), that has resulted in a commercial product (C-Quant from Oculus). A maximum likelihood estimation is performed, fitting a psychometric function to the patient responses for 25 comparisons, including a reliability estimate of the obtained straylight value. The method was applied to 2400 subjects in the European GLARE study. Repeated-measures standard deviation for the method is about 0.06 log units, to be compared with differences in the young normal population of 0.2 log units, increasing with healthy aging by 0.5 log units at 80 years, and by 1.0 or more log units with (early) cataract or corneal disturbances.

POSTER SESSION

ATTENTION

◆ **Improving selective attention with riding simulator**

A Bastianelli, G Vidotto ¶ (Department of Psychology, University of Milano-Bicocca, Milan, Italy; ¶ University of Padua, Padua, Italy; e-mail: alessia.bastianelli@unimib.it)

The visual environment contains considerable amounts of information involving the relations between objects in space and time; the observer, who pays selective attention to the relevant set

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of stimuli, can automatically extract the appropriate information. In driving behaviour, this process is particularly relevant, especially if the set of stimuli has a dangerous connotation. The object of this work was to find whether a riding simulator could improve the selective attention and awareness toward dangerous stimuli in teenagers as previous studies suggested for novice drivers. The simulator presents twelve training tracks in different visual environments with eight experimental situations. On-screen, the rider sees and hears a realistic three-dimensional world. The experimental procedure involves a pre/post randomized experimental design with an experimental group and a control group, both of two hundred participants randomly assigned. Post-test shows an improvement in participants' performance. Data are interpreted in light of space-based theory of visual attention.

[Research carried out on behalf of Honda Riding Trainer—Psychological Evaluation.]

◆ **Temporal attention in face and object recognition: Holistic and feature-based processes**

C T Benito, I M Harris (School of Psychology, University of Sydney, Sydney, NSW, Australia; e-mail: Claireb@psych.usyd.edu.au)

Models of face and object recognition generally concede that faces are processed holistically and objects in a feature-based manner. Research comparing priming for attended and ignored stimuli suggests, however, that attention may modulate whether a stimulus is processed holistically or featurally. Stankiewicz et al (1998 *Journal of Experimental Psychology: Human Perception and Performance* **24** 732–744) reported that holistic processing of objects requires no attention, whereas Palermo and Rhodes (2002 *Cognition* **82** 225–257) reported that holistic processing of faces requires attention. We investigated the role of temporal attention in holistic and feature-based processing of faces and objects to establish whether conflicting results are due to fundamental differences between face and object processing or task artifacts of previous studies. We used repetition effects as an index of recognition and compared object and face recognition when the stimuli were (a) attended or ignored and (b) intact or degraded (ie where holistic/configural processes are disrupted). Results are discussed in relation to current models of visual processing in the absence of attention.

[Supported by a University of Sydney Research Early Career Researcher Grant.]

◆ **Illuminating the shadow economy of dark attention**

E Blaser, T Shepard (Department of Psychology, University of Massachusetts, Boston, USA; e-mail: erik.blaser@umb.edu)

In 1911, Wohlgenuth asked if withdrawing attention from an adaptor reduced motion aftereffects (MAEs). He noted no reduction. Replications in 1990 through Chaudhuri have shown dramatic reductions. Such studies have implications for how unattended stimuli are processed. We hypothesized resources—dark attention—distinct from aware attention yet flexibly allocated. We unconfounded the two by employing concurrent tasks that competed for the latter, but not necessarily the former. The tasks were: (i) observers detected plateaus in the luminance modulation of a field of drifting dots; (ii) a visual or auditory 2-back memory task. Instructions varied (attend luminance task exclusively, 50/50, 10/90, or 2-back exclusively). MAEs were measured. Tradeoffs in awareness and performance between tasks were induced, but, critically, MAEs were only reduced with the visual 2-back task, not the auditory. This resolves the discrepancy: Wohlgenuth's alternate task did not require a reallocation of dark attention, while Chaudhuri's did.

◆ **Effect of induced unilateral neglect on reading**

A Brenk, P Jaskowski¶ (Faculty of Physics, Adam Mickiewicz University, Poznań, Poland; ¶ University of Finance and Management, Warsaw, Poland; e-mail: alicja@optyka.com.pl)

It has been recently demonstrated that the dyslexics show an asymmetry of attentional distribution between visual fields of the two eyes, which resembles mild symptoms of unilateral neglect. In addition, it is known that adaptation with prism spectacles shifting the visual field to the left induces slight temporary unilateral neglect. Here, we report preliminary data on the effect of prism adaptation on reading. The severity of the induced neglect was assessed through a line-bisection test. In the main experiment, the healthy participants performed visuo-motor tasks. During this training they were wearing prism spectacles shifting the visual field by 15° to the left. Before and after prism adaptation participants performed the bisection and a reading test. We found that after prism adaptation the participants bisected lines with a right bias with respect to the pretest. This is a typical symptom of unilateral neglect. Moreover, participants read significantly more slowly after prism adaptation than before. This finding suggests that dyslexia is related to mechanisms implied in unilateral neglect.

◆ **The role of goal-directed eye-movements in joint attention orienting**

E Bricolo, P Ricciardelli, S Carcagno[¶], G Fernaroli, G Vallar (Department of Psychology, University of Milano-Bicocca, Milan, Italy; [¶] Lancaster University, Lancaster, UK; e-mail: emanuella.bricolo@unimib.it)

Distracting gaze stimuli can elicit an automatic gaze-following response (Ricciardelli et al, 2002 *NeuroReport* **13** 2259–2264). Using an oculomotor task, we investigated whether the tendency to follow another person's gaze is related to context. Participants were asked to saccade towards one of two peripheral targets, depending on the colour of an instruction cue appearing between the eyes of a distracting face. At different intervals from the time of instruction, the face shifted the eyes towards a location. The distracting eye movements were either directed to one of the two peripheral targets (goal-directed eye movements) or towards an empty spatial location (no-goal-directed eye movements). In the goal-directed condition, eye movements were congruent or incongruent with respect to the direction indicated by the instruction. Eye-movement recordings showed that in incongruent trials participants made a higher proportion of gaze following errors (errors in the direction of the distracting gaze stimulus) in the goal-directed condition, compared to the no-goal-directed condition. These findings elucidate the mechanisms of automatic gaze-following responses, highlighting the role of goals in the deployment of attention.

◆ **Object-based attention with valid endogenous cues**

Z Chen, K R Cave[¶] (Department of Psychology, University of Canterbury, Christchurch, New Zealand; [¶] Department of Psychology, University of Massachusetts, Amherst, USA; e-mail: zhe.chen@canterbury.ac.nz)

Our previous research has shown that object-based attention can arise under conditions of positional certainty if participants interpret the stimulus pattern as two separate objects. In the present experiments, we extended this finding by combining spatial invariance with endogenous cues. In several experiments, we manipulated the locations of the targets relative to an endogenous cue. To ensure that participants did not need to search for the targets, the cue was 100% valid. The results showed faster reaction times when the cue and the targets were on the same object than on different objects. Furthermore, this object effect was eliminated when the exposure duration of the target displays was reduced. These results suggest that the deployment of object-based attention requires the encoding of the structural organization of a stimulus pattern, which in turn takes time to develop. They also provide converging evidence to our previous finding that object-based attention reflects enhanced representations of the selected object instead of a byproduct of priority in visual search.

◆ **Perceptual load, attentional prioritization, and the flanker effect**

F K Chua (Department of Psychology, National University of Singapore, Singapore; e-mail: fkchua@leonis.nus.edu.sg)

Using a visual search paradigm, Navie et al showed that when load was low (leading to efficient search), a flanker, though not part of the search set, would still be processed, a result compatible with the late-selection view. But when load was high (non-efficient search), the same flanker would be ignored, thus supporting early selection. Some recent experiments showed that other factors (eg attentional control setting) modulate the effects of perceptual load. In four experiments, we showed that top-down control settings need not modulate the perceptual load effect. Rather, the disappearance of the flanker effect could be attributed to effective attentional prioritization of target locations. When prioritization was encouraged, as would be the case when the observer knew where the stimuli would appear (and thus prioritized these locations), a flanker that appeared elsewhere failed to be processed even when there the main task did not completely consume all the attentional resources.

[Supported by NUS Grant R-581-000-042-112.]

◆ **Psychophysical correlates of the effects of cross-modal attention are more consistent with fMRI responses in V1 than MT+**

V M Ciaramitaro, G Boynton (Department of Systems Neurobiology, The Salk Institute, La Jolla, USA; e-mail: vivian@salk.edu)

Previously we showed that fMRI responses to unattended visual stimuli depended on the modality attended. In V1/V2 the response to an unattended stimulus was weakest when attending another visual stimulus, whereas in MT+ it was weakest when attending an auditory stimulus. Here we use a visual motion aftereffect (MAE) to measure behavioral responses to unattended stimuli to determine if a psychophysical correlate for attention effects agrees with responses in V1 or MT+. A central cue directed attention to one of four stimuli (two visual gratings, two auditory tones) where subjects performed a visual speed or auditory frequency discrimination. The contrast of the gratings varied between blocks of trials and MAE strength was measured for each trial by a

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nulling procedure. Consistent with fMRI results in V1/V2, the MAE was weaker when attending a visual stimulus. Furthermore, MAE strength increased with contrast, consistent with V1 contrast-response functions. Psychophysical results reflect responses in earlier stages of visual processing. [Supported by grant NIH-NEI 12925.]

◆ **Object and spatial representations in the corner enhancement effect**

G G Cole, P Skarratt, A Gellatly¶ (Department of Psychology, University of Durham, Durham, UK; ¶ The Open University, Milton Keynes, UK; e-mail: g.g.cole@durham.ac.uk)

Targets presented adjacent to geometric corners are detected more efficiently than targets presented adjacent to straight edges (Cole et al, 2001 *Journal of Experimental Psychology: Human Perception and Performance* 27 1356–1368). We present four experiments examining how this corner enhancement effect is modulated by corners of object representations (ie corners that define an object's shape) and local base-level corners that occur as a result of, for instance, overlapping straight edges of two objects. Results show that the corner phenomenon is greater for corners of object representations than for corners that do not define an object's shape. We also examined whether the corner effect persists within the contour boundaries of an object as well as on the outside. Results showed that a spatial gradient of processing accompanies the corner effect outside the contour boundaries of an object but processing within an object is uniform with no corner effect occurring. We discuss these findings in relation to space-based and object-based theories of attention.

◆ **Eye movements, luck, and inattentive blindness**

S J Duensing, P F Heard¶, C Gibbs¶ (Education and Professional Studies, King's College, London, UK; ¶ University of the West of England, Bristol, UK; e-mail: sally.duensing@kcl.ac.uk)

Twenty naive student observers watched the basket-ball movie (Simons and Chabris, 1999 *Perception* 28 1059–1074) and counted the passes by the white team. Ten noticed the gorilla walking through and beating his chest, the other ten did not. Their eye movements were recorded using the ASL system and Gazetracker. The observers also watched a card trick provided by Richard Wiseman of the University of Hertfordshire, and a disappearing cigarette magic trick, while also being eye tracked. They completed a pencil-and-paper number cancellation task and a luckiness questionnaire [Wiseman, 2003 *The Luck Factor* (London: Random House)]. All observers were fooled by the card trick and one noticed the cigarette drop. It was found that most of the non-perceivers of the gorilla looked at it for over 300 ms, though overall most of the gorilla perceivers looked for over 800 ms. The gorilla perceivers rated themselves as more 'lucky' than the non-perceivers, but made more errors in the number cancellation task, suggesting that they are worse at focusing attention.

◆ **The role of visuo-spatial attention in non-word reading**

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Phonological decoding is a critical index for successful reading acquisition and it requires not only appropriate phonological skills but also a precise graphemic parsing process (segmentation of a letter string into graphemes). Visuo-spatial attention has been linked to graphemic parsing in developmental dyslexia (Facchetti et al, 2006 *Cognitive Neuropsychology* 23 841–855) and it is endorsed by the CDP+ computational model of reading aloud (Perry et al, 2007 *Psychological Review* in press). We investigated this issue in thirty skilled adult readers by collecting measures of visuo-spatial attention, phonological skills, and reading performance. Regression analyses showed that visuo-spatial attention accounts for a significant variance in non-word reading fluency even after controlling for individual differences in phonological skills. Faster nonword readers showed a larger Navon interference and a smaller negative priming effect in comparison to slower non-word readers that can be accounted for by a smaller and more efficient attentional focus in the former. The present findings indicate that visuo-spatial attention can be specifically linked to the graphemic parsing process.

◆ **Does visual attention respect object boundaries? Evidence based on the effect of flankers in a visual-discrimination task**

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We used the effect of flankers to determine whether the distribution of visual attention respects the contours of a frame in which the target of a visual discrimination task is presented. The frame was a vertical rectangle with either continuous or opened sides in the central region. The target was presented in the center of the frame and flankers were presented outside. The interference of flankers

was greater when these were presented side by side with the target and the frame with bilateral (experiment 1) or unilateral openings (experiment 2) than when the frame was closed. The effect of flankers was weaker when these were vertically displaced in relation to the target (experiment 3). Two subject groups were identified on the basis of the reaction time coefficient of variation. Participants with lower coefficients are more affected by the compatibility between flankers and target; participants with higher coefficients are more affected by the opening in the frame. Attention distribution depends on the frame, as well as on individual characteristics of participants. [Supported by grants FAPESP (03/13534-1), CNPq (308671/2006-6).]

◆ **The time-course of attention shifts between extra-personal and personal space triggered by body shadows**

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Mere observation of our own body shadows induces attention shifts towards the body parts casting them. In three experiments aimed to address the time-course of this phenomenon, we used a spatial-cueing paradigm with uninformative lateralized hand shadows. We manipulated shadow target SOA (100, 600, 1200, and 2400 ms) and target modality (tactile in experiment 1, visual near-shadow in experiment 2, and unpredictably visual near-shadow versus tactile in experiment 3). In both experiments 1 and 2, participants showed better performance for valid over invalid trials independent of SOA. Remarkably, in experiment 3 shadow facilitated responses for visual stimuli in the portion of space they occupy at the 100 ms SOA, then facilitated responses for tactile stimuli in the portion of space they refer to at the 600 ms SOA, and finally acted as a lateralized attentional cue selectively for the hand casting the shadow at the longest SOAs. Orienting driven by body shadows contravenes the exogenous/endogenous dichotomy, and evokes attention shifts between extra-personal and personal space. [Supported by MIUR.]

◆ **Dynamics of beta cortical activity in cats trained in visually guided task**

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We have previously shown that local field potentials (LFPs) recorded during spatial discrimination task in cat's primary visual cortex in an attention-related situation were characterized by an enhanced power in beta frequency range (16–24 Hz). In the same experimental model we have now calculated the beta peak amplitude of power spectrum of LFPs from cats visual cortex in consecutive stages of the experiment: learning, assessment of the level of performance, overtraining, and learning with new stimuli. The recordings were performed from electrodes chronically implanted in retinotopically different parts of visual cortical areas 17 and 18. At the beginning of the learning phase the amplitude wavered and then started to grow in stabilized fashion. During the assessment stage of performance the high amplitude of power spectrum in beta band tended to decrease from session to session, while during the overtraining no significant changes in beta band were observed. Our observations indicate that the beta activity in primary visual cortex correlates with visual attention only during acquisition of the new visual task. [Supported by the Polish State Committee of Scientific Research, Grant 6P05A09020.]

◆ **Accepting banknotes: A mixture of visual perception, tactility, and trust**

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The European Central Bank's (ECB) right to issue banknotes within the European Community entails a public responsibility in the development of Euro banknotes enabling strong recognition, thus making it easier for the European citizens to be alerted in case of counterfeit reception. The 2007 research programme aims to gain deeper understanding of the interaction between a Euro banknote and the receiving person, especially at the very first step of alerting: why does somebody decide to invest more time to check whether or not a banknote is genuine? The programme started by applying the available knowledge to specific banknote issues: investigation of the preferred image for a secure watermark, comparison of the attractiveness of security features considered in the preparation of the Euro second series. A first attempt to analyse jointly visual perception and tactility demonstrated that this aspect should be addressed in greater depth. At present, the European Central Bank is contemplating to launch a 2008 research programme addressing both visual perception and tactility in the context of a relationship governed by trust.

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◆ **Task-dependent effectiveness of gaze capturing**

E S Groenewold, R Renken ¶, F Cornelissen ¶ (Laboratory of Experimental Ophthalmology, University Medical Centre Groningen, Groningen, The Netherlands; ¶ also BCN Neuroimaging Centre, Haren, The Netherlands; e-mail: esgroenewold@gmail.com)

Vision is the primary sensory modality for many tasks in everyday life, but is known to have a limited capacity for information processing. Therefore it has been proposed that directing gaze to locations of interest may help improve visual performance in many tasks. One of the key questions is to what extent the ability to capture a persons gaze is dependent upon the task at hand. To examine this question, we measured subjects gaze-directions while we presented brief gaze-capturing events (GCE; a 0.1 s red imploding circle). Subjects ($n = 4$) either performed a search task, or were instructed to gaze freely over the display (a matrix of circles with gaps). During free viewing GCEs captured gaze on average in 31% of the trials, while during search this occurred in 66% of the trials (paired t -test: $p = 0.01$). We conclude that the effectiveness of gaze capturing is strongly dependent upon the task at hand.

[Supported by the European Commission within the GazeCom project (contract IST-C-033816).]

◆ **Spatial attention to the left visual hemifield induced larger attention-driven hemodynamic responses in the posterior cortex: fNIRS study**

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This study is possibly the first study showing asymmetric representation of visual hemifields in spatial attention processing using functional near-infrared spectroscopy (fNIRS). Stimuli consisted of four radial gratings positioned around the fixation point. Ten 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 participant's head. We measured oxy- and deoxy-Hb from 24 measurement points simultaneously at a rate of 10 Hz. We obtained task-related cerebral activity for the measurement points, number of attended stimuli, and attended visual hemifield. Trends of contra-lateral dominance were observed at several measurement points, where attention to the left visual field (VF) induced larger activities in right hemisphere and vice versa. The effect of the attentional load was significantly larger when attending to the left VF than when attending to the right VF. This suggested that feedback signals to visual cortices from the right cerebral hemisphere seemed larger than from the left hemisphere.

◆ **Serial Gestalt grouping**

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Here we propose a new theory called the incremental grouping theory that suggests that although local groupings are extracted in parallel, Gestalt grouping is a serial process whenever multiple local groupings need to be combined in a transitive way. To test the theory, we constructed a new task where participants saw two strings of colored circles and identified a cue on the target string. The strings were defined by proximity and/or similarity cues. Furthermore, we varied the difference between the colors of the strings and the similarity of the colors within a string. Perceptual grouping was serial in all conditions, implying that Gestalt grouping by similarity and proximity is indeed a serial process. Furthermore the speed of this process was influenced by the availability of the cues in an interactive way. Incremental grouping theory explains the results by suggesting that chunks of image elements are added successively to the evolving incremental group.

◆ **How does attention modulate crowding during spatial cueing and dual-task paradigms?**

C J Howard, P Sumner (Department of Psychology, Cardiff University, Cardiff, Wales, UK; e-mail: howardcj@cardiff.ac.uk)

There is a debate over whether crowding arises from a failure of attentional processes or at a lower-level locus, eg summation by complex cells. Dakin et al [(2007 *Perception* **36** 303 (abstract))] used equivalent noise methods to claim that the effect of attention was qualitatively different from that of crowding. Observers reported the overall orientation of six Gabor patches with and without crowding stimuli and in single-task and dual-task conditions. It appeared that high attentional load decreased the efficiency with which information was sampled from stimuli, while crowding increased internal noise. We considered whether this apparent result was peculiar to dual-task experiments, which might encourage attending to fewer stimuli. We therefore adapted Dakin et al's approach to manipulate attention in two different ways: either by cueing attention to many or few locations, or by adding a dual-task load. We find that the effect of spatial attention does not appear to be qualitatively separable from that of crowding, because both influence internal noise.

[CH is supported by the School of Psychology, Cardiff University, the ESRC, and the EPSRC, UK.]

◆ **Selective inhibition of distractors in attention-induced motion blindness: Is it based on features or expectation?**

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The ability to ignore irrelevant information is vital for effective cognitive functioning, but can also impair responses to previously irrelevant information. Attention-induced motion blindness (AMB) is an example of such impairment. AMB is the failure to detect a brief episode of coherent motion, embedded in a stream of random motion episode, if that motion target is preceded by irrelevant coherent motion distractors which can be ignored. AMB results from inhibition allocated to those distractors. The current study examined whether inhibition in AMB is under the control of expectation of the observer (top-down) or if it is triggered automatically (bottom-up). In three experiments, perception of coherent motion targets was compared in conditions where direction of target and distractors was predominantly congruent or incongruent. The AMB effect was stronger with congruent distractors than incongruent ones, but prior knowledge of the direction of the target had little effect. The findings indicate that inhibition is allocated to features of the distractors and that the influence of top-down processes (ie expectation) on inhibition allocation is minimal.

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◆ **Are faces processed as a whole? Evidence from comparison of face processing with word- and nonword-processing**

M A Khatibi Tabatabaei (Department of Psychology, Tehran-Oxford Neurodevelopmental Center, Tehran, Iran; e-mail: ali.khatibi@gmail.com)

Objects can be recognized either as a whole or as parts, first processed and then linked together. Accordingly, there are separate routes in word recognition: lexical (perceiving whole word) and nonlexical (reading letter by letter). The subjects took part in a match-to-sample experiment (they were asked to identify the previously viewed face or word among two changed and unchanged versions of that image). The change in a word was applied by interchanging two of its characters or by inserting a new one into it. The change in a face was applied by replacing its structural parts with each other or by introducing a part from another face. To check the subjects' attentional status during the test, a parallel task was applied by using a dot-probe paradigm. Subjects acted differently in the two independent tests. In word subtest, nonwords received more attention than words; however, recognition of words was easier than that of non-words. In face subtest, unusual faces received more attention, but unusual faces were recognized easier than usual faces.

◆ **Attending to the parts of a 3-D object**

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Visual selective attention is generally considered to be either space-based or object-based. We investigated three issues that have been largely ignored. First, because objects are hard to define, focusing on object parts seems to be a more fruitful approach. Structural differences (ie within-part/between-part) can then be based on relatively straightforward theories of part segmentation. Second, compared to 2-D objects, 3-D objects are more veridical. Therefore, projected multipart 3-D objects are used here. Third, to examine the nature of visual selective attention, various distance relations were investigated by controlling for either space-based distances, object-based/part-based distances, or both. In three experiments, participants judged the similarity of features belonging to the same part of a 3-D object, or to different parts. We discuss two important findings. First, structurally, within-part advantages are more pronounced at the extremes of a 3-D object as compared to the center of a 3-D object. Second, temporally, in case of multipart 3-D objects, visual selective attention seems to consist of a preliminary space-based stage, followed by a part-based stage.

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◆ **The role of the superior colliculus in visual attention**

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In addition to its well-known role in the motor control of eye movements, the superior colliculus (SC) has recently been implicated in target selection and visual attention. Here, we investigated the function of the SC in these non-motor processes using a motion discrimination task that manipulated voluntary attention with spatial cues. First, recording in the intermediate layers of

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the SC in a rhesus macaque, we found that visuomotor neurons show a preference for the cued patch even though it was not the target of a saccade. Second, we found that focal inactivation caused by microinjection of muscimol within these layers of the SC caused a profound impairment in discrimination when the patch was placed in the affected region of the visual field, in addition to the expected deficit in directing saccades toward the affected region. These findings show that SC neurons are modulated by the allocation of visual attention, and that activity in the SC plays a causal role in the control of visual attention.

[Supported by Aginsky Foundation.]

◆ **Object-based and feature-based priming in visual search**

Á Kristjánsson, A Ingvarsdóttir, U Teitsdóttir (Department of Psychology, University of Iceland, Reykjavik, Iceland; e-mail: ak@hi.is)

Two contrasting accounts for priming in visual search have been proposed. The main difference between the two accounts is the level of perceptual processing that the priming effects are assumed to occur, whether priming is assumed to operate through the selective facilitation of features or at the level of selection of objects for response. The aim of the two experiments here was to contrast these accounts. Observers performed a search for the odd diamond among two distractor diamonds. Each diamond had two colors but the configuration of colors within the diamonds was different for the two experiments, configurations previously shown to lend themselves in different degrees to object formation. The results show that priming can be both feature-based and object-based depending on the topological properties of the stimuli in each case. Priming is thus assumed to operate at various levels of perceptual processing, a result consistent with new findings from neuroimaging and neuropsychology.

[Supported by the Human Frontiers Science Program and the Research fund of the University of Iceland.]

◆ **Attentional effects in colour-based global motion processing**

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Global motion extraction does not automatically benefit from correlations between colour and motion but small improvements in performance were found with attentional focusing. But what is the nature of such attentional enhancement? Random-dot kinematograms containing two colours differing only in the S-cone signal (an increment—magenta or a decrement—orange) were generated. Spatial and temporal parameters were chosen such that global motion processing relied solely on L and M cone inputs, but S-cone signals still affected colour appearance. With colour contrasts fixed at threshold to ensure equal effectiveness for motion extraction, participants discriminated between coherent and random motion and d' s were measured for 'uncorrelated', 'uncued correlated', and 'cued correlated' conditions. (i) As expected, motion–colour correlation did not automatically improve performance. (ii) A significant interaction of attention and colour was found. While attentional focusing caused enhancements for S cone increments, its effects on S cone decrements were less consistent. We conclude that colour appearance crucially influences segmentation and underlies the attentional effects in global motion processing.

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◆ **Attentional bias to emotional facial expressions: Social anxiety influences on a visual search efficiency**

E Matsumoto (Kobe University, Kobe, Japan; e-mail: ermatsu@kobe-u.ac.jp)

Negative emotional faces tend to attract more attention than positive faces. Several studies reported that highly socially anxious individuals exhibited advantage through anger. It is thought that anxiety is associated with a bias for interpreting threatening information. Using a visual search paradigm and an anxiety questionnaire (STAI), we investigated the relationship between the social anxiety level and attentional process of emotional facial expressions. Participants were asked to search for a discrepant facial expression among other homogeneous faces. This study compared: (i) finding an angry discrepant face among happy faces (A-H search) vs finding a happy face among angry faces (H-A search), (ii) finding an angry face vs finding a happy face among neutral faces (A-N and H-N search). The results demonstrated that search asymmetry is found in A-H/H-A condition, and search efficiency in the A-N condition is influenced by the anxiety level. The findings suggest that the emotional expression of the target, rather than the distractors, affects high anxiety individual's search efficiency.

◆ **Multiple object tracking in chimpanzees (*Pan troglodytes*)**

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Previous studies revealed that we humans can simultaneously attend to and track movements of multiple objects (eg Pylyshyn and Storm, 1988 *Spatial Vision* 3 179–197). In contrast to the intensive investigations of the characteristics of the attentional tracking in humans, the ability to track objects has not been investigated to the same degree in non-human animals. Here, we report on the multiple object tracking abilities of chimpanzees assessed in similar test settings to those used in previous studies on humans. In the experiments, chimpanzees were trained to track moving discs generated on a CRT screen. At the beginning of each trial, 1 to 5 discs of a total of 8 or 10 discs flashed, which indicated that they were the targets. After the discs were displaced with smooth motion, subjects were required to select the targets. The performance of chimpanzees in the detection of targets (up to 4) was above chance level. These results suggest that chimpanzees are capable of tracking multiple objects simultaneously as humans do, and that chimpanzees and humans share underlying mechanisms for representing objects across space and time.

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◆ **How does attentional capture affect target detection sensitivity and response bias?**

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In spatial cueing paradigms, attentional capture is commonly observed with abrupt onset cues, or with cues contingent on target characteristics. We investigated the nature of attentional capture and its interaction with selective attention by applying signal detection theory to the data of spatial cueing experiments. The target was a weak colour change on either of two green crosses. Onset cues were uninformative flashes of a white disk. Contingent cues were uninformative colour changes on either of two permanently visible disks. Both types of cues reduced target detection sensitivity but enhanced the bias to respond. With onset cues, the sensitivity loss was larger than with contingent cues. The effect interacted with the need to pay selective attention to the target. We conclude that attentional capture counteracts endogenous attention by disrupting selectivity. The more selective attention a task requires, the more immune it might be to disruption. In addition, attentional capture might lower the response threshold, which might yield the commonly observed response time effects.

◆ **Effects of goal-directed movements on the relation between size of the attentional area and efficiency of visual search**

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Previous findings have proposed an inverse relation between size of the attentional area and processing efficiency; processing is less efficient when the attentional area is wide than when it is narrow. We examined how goal-directed movements would affect this relation. Participants were required either to grasp a target cube (grasping task) or just to detect it (detection task). There were six possible locations where the target would appear. To control the size of the attentional area, before the target appeared, a cue which indicated where the target would appear was given by turning on two, four, or six cubes briefly. Reaction time was defined as the interval between target onset and response initiation. Results showed that in both tasks reaction times increased as the number of cubes in the cue increased. And the increased time was larger in the grasping task than in the detection one. We thought grasping the target required more precise comprehension of target location than detecting it, and this would cause the differential increased time between the two tasks.

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◆ **Volitional orienting to colour**

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Recent research has shown that predictive central arrows, which have long been used to measure volitional attention, engage in fact reflexive and volitional orienting. It has been suggested that predictive central number cues (eg 3 predicts a target on the right, 9 predicts a target on the left) are a better means of measuring volitional attention in isolation. We now tested another type of cue—colour cues—to estimate volitional attention effects and compared the cueing effects to those triggered by central arrows. Participants completed four conditions: nonpredictive arrows, nonpredictive colours, predictive arrows, and predictive colours (eg green predicts a

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target on the left, red predicts a target on the right, and vice versa). The results showed that colour cues only produced orienting effects if made predictive of target location, suggesting that they are providing an estimate of volitional orienting. Further, cueing effects triggered by predictive arrows exceeded those of predictive colour cues, confirming the notion that predictive arrows measure more than solely volitional attention.

◆ **Selective attention to multi-spectral visual and auditory stimuli biases motion aftereffects**

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The object of our study was how endogenous selective attention to motion signals carried by high (or low) frequency auditory or visual stimuli during adaptation biases motion aftereffects (MAE). Visual adaptation stimuli consisted of two superimposed groups of sinusoidal gratings moving in opposite directions. The two groups and the test stimulus were composed of low, high, and medium frequency gratings, respectively. Correspondingly, auditory stimuli were composed of groups of pure tones at low, high, and medium frequencies. Observers attended to one of the competing motion stimuli during adaptation and performed a direction discrimination task on the test stimuli. Attention was found to play a significant role in biasing the MAE in the direction opposite to the attended one. However, the MAE strength was reduced when competing adaptation stimuli were used as compared to unidirectional stimuli. Our results in the visual/auditory domain confirm/extend earlier studies in vision that selective attention to one of two competing stimuli modulates motion processing and the ensuing MAE.

◆ **Contrast-detection experiments shed new light on the relationship between extinction and neglect following right-hemisphere damage**

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To investigate whether the expression of visual extinction is dependent upon the contralesional low salience existing in neglect, we tested stroke patients, as well as normal controls, on detection of a peripheral Gabor patch, while a competing patch was presented simultaneously on the other side. To compensate for uneven salience we set the contrast level relative to the detection threshold on each side. Patients showed contralesional extinction even for stimuli set at threshold level. They differed from controls in their sensitivity to changes in relative contrast between sides, showing stronger tendency for extinction and requiring much higher contrast increments in the target patch in order to eliminate extinction. The differences between normal and pathological extinction, shown despite compensation for contralesional perceptual attenuation due to neglect, suggest an additional extinction-specific deficit related to an abnormal interplay between the bilaterally presented stimuli. These findings demonstrate that the hypothetical 'attentional gradient', taken to explain reduced salience of stimuli in the neglected side, cannot fully account for the phenomenon of extinction.

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◆ **Bridging neurophysiological and psychophysical effects of attention on contrast sensitivity**

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Human psychophysical studies show that attention affects the contrast response function via contrast gain, response gain, or both. Correspondingly, neurophysiological studies show that attention modifies the contrast response functions of neurons in early visual areas, such as V4 and MT, by either contrast- or response-gain mechanisms. Contrast gain corresponds to a change in sensitivity of the contrast response function; response gain corresponds to a multiplicative increase in response. Comparisons between psychophysical and neurophysiological studies should be made with caution. To make an explicit link between psychophysical data and single-unit recordings, we model expected population contrast response functions by fitting two different models to psychometric functions. The models make quantitative predictions regarding gain changes in neural response as a function of performance in 2AFC orientation discrimination tasks, in which performance increases with contrast. By changing the parameters of the assumed population, the models predict attentional modulation at several visual areas (eg V1, V4).

◆ **Category selectivity in the ventral visual pathway confers robustness to clutter and diverted attention**

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The pattern of fMRI responses across the ventral visual pathway to objects presented in isolation carries information about the category of the object. However, natural images usually contain multiple objects (clutter), a notorious challenge for distributed representations. Here we used pattern analysis methods to ask whether category information in the fMRI response is preserved under conditions of clutter and diverted attention, and whether the answer to these questions depends on the category of object viewed. We found that information in the spatial pattern of fMRI response about standard object categories (shoes and cars) is severely disrupted by clutter, and eliminated when attention is diverted. However, information about preferred categories in category-specific cortical regions (faces in the FFA and houses in the PPA) is undiminished by clutter, and partly preserved under diverted attention. These findings suggest that, under natural viewing conditions, the spatial pattern of fMRI response provides robust information about object category only for special categories that are coded in their own selective cortical regions. [Supported by grant EY 13455 to NK.]

◆ **Modulation of orientation discrimination thresholds by positive reward in the absence of attention**

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Several neurophysiological studies have suggested a top-down influence of reward to low-level sensory systems. However, the issue has been raised that the effect of reward cannot be dissociated from that of attention. We used a dual task loading attention to the center of the display, by requiring observers to perform accurate counting of a central disc at luminance threshold, and asking them to discriminate the tilt of a peripheral Gabor around $+45^\circ$ or -45° . Only one of the two features, based on a cue presented at the beginning of each trial, was reinforced in the presence of correct identification. We measured thresholds and response distributions (by magnitude matching) and found that rewarding correct identification of only one feature positively influences thresholds and distributions for the pre-cued direction even if attention is busy with a concurrent task.

[Supported by an Italian MIUR-PRIN grant to SB.]

◆ **Notice of measuring blinks changes causal relationship between perceptual reversal of Necker cube and blinks**

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It is controversial whether blinks cause perceptual reversal of ambiguous depth perception. Here, causal relationship between blinks and perceptual reversal was examined by comparing two experimental conditions. In the first experiment blinks of subjects and timing of perceptual reversal were recorded without notice of measuring blinks. In the second experiment the same procedure was used but subjects were informed that their blinks would be measured. Results showed that the spontaneous blinks followed perceptual reversals in the first experiments, whereas blinks preceded perceptual reversal in the second experiment. Voluntary blinks can thus reset perception, then they can reverse the depth perception. It was difficult to blink naturally and spontaneously for the subjects if they were conscious of blinking as in the second experiment. In contrast, during information processing in the brain, blinks tend to be suppressed and after completing the process spontaneous blinks were observed. This is the case of the first experiment.

◆ **Influence of task requirements on space-independent attentional modulation**

D Wegener, F Ehn, M Aurich, F O Galashan, A Kreiter (Center for Cognitive Sciences, University of Bremen, Bremen, Germany; e-mail: wegener@brain.uni-bremen.de)

Recent experiments have demonstrated that visual attention can be directed to space, features, or objects as a whole. Accordingly, space-based, feature-based, and object-based mechanisms of visual attention have been described. Here we ask whether the type of attentional modulation is influenced, or determined, by task requirements. We asked human subjects to detect slight changes of either the velocity, or the colour of one of two simultaneously presented Gabor gratings. The task was designed as a Posner paradigm, in which for 75% of all trials both location and change feature were correctly cued. For the remaining 25% of the trials, either space, or change feature, or both were incorrectly cued. In this experiment reaction times revealed strong support for space-independent feature-based attentional modulation. These data are contrasted with a second experiment in which the same task is performed but no cue for

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the type of feature change is given. Our experiments support a view that favours task requirements as determinants for the type of attentional selection.

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◆ **A memory-based interference effect in midstream order deficit**

Y Yagi (Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Japan; e-mail: yyagi@human.tsukuba.ac.jp)

Participants were asked to report letter identities and relative order of a four-letter sequence presented in rapid serial visual presentation. The four-letter sequence was repeated five times (cycling condition) or embedded once within a stream of distractor symbols (single-presentation condition). The results revealed that midstream order deficit (MOD) could be replicated; relative-order accuracy was lower in the cycling condition than in the single-presentation conditions and letter-identity accuracy was higher in the cycling condition (experiment 1). Robust MOD was still observed even when the letters between the 9th and 16th presentations in the cycling condition were replaced with a distractor sequence (experiment 2). This finding is inconsistent with the previous view that discontinuity between the letter and distractor sequences causes MOD. Furthermore, a MOD-like effect could be observed in a relatively slow stream when an irrelevant letter sequence was presented before the target letter sequence (experiment 3). A new explanation for MOD is proposed which is based on interference between the representations of order in memory and current perception.

[Supported by the COE program for the 21st century from the Japan Society for the Promotion of Science.]

◆ **Spatio-temporal characteristics of peri-saccadic oculomotor feedback to extrastriate visual areas**

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We have previously developed a computational model which accounts for major aspects of peri-saccadic compression in both space and time. It is based on the assumption that the planning of a saccade is accompanied by a spatially selective feedback signal directed to multiple visual areas. Here, we tested the hypothesis that the feedback signal might originate from oculomotor-related areas like the FEF or the SC. We varied the temporal and spatial aspects of the feedback signal and compared the model prediction with behavioral data. We observed that the 'effective' feedback signal is best described by a population of cells with closed movement fields showing movement-related as well as clipped activity.

[Supported by the Federal Ministry of Education and Research grant (BMBF 01GW0653).]

BRAIN IMAGING

◆ **Visuo-motor priming in the absence of visual awareness: An MEG study**

F A Boy, S Muthukumaraswamy, K Singh, P Sumner (School of Psychology, Cardiff University, Cardiff, Wales, UK; e-mail: boyf@cf.ac.uk)

When the identity of a visual stimulus requires subjects to make a rapid behavioural decision, neurophysiological studies in monkeys and investigations of humans with brain damage suggest that some regions of the frontal supplementary motor complex (SMC) are involved. Here, we investigated the dynamics of frontal brain activity during a visual masked-prime paradigm in normal subjects using magnetoencephalography (MEG). The task employed here elicits a negative priming effect (shorter RTs for the condition in which prime and target are incongruent), allowing us to probe both activation and inhibition phases in the selection of the behavioural response. We found contrasting patterns of brain activity around the SMC (in terms of activation timing and extent) between congruent and incongruent prime-target couples, suggesting that these regions are involved in steering the selection of an adequate behavioural response to visual stimuli.

[FB is funded by Cardiff University, School of Psychology.]

◆ **Categorical selectivity and positional invariance in fusiform face area (FFA)**

T A Carlson, H Hogendoorn ¶, H Fonteijn ¶, F Verstraten ¶ (Department of Psychology, Harvard University, Cambridge, USA; ¶ Helmholtz Institute, Utrecht, The Netherlands; e-mail: tom@wjh.harvard.edu)

Some argue that FFA is a module specialized for processing faces, while others posit FFA is part of a larger network of areas jointly coding categorical information about objects. To gain additional insight into this debate, we examined the spatial specificity of the representation of information about objects in FFA. In an fMRI experiment, subjects were shown images of faces, houses, animals, and cars presented to the four quadrants of the visual field. Four classifiers, one for each location, were trained to predict the category of the object shown to the observer.

When the classifiers were tested with data from the trained location, performance was above chance for all categories, but significantly higher for faces. Interestingly, this face advantage was not present when tested with data from stimuli presented to a different location in the visual field. The results of our study suggest that FFA maintains weak position-invariant information about several categories of objects, but is specialized in the sense that it also codes the location of faces.

◆ **The role of visual area hMT/V5 in dissociating perceptual decision from veridical stimulus properties**

M Castelo-Branco, L R Kozák ¶, J Teixeira§, J Xavier§ (IBILI – Faculty of Medicine, Coimbra, Portugal; ¶ Hungarian Academy of Sciences, Budapest, Hungary; § Hospital Geral de Santo Antonio, Porto, Portugal; e-mail: mcbranco@ibili.uc.pt)

The mechanisms triggering perceptual decision were studied with bi-stable stimuli: during neuroimaging experiments subjects were asked to report, by means of button presses, their interpretation of two superimposed gratings moving in different directions (plaid stimuli). Plaids may be perceived either as two surfaces, one being transparent and sliding on top of the other (component motion) or as a single coherent pattern whose direction of motion is intermediate of the component vectors (pattern motion). We have constructed textured plaid stimuli that can be physically disambiguated into pattern and component motion by parametrically defined local dot movement. We found that hMT+ complex directly encodes and triggers decision processes related to surface segmentation, even when perception is dissociated from veridical stimulus properties.

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◆ **Neural correlates of viewing emotional stimuli**

A Deák, G Revesz, T Auer, T Doczi ¶, J Janszky, A Schwarcz§ (Institute of Psychology, University of Pecs, Pecs, Hungary; ¶ also Hungarian Academy of Science; § also Diagnostic Center of Pecs; e-mail: deakanita@freemail.hu)

Neuroimaging studies of emotion have used two different visual stimuli—either facial expressions of different emotional states or emotionally evocative pictures. Common and different areas of activation have been reported across different studies, but it remains an unanswered question whether different affective states induced by pleasant or unpleasant stimuli entail the same process. In our fMRI study we compared BOLD activation patterns to fixation cross and to complex emotional pictures from the International Affective Picture System (IAPS) to determine if pleasant and unpleasant stimuli would activate similar or distinct brain regions. Healthy subjects passively viewed blocks of pleasant and unpleasant IAPS pictures interleaved with blocks of fixation. In addition, subjects gave scores of SAM and their judgments were correlated with brain activation.

◆ **Attention disengagement operation, activity of parietal lobes, and diurnal variability: fMRI study**

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Neuroimaging techniques enabled us to identify attention orienting network: parietal lobes disengage attention from its primary focus, superior colliculus moves the attention index to the target location, and the pulvinar engages attention in the target. Diurnal effect on the attention disengagement operation was investigated. Six male volunteers (aged 25–35 years) were subjected to a semi-constant routine condition. Using fMRI (block design) we measured the activity of parietal lobes five times a day, every four hours starting from 6 am. Images were acquired with a 1.5 T scanner (GE Signa). Subjects kept their gazes fixed on the central point, while covertly following the shifted target point. In the control condition, subjects maintained their full attention on the central point. Eye movements were controlled with EOG. An analysis (SPM software) of diurnal variability of parietal lobe activity, based on a hypothesis according to which in the course of the day the left hemisphere undergoes inhibition while the activity of the right hemisphere shows disinhibition, is presented.

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◆ **Localization of the decision center for pattern discrimination in the human brain**

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(Department of Radiology, Medical Military Academy, St Petersburg, Russia;
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Our aim was to identify cortical areas involved in processing of figures with different level of order. Anatomical and functional MRI was performed on twelve healthy volunteers, aged 18–30 years, with a 1.5 T MR-scanner. For visual stimulation we used a matrix of a 10×10 Gabor grating. In the 'simple' stimulus most elements had horizontal or vertical orientation. In the 'complex' stimulus only some elements had ordered orientation. 'Complex' stimuli, in comparison with simple stimuli, caused activation in parietal lobes, BA7 and BA37, BA39. 'Complex' stimuli also activate inferior frontal gyrus (BA9). In cases of active observation, when a volunteer had to choose preferred orientation of elements by pressing a button, 'simple' stimuli caused activation of BA6, BA9/10. Thus, a complex stimulus causes additional activation in the parietal lobes. Cases of active observation demonstrate an additional activation locus, in the prefrontal cortex, which presumably reflects the work of the 'central executive mechanism'.

◆ **Using noise to uncover the effect of transcranial magnetic stimulation (TMS) on perceptual processing**

J A Harris, C W G Clifford, C Miniussi ¶ (Department of Psychology, University of Sydney, Sydney, Australia; ¶ University of Brescia, Brescia, Italy; e-mail: justinh@psych.usyd.edu.au)

Transcranial magnetic stimulation (TMS) is a popular tool for mapping perceptual and cognitive processes in the human brain. It uses a magnetic field to stimulate the brain, modifying ongoing activity in neural tissue under the stimulating coil. However, research into its functional basis lags behind its application. Acutely, TMS has been likened to a virtual lesion, implying the interruption of neural processes, but has also been attributed to an injection of neural noise, consistent with its immediate and effectively random depolarization of neurons. To test these alternatives, we delivered TMS to the visual cortex and measured its effect on a simple visual discrimination task, while concurrently manipulating the level of image noise in the visual stimulus itself. Both TMS and image noise increased thresholds overall, and these two effects interacted multiplicatively, consistent with a reduction in the strength of the visual signal. Indeed, there was no evidence that TMS independently added noise to the visual process. Our findings indicate that the TMS-induced virtual lesion is a momentary interruption to ongoing neural processing.

[Supported by the University of Brescia (Fondo di Ateneo per attività internazionali) and the Australian Research Council.]

◆ **Occipital brain activation in visual change perception with attention**

H Kojima, T Suzuki (Department of Psychology, Kanazawa University, Kanazawa, Japan; e-mail: hkojima@kenroku.kanazawa-u.ac.jp)

We investigated the relation between attention to visual stimuli and cerebral blood flow around visual cortex in the occipital lobe. We basically used the change blindness paradigm for the experimental procedure. Stimuli were common scenery pictures in campus. We presented the set of original and modified pictures on a PC monitor with time intervals for 30 s. Some picture frames included a 0.7 deg-high digit around the center. Subjects' task was to read aloud the digit and find a changing part in the picture, then press a key immediately when they found such a part. The task was examined with ten different pictures. The oxy-hemoglobin concentration at around occipital lobe during the task was monitored with a near-infrared spectroscopy, Hitachi ETG-4000. The oxy-hemoglobin concentration as an index of the brain activation was significantly higher when the subjects could not find the change regardless of attentive looking, than when they found the change, or when they just read aloud the digits and responded immediately when the digit was zero.

[Supported by the COE programme of the Japanese Ministry of Education and Science.]

◆ **Instantaneous stimulus paradigm: Perceptual organization networks and dynamics**

L T Likova, C W Tyler (Smith-Kettlewell Eye Research Institute, San Francisco, USA; e-mail: lora@ski.org)

To reveal the neural dynamics of the cortical networks underlying different types of perceptual organization, we developed a novel paradigm that creates distinct and prolonged percepts of spatial structures by instantaneous refreshes in random-dot fields. Three different configurations were generated by refreshing: (i) the whole stimulus field (uniform field), (ii) the ground region only (negative-figure or hole), and (iii) the figure and ground regions in brief temporal asynchrony (figure–ground). fMRI responses were measured throughout the brain. The uniform-field refresh activated the posterior part of the brain only, but the figure–ground and the negative-figure conditions activated two distinct networks extending beyond the occipital lobe toward the frontal

cortex. For each of the three brief stimulus types, a wide variety of BOLD waveforms was found even within the same regions of cortex. Such expressly different responses within identical cortical regions ensure that the differences could be securely attributed to the neural dynamics, not to spatial variations in the hemodynamic response function. Even where activations are partially overlapping, an integrated analysis of the temporal properties of the BOLD response enables the functional specificity of the cortical areas to be distinguished.

[Supported by NIH EY 13025 and The Pacific Vision Foundation.]

◆ **Orientation-specific contextual modulation in human visual cortex**

J S McDonald, K J Seymour, C W G Clifford (Department of Psychology, University of Sydney, Sydney, Australia; e-mail: scottM@psych.usyd.edu.au)

Contextual modulation is a fundamental characteristic of human vision. Here, we used fMRI to investigate the basis of orientation-specific centre-surround effects in visual cortex. Subjects' brains were scanned at 3 T while performing a dimming task at fixation. The circular stimulus aperture was divided into a test annulus and the remaining inducing region. Five types of stimulus blocks were presented in a balanced design: test only; inducer only; parallel test and inducer; orthogonal test and inducer; blank (fixation only). Each 16 s block contained 16 different orientations of stimuli, presented in a pseudo random order, thus controlling for oblique effects. GLM and percentage-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. We interpret these results as indicative of greater suppression from parallel surrounds, consistent with the observed psychophysical data on contrast-contrast and the tilt illusion.

◆ **Cortical networks associated with perceptual alternation in magnetoencephalography**

T Minami, T Murata, S Yano, S Munetsuna, R Suzuki (Kobe Advanced ICT Research Center, NICT, Kobe, Japan; e-mail: minami@po.nict.go.jp)

Neuronal interactions among brain regions are the key to consciousness. The neural processes underlying perceptual alternation are concerned with such neuronal interactions among multiple cortical areas according to recent imaging studies. However, temporal relationships among these areas in perceptual alternation have not been elucidated. In this study, we analyzed the magnetoencephalographic signals during the percept of apparent motion to study the dynamics of brain activity during perceptual alternation. We estimated spatiotemporal cortical maps of power and phase locking value, employing Hilbert transform and cortically constrained minimum-norm imaging to a single-trial magnetoencephalographic signal, and analyzed phase relations between the estimated cortical sources. As a result, we detected significant phase-locked frontoparietal-posterior networks in the range 30 Hz–40 Hz during perceptual alternation. These results suggest that synchronous activities among multiple cortical areas of frontoparietal-posterior networks play an important role in perceptual alternation.

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◆ **Functional neuroimaging of visual hallucinations during prolonged blindfolding**

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Prolonged visual deprivation can induce visual hallucinations. An fMRI study was conducted on a 30-year-old healthy female subject with visual hallucinations after three weeks of visual deprivation. fMRI data were acquired with a Siemens 3 T Magnetom Allegra MRT. Hallucinations were indicated by button press. The subject reported the occurrence of moving amorphous patterns, flashes, and changing colours during the scan. Neural activity correlated to hallucinations was found in occipital visual, bilateral posterior, parietal, and prefrontal regions. This result suggests that alterations in perceptual and attentional regions are related to the experience of visual hallucinations.

[The authors (HMM and VO) contributed equally to this work. Both authors are first authors.]

◆ **5-HT_{2A} receptor gene polymorphism can explain ventral prefrontal cortex activation to monetary reward during go/no-go task**

M Nomura, H M Kondo¶, M Kashino¶ (Department of Psychology, Tokaigakuin University, Kakamigahara, Japan; ¶NTT Communication Science Labs, Atsugi, Japan; e-mail: michan900@yahoo.co.jp)

Impulsive behaviour has been suggested to be due to a dysfunction of serotonergic 5-HT neurotransmission. Recently, neuroimaging studies have established physiological links between functional genetic polymorphisms and differences in information processing within distinct brain regions. We examined whether this 5-HT_{2A} receptor gene polymorphism is involved in impulsive

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behaviour by evaluating a 'go/no-go' task using fMRI. Twenty-seven participants were instructed to learn to respond to 'go' stimuli and inhibit their response to 'no-go' stimuli under both the reward-only (R) condition and the punishment-only (P) condition. During no-go trials, signal intensity of the right ventral prefrontal cortex (VLPFC) under the R condition was higher for the AA allele carriers than for the GG allele carriers. In contrast, under the P condition, the right amygdala activation was higher in participants for the AA allele carriers compared with those for the GG allele carriers. Our finding that genetic variations in the 5-HT2A affect motor-control-related patterns in the VLPFC and amygdala provides support for a role of serotonergic neuro-modulation in human impulsive behaviour.

◆ **Event-related potentials elicited by processing the appropriateness of visually presented cooperative actions**

H Shibata, J Gyoba (Department of Psychology, Tohoku University, Sendai, Japan;
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Event-related potentials (ERPs) were recorded while evaluating the appropriateness of visually presented cooperative actions. A pair of photos in which one person passed an object and another made a hand posture to receive it were presented successively. Eleven participants made judgments on whether the receiving hand postures were appropriate or inappropriate to the passing actions. The inappropriate hand postures elicited larger ERP negativities than the appropriate ones. The negativities had two peaks (around 330 ms and 850 ms) after the stimulus onset. The first negativity was largest in the parietal area, while the second negativity was largest in the frontal area. It is known that semantically incongruous stimulus elicits a negative component approximately between 250 and 500 ms after stimulus onset (N400). Thus, the first negativity might reflect semantic processing to the visually presented cooperative actions. The later frontal negativity can be assumed to reflect the activation of image-mediated representations. The inappropriate hand postures might evoke the involvement of the mental image process.

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◆ **Human imagery of naturalistic stimuli studied with fMRI**

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Human visual processes are typically studied under highly controlled experimental settings. However, recently we have demonstrated that using naturalistic stimuli produces a surprisingly robust and wide-spread cortical activation. Here we extend this paradigm to the realm of internally generated imagery. In the experiments, subjects underwent fMRI scanning while they were exposed to personalized video clips derived from highly familiar material. Immediately following the visual stimulation, they were asked to close their eyes and to recollect as vividly as they could the video clips they just observed. Comparing the brain activations during the stimulation vs the imagery conditions revealed, in some subjects, strikingly robust activation patterns, which were remarkably similar to those obtained during actual visual stimulation. A major difference that was consistently observed between the visual and imagery conditions was the absence of activation and occasionally even inhibition of early visual areas during the imagery conditions. The results argue against a robust involvement of early visual cortex in visual imagery.

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◆ **Neural correlates of still-image qualities**

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Vision is arguably the most vital sensory modality through which we obtain information regarding the world. In the modern age, we are increasingly dependent on artificial sources such as photos or videos for visual information. The quality of these media affects our experience and poses important practical problems. For example, we take pleasure in an image which is displayed in very good quality, but feel uncomfortable in the presence of a bad image quality. Here we study the human brain activities when subjects observed original clear photos and a series of degraded images with different qualities. We conducted fMRI experiments to measure the brain activities and found that the activated brain areas for different image qualities were variable. The degraded images recruited more brain areas and resulted in stronger brain activities. There were more frontal/prefrontal cortex activated in the case of degraded image qualities. We discuss the correlation between brain activities and image qualities, and explore their possible applications.

CLINICAL VISION

- ◆ **The perception of social and physical causality in high-functioning children with autism**
S Congiu, A Schlottmann¶ (Dipartimento de Filosofia e Scienze Sociali, University of Siena, Siena, Italy; ¶ University College London, London, UK; e-mail: congiu@media.unisi.it)
We investigated perceptual causality for launch, reaction, and related events in twenty high-functioning children with autism (mean CA = 13, VMA = 9.7) and twenty-two typically developing controls. We employed a picture-choice methodology with low verbal demands following Ray and Schlottmann (2007 *Research in ASD* in press). Children watched 14 different animations and chose one of three pictures depicting physical or social causality, or non-causality. The performance of children with autism was comparable to that of typically developing children, with no deficit in launching or reaction, in contrast to previous work. This suggests that deficits in launching found in a younger sample (Ray and Schlottmann, 2007 loco cit.) may be overcome with age/higher verbal IQ. Generally weak performance as found by Bowler and Thommen for both groups (2000 *Autism* 4 147–171) may mainly reflect the high verbal demands of their test, while specific deficits on social animations (Bowler and Thommen, 2000 *Journal of Child Psychology and Psychiatry* 41 831–846) may only appear for more complex stimuli.
- ◆ **Filling-in and the induced twinkle aftereffects occur at different stages of visual processing**
M D Crossland, P Bex¶ (Institute of Ophthalmology, University College London, London, UK; ¶ Schepens Eye Research Institute, Boston, USA; e-mail: m.crossland@ucl.ac.uk)
A real or artificial scotoma within a dynamic noise field fills in within a few seconds. When the dynamic noise is replaced with a homogenous field, a twinkling aftereffect is induced (Ramachandran and Gregory, 1991 *Nature* 350 699–702). We have used this phenomenon to perform rapid perimetry in patients with retinal scotomas. To analyze the loci and mechanisms of filling-in and its aftereffects, we examined orientation-tuning and interocular transfer by measuring contrast-detection thresholds for stimuli presented in areas that were filled in or contained a twinkling aftereffect. Detection thresholds were elevated by filling-in and were narrowly tuned for orientation. Thresholds were also elevated by the twinkling aftereffect but were not tuned for orientation and did not display interocular transfer. Our data indicate that filling-in occurs at a higher level of visual processing, whereas the induced-twinkle aftereffect is precortical in origin.
[Supported by The Wellcome Trust.]
- ◆ **Visual scanning in children with autistic spectrum disorder: The role of symmetry**
T C J de Wit, R van Lier, S Swinkels, J Buitelaar (Nijmegen Medical Centre, Radboud University Nijmegen, Nijmegen, The Netherlands; e-mail: t.dewit@psy.umcn.nl)
What is the effect of global and local symmetries on information intake in children with autistic spectrum disorder? Eye movements for different displays were measured during a passive looking task. On the local level, our stimuli consisted of different elements that could be symmetrical or not. On the global level, both the position of the elements and the identity of the elements were manipulated. We analysed spatial and temporal aspects of scanning, and found that main effects showed a clear influence of symmetry. For the controls, we found the median distance between fixations to be higher for displays containing either symmetry in the position of the elements, or symmetry in the identity of the elements. In addition, symmetries in both position and identity resulted in a strong pattern of symmetry-orthogonal scanning. That is, the location of consecutive fixations alternates across the symmetry axis. However, all these effects were much weaker in the clinical group. Further effects are discussed.
- ◆ **Competition between perceptual grouping principles reveals latent selective grouping abnormalities in autism**
C M Falter, K Plaisted, G Davis (Department of Experimental Psychology, University of Cambridge, Cambridge, UK; e-mail: cmf42@cam.ac.uk)
We investigated the influence of perceptual grouping principles on visual organisation in autism. A conflicting situation was created in which proximity grouping was competing with similarity grouping in order to test the individual strength of the two most prevalent grouping principles in children with an autism spectrum disorder (ASD), compared with those in chronological and mental-age-matched typically developing (TD) children. As expected, we found that the TD group used similarity grouping and proximity grouping to a similar extent, while the ASD group showed a generally less grouping advantage compared to the TD group. Importantly, the ASD group showed a preference for proximity grouping over similarity grouping. This research provides important evidence in support of the approach that individuals with autism show enhanced discrimination and reduced categorisation. Individuals with autism are shown to be able to group parts into wholes, and they show an enhanced dominance of proximity grouping over similarity grouping.

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- ◆ **Seeing the bigger picture: Evidence for altered global motion processing in migraine**
G E Gordon, V Manahilov, G Dutton, U Shahani, W Simpson¶ (Department of Vision Sciences, Glasgow Caledonian University, Glasgow, Scotland, UK; ¶ University of Plymouth, Plymouth, UK; e-mail: g.gordon@gcal.ac.uk)

Visual deficits are common in migraine but are subtle and hard to measure. We studied patients with persistent migraine aura, a rare complication which might allow impaired processes to be examined more readily. We applied classification-image techniques to probe strategies used by observers in a task requiring the discrimination of the global motion direction of an array of 9×9 high-contrast elements. Direction of motion of each element was varied randomly ($SD = 15^\circ$); observers judged whether the near-threshold global-motion was to the left or right of vertical. Classification images were calculated by summing (element-by-element) noise samples eliciting right responses and subtracting samples producing left responses. Migraine-free controls used motion information from only the central $1^\circ - 2^\circ$ to determine direction of motion. pMA subjects, however, integrated motion information across a wider sparsely sampled area. This larger field of integration is suggestive of imbalanced centre-surround suppression in motion-processing mechanisms in pMA. The global nature of this task implies a locus for this effect beyond V1.

- ◆ **Alteration of visual evoked potentials (VEPs) in successfully treated amblyopic children**
J Hotte-Bernard, M-S Roy, M-L Bélair, J-L Jacob, F Lepore¶, D Saint-Amour (Centre de Recherche CHU Sainte-Justine, Montréal, Canada; ¶ Université de Montréal, Montréal, Canada; e-mail: judith.hotte-bernard@umontreal.ca)

We aimed to assess the functional integrity of the visual cortex after a successful clinical treatment of amblyopia by patching. Eighteen successfully treated amblyopics and nineteen normal children were tested. Pattern-reversal VEPs were recorded at Oz in response to stimuli defined by two spatial frequencies (0.5 and 2.5 cycles deg^{-1}) and four contrast levels (4%, 12%, 28%, and 95%). Results show that N75 latency was significantly delayed in the treated amblyopic eye as compared to the non-amblyopic eye, but this difference appeared at 4% contrast only. The P100 was significantly delayed in the treated amblyopic eye as compared to the non-amblyopic eye. Finally, the P1 amplitude was significantly lower in the treated amblyopic eye when compared to both the non-amblyopic and the normal eye. This study suggests that a successful clinical treatment does not necessary imply a complete recovery of visual function. Our results suggest a preferential alteration of the magnocellular system. Furthermore, the residual deficit is likely to involve extrastriate areas because of the origin of P1 generators.

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- ◆ **Electrophysiological changes of visual information processing in recently abstaining methamphetamine-dependent individuals**

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Methamphetamine as a dopamine indirect agonist can temporarily increase cognitive performance. However, long-term abuse may cause cognitive and attentional impairment (Nordahl et al, 2003 *Journal of Neuropsychiatry and Clinical Neurosciences* **15** 317–325). We explored electrophysiological markers of visual processing from the primary up to associative and cognitive visual areas in a group of recently abstaining methamphetamine abusers (three females, fourteen males, duration of methamphetamine abuse 5.3 ± 2.7 years) and among the age- and sex-matched group of healthy individuals. In the group of former abusers we found prolonged VEPs latencies ($p < 0.005$) to pattern reversal (10 min of arc checks) and radial motion-onset (full or central 8 deg of the visual field) stimuli together with systematic deficiency of ERPs in visual mismatch-negativity paradigm (Kremláček et al, 2006 *Vision Research* **46** 485–490) related to the length of methamphetamine abuse ($r > 0.58$, $p < 0.05$). We did not observe significant differences in responses to pattern-reversal of 40 min of arc checks, linear, or peripheral radial motion-onset, cognitive ERPs, or in the reaction time task. The results suggest that methamphetamine abuse can partially impair visual processing. The impairment can progress with the abuse duration.

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- ◆ **Discomfort glare in myopic and emmetropic subjects**

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While visual health and age are acknowledged parameters affecting the sensitivity to glare, very little is known about possible differences in the response to glare between myopic and emmetropic subjects. We compared glare discomfort in these two groups under mesopic conditions.

We used as a glare stimulus a series of flashes produced while the subjects were looking at a dark field. The glare discomfort was subjectively rated on the DeBoer scale. The control of the presentation sequence and the recording of the responses were done by a Biopac MP100 system with SuperLab module (Biopac Systems, Inc.). The results showed that myopes and emmetropes experience different glare discomfort with the same glare stimulus. On the average, the myopes assessed their level of discomfort higher than the emmetropes with the corresponding position on the DeBoer scale differing by more than one unit. These findings show that myopic subjects exhibit higher glare vulnerability which may be deleterious in glare-enriched environment such as night driving.

◆ **Changes in magnocellular and parvocellular pathways in patients with an early stage of multiple sclerosis**

S Muravyova, Y Shelepin, A Deshkovich ¶ (Pavlov Institute of Physiology, Russian Academy of Sciences, St Petersburg, Russia; ¶ Military Medical Academy, St Petersburg, Russia; e-mail: mlanka@freemail.ru)

In electrophysiological and psychophysical investigations we tested the hypothesis that in patients with multiple sclerosis in its early stage (3–5 years from first manifestation) either phasic cells of the magnocellular pathway or tonic cells of the parvocellular pathway are disordered. Stimuli were checkerboard patterns of different spatial frequency presented on a uniform background. Visual evoked potential (VEP) recordings revealed that latency of different VEP components increases and their amplitude decreases with increase of spatial frequency. Cluster analysis by the K-means method was carried out to separate patients by their VEP latencies and amplitudes into two clusters. First group of patients showed changes of positive-wave P100, whereas in the second group of patients changes of the negative-wave N80 dominated as compared to healthy subjects. According to some literature data these changes were specific for M-pathway and for P-pathway. Electrophysiological data are in good accordance with psychophysical measurements of contrast sensitivity in static and dynamic gratings and measurements of internal noise in the visual pathways.

[Supported by RFH 05-06-06085.]

◆ **Induced gamma-band EEG activity reveals impairments of Gestalt perception in the intact hemifield of hemianopic patients**

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In the visual modality, gamma-band responses have been associated with Gestalt-perception processes. In the present EEG study, we investigated the effects of Gestalt perception on the visual gamma-band response in the perimetrically intact visual field of patients with homonymous hemianopia and compared them with those of healthy subjects. All observers were presented either random arrays of Gabor patches or arrays with an embedded circular arrangement. For the hemianopic patients, the circle was presented in their intact hemifield only. The participants were instructed to detect the circle by pressing a corresponding button. Analysis of the early evoked gamma-band responses yielded no significant differences between Gestalt-like patterns and non-Gestalt patterns in the two groups. However, the late induced gamma-band response in a time interval between 200 ms and 400 ms after stimulus onset was significantly increased for Gestalt-like patterns in healthy participants. This effect was not found in patients. The present findings indicate differences in the neural processing of Gestalt patterns in the intact hemifield of hemianopic patients compared to healthy participants.

◆ **When the molehill becomes a mountain: Impaired size constancy after unilateral brain damage**
C Grimsen, M Fahle (Institute of Human Neurobiology, University of Bremen, Bremen, Germany; e-mail: cgrimsen@uni-bremen.de)

Although objects produce retinal images of different size depending on viewing distance, humans can accurately judge veridical size, achieving so-called size constancy. Patient HE (female, aged 54 years), had a haemangioma excised from her right parieto-occipital cortex. Thereafter, HE suffered from incomplete hemianopia to the left side and complained about perceiving objects as enlarged. To test her size perception, two circles were displayed on two monitors. She had to adjust the diameter of the target circle on one monitor, located at variable distances, to the size of the reference circle on the other monitor at 2 m distance. When the monitor with the adjustable circle was closer than the reference, HE always scaled down its physical size, when it was farther away, she consistently enlarged its size. The results show that HE tends to judge object size by the retinal image size. Hence she exhibits strong reduction of size constancy.

Thursday

◆ **Evaluation of visual acuity in children with periventricular white matter damage: Comparing acuity cards and sweep VEPs**

F Tinelli, F Pei, S Baldassi¶, A Guzzetta, A Bancale, G Cioni§ (Department of Developmental Neuroscience, Stella Maris Scientific Institute, Pisa, Italy; ¶ University of Florence, Florence, Italy; § University of Pisa, Pisa, Italy; e-mail: f.tinelli@inpe.unipi.it)

Periventricular leukomalacia (PVL) is the major cause of visual impairment in prematurely born children, including reduction of visual acuity. To compare the results of behavioural and electrophysiological measures of acuity we used Teller acuity cards (TAC) and sweep visual evoked potentials (sVEP) in 29 children with PVL confirmed by brain MRI. A high correlation between the results of TAC and sVEP was shown, even if there was a tendency towards a higher estimation of visual acuity by the TAC, as opposed to the sVEP. This may be related to the different neurophysiological bases underlying the responses to the two methods.

DECISION

◆ **Is visual perception the key to success in young soccer players?**

D L Eaves, D Anderton, M Taylor (Sport and Exercise Science Section, University of Teesside, Thornaby-on-Tees, UK; e-mail: d.eaves@tees.ac.uk)

The relative contributions of the perceptual, cognitive, physiological, and soccer-specific skills attributed to elite performance in open-play soccer situations were examined. Participants played regularly in the English League Divisions 1 or 2 before either receiving an employment contract with a professional club at the age of 16 years (elite; $N = 8$) or not (sub-elite; $N = 8$). Perceptual and cognitive skills were assessed via a temporal-occlusion methodology requiring subjects to respond by kicking footballs towards images of team-mates in dynamic game situations projected onto a large screen. Aerobic capacity was measured indirectly in a multi-stage fitness test. Soccer-specific skills (dribbling, passing, shooting) were measured with a standardised point-based system. Reaction times (RT) were significantly faster in the elite group, yet RTs in both groups increased whilst movement times decreased across blocked trials. Kicking accuracy was also higher in the elite group. The groups did not differ significantly in aerobic or skill-based variables. These data suggest visual perception is a discriminative variable for talent identification and selection in football.

◆ **ERP correlates of decision making in a motion direction discrimination task**

I Kóbor, V Gál, É Bankó, J J Kórtvélyes, L R Kozák¶, Z Vidnyánszky (Faculty of Information Technology, Peter Pazmany Catholic University, Budapest, Hungary; ¶ Semmelweis University, Budapest, Hungary; e-mail: kobor@digitus.itk.ppke.hu)

We used electroencephalography (EEG) to investigate how task difficulty affects neural decision-making processes. Observers performed a motion-direction discrimination task. Discrimination difficulty was regulated by changing the percentage of coherently moving dots in the random-dot motion display used as stimulus. Average ERP amplitudes on the occipito-temporal electrodes were modulated by the motion coherence level within two intervals: 200–400 ms after stimulus onset amplitudes were more negative whereas between 400–600 ms they were more positive with increasing motion coherence. On the parietal and frontal electrodes, however, motion-coherence-dependent modulation started later: amplitudes became more positive starting from ~300 ms as coherence was increased. The onset delay of the later component on the occipito-temporal electrodes and the onset of the modulation on the parietal and frontal electrodes was inversely correlated with motion coherence. These results suggest that decision difficulty is reflected in ERP responses and that in the direction-discrimination task used in our study decision difficulty component arises ~300 ms after stimulus presentation.

[Supported by the Hungarian Scientific Research Fund (OTKA T048949) to ZV.]

◆ **Direct behavioural evidence of the effect of internal noise on the time course of perceptual decisions**

N Megna, S Baldassi (Department of Psychology, University of Florence, Florence, Italy; e-mail: nicolamegna@gmail.com)

Reaction times were recorded from young adults during the execution of a feature search task in which they were required to report the exact orientation of a Gabor patch surrounded by a variable number of vertical Gabor patches. We measured both subjects' response distribution for each target orientation and the response times associated with each perceived tilt. Even if the stimulus was kept constant, we found that reaction times diminished with the strength of the internal representation of the target orientation. According to classic integrator models, such as the drift diffusion model, which have been used successfully to explain response time and physiological data, this result can be interpreted as a behavioural evidence of fluctuations in

the decisional criterion and/or the variability in the quality of information about the stimulus. Further analysis and pilot data from a control experiment indicate that decisional noise, rather than perceptual noise, is mainly responsible for the observed effect.

[Supported by an Italian MIUR PRIN grant to SB.]

◆ **Bistable percept – choice dynamics explained by early interactions between stimulus timing, voluntary bias, and perceptual history**

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When a rivalrous or ambiguous stimulus reappears after an interruption, one of the competing percepts rapidly dominates, and each choice depends on stimulus ON/OFF-timing and perceptual history. Our neural model, which does not rely on high-level decision-making or memory, explains choice-repetition for long OFF-times, and choice-alternation for short OFF-times. Counterintuitively, even repetition emerges from neural adaptation, through its interaction with a fixed neural baseline. We report psychophysical experiments designed to test the model, including the predicted modulation of its stimulus dependence by the independently variable neural gains of preceding stages. We found an ON/OFF-time dependence of percept-choice for kinetic-depth spheres and binocularly rivalrous gratings which fits the model well when we take into account the preceding adaptation dynamics. We also instructed subjects to favour either (i) percept 1 or 2 throughout, or (ii) repetition of any percept, or (iii) alternating percept choices. In all cases, the model fits the data well when we incorporate a small instruction-dependent bias in pre-stage gains. Notably, such bias alone cannot explain the choice-sequence dynamics.

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◆ **Localization of the decision-making mechanism for spatial vision**

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In our model of pattern discrimination, there are four stages: primary filtering, matched filtering, decision making, and motor response. Our present aim was to use fMRI to localize the decision center for discriminating patterns with different spatial properties. We used two experimental paradigms: either (i) passive viewing or (ii) active discrimination of the predominant orientation of Gabor patches that were organized in a matrix. The matrices varied in complexity, according to the number of patches with the same orientation. The dominant orientation of the matrix changed randomly, so that the observer’s motor response was independent of the decision response. We compared the BOLD response to matrices where the patches were ordered in orientation with the response to a randomly organized matrix. We obtained differences in the occipital, parietal, and frontal lobes. In both passive and active paradigms, the more-random matrix produced additional activation in the occipital and parietal lobes, and partly in the temporal lobes. In the active paradigm, the differences extended to the frontal lobe. We localize the decision centers for ordered and random patterns in distinct but neighboring parts of the frontal cortex.

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◆ **Comparison of four scales with different units in a similarity-estimation task**

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The purpose of this study was to examine whether types of scales could influence participants’ judgment in perception. Four scales (7 point Likert scale, 10 point scale, 10 point with the first decimal place scale, and 100 point scale) were compared in a similarity-estimation task, using correlation coefficient, the degree of difficulty, and the response time. Participants were eighty-four undergraduate students who were asked to rate the similarity of stimuli consisting of 288 pairs of photo-images. Correlation coefficients between the scores of the 7 point Likert scale, 10 point with the first decimal place scale, and 100 point scale were significantly high (over 0.93) but there was a relatively low correlation (under 0.50) between the 10 point scale and others. No statistical difference was found in degree of difficulty across the four scales. Response time was significantly longer for the 10 point with the first decimal place scale than for the other scales. These results suggest that units of scales could affect participants’ judgment of perception in a similarity-estimation task.

Thursday

FACE PERCEPTION◆ **The multiple-faces phenomenon: An fMRI pilot study**

A C Albuquerque, M L Simas, W P dos Santos, R E de Souza (Department of Neuropsychiatry, Universidade Federal de Pernambuco, Recife, Brazil; e-mail: actaunay@gmail.com)

The multiple-faces-phenomenon (Simas, 2000 *Perception* 29 1393–1394) was studied with fMRI, using BOLD contrast. A non-naive healthy male subject (26-years-old) was tested. A printed face (18-years-old female) was presented binocularly, either at the center, or at the right or left sides. The 6 conditions were: 3 with face presentations, 2 with index finger motion, and 1 with neither. These were consecutively repeated, yielding 12 conditions. Presentation was continuous for 35.25 s and focus sustained at a black dot. Whole-brain fMRI data were acquired on a Magnetom Sonata (Siemens) of 1.5 T equipped with a head volume coil. Six blocks of 36 axial slices (3 mm) per condition were obtained (ie three with and three without any of the stimuli). Time of repetition was 3520 ms and the trials lasted 3 min 35 s. A paired *t*-test showed activity at the left fusiform gyrus and both occipital areas. Repetition effect was higher for the centered face than for faces at periphery. We conclude that the multiple-faces phenomenon may be related to the observed sustained activation of visual areas.

[Supported by CNPq and FACEPE.]

◆ **A threat superiority effect with extremely schematic stimuli**

A A Alvarez, N Fernández (Department of Social and Basic Psychology, and Methodology, University of Santiago de Compostela, Santiago de Compostela, Spain; e-mail: antal@usc.es)

With schematic faces, it has been found that a threatening face is better detected among neutral faces than are other emotional expressions (Öhman et al, 2001 *Personality and Social Psychology* 80 381–396). The present work was designed to investigate this threat superiority effect in very simplified conditions. Thus, thirty-seven university students had to detect an odd stimulus in sets of 3, 4, or 5 triplets of segments that formed schematic faces. The distractors (neutral faces) were triplets of horizontal segments. The targets were combinations of 135°, 45°, and horizontal segments depicting a threatening face (135°-segment = left eyebrow; 45°-segment = right eyebrow), or a non-threatening emotional face (the other way around). In the first block of trials, all the emotional expressions were presented. In the other two blocks, only the 135°-segment or (in the other block) the 45°-segment defined the targets. The subjects detected more quickly the threatening than the non-threatening emotional schematic face among neutral ones, even in blocks where only the single segment defined the two facial expressions.

◆ **Evaluating temporal dynamics of different facial information in face perception**

Z Bassetta, A Zadbood¶, A Borji§, B Esmacili¶, M Harirchian (Iranian Center for Neurological Research, Imam Khomeini Hospital, Medical Sciences/University of Tehran, Tehran, Iran; ¶ also Students' Scientific Research Center, Medical Sciences/University of Tehran, Tehran, Iran; § Institute for Studies in Theoretical Physics and Mathematics, Tehran, Iran; e-mail: zbassetta@gmail.com)

Human face, as a visual stimulus for human brain, provides different types of information such as featural and configurational. Previous studies have shown that processing of a face takes 110–130 ms. Our objective was to highlight temporal dynamics of different facial information in face processing and compare their importance and priority. Masking paradigm was used and the effect of four mask types (noise, facial features, global head shape without internal features, complete face) at 5 SOAs (30, 50, 80, 110, 140 ms) on face discrimination performance was evaluated. Synthetic faces were used in order to measure the thresholds precisely. Head shape and complete face mask effect were significantly higher than feature and noise mask at SOAs of 30, 50, 80 ms. The effect of head-shape mask was significantly lower than that of complete face. Feature mask did not show this pattern and was not significantly different from the noise mask except at SOA = 80 ms. It seems that global head-shape process begins sooner than that of features and it is an important component of a face stimulus to be recognized.

[We are grateful to Dr Maryam Vaziri Pashkam and Dr S Reza Afraz for their kind help and helpful comments.]

◆ **Emotion classification and face identification, a bio-inspired model**

A Benoit, N Guyader, A Caplier, J Herault (DIS – Image and Signals, Gipsa-Lab, Grenoble, France; e-mail: benoit@lis.inpg.fr)

Gosselin and Schyns (2001 *Vision Research* 41 2261–2271) had demonstrated that two distinct categorizations of the same faces require different visual information: the mouth is the only diagnostic region for the expression whereas the eyes and the center of the mouth are needed to recognize the gender. Using some images from their database, we propose a model of the human visual system (HVS) dedicated to face analysis. Our HVS model is divided into two parts:

a retina model that enhances the structure and texture data, and a cortical model (V1) that extracts the description of the orientations and frequency bands of the visual stimuli. This model confirms the behavioural results of Gosselin and Schyns and, in addition, shows that the upper part of faces contains the identity (and not only the gender) of a person (around 80% of correct identification) whereas only the lower part is needed to classify emotions (angry, happy, or neutral, around 85% of correct classification). Further experiments are carried out to test our model on larger databases.

◆ **fMRI adaptation in fusiform face area and occipital face area**

L R Betts, H R Wilson (Centre for Vision Research, York University, Toronto, Canada; e-mail: lbetts@yorku.ca)

Several regions in the right hemisphere of the human visual cortex, including the fusiform face area (FFA) and the occipital face area (OFA), produce robust BOLD activation to synthetic face stimuli. Here we demonstrate that BOLD responses to internal facial features are equivalent to full-face responses in the FFA and OFA. The presentation of synthetic head outlines also activated these regions of interest, but significantly less than full faces or features alone. We used an event-related fMRI adaptation paradigm to measure the responses to full faces, features, and head outlines after 5 s of adaptation either to full faces, features, or head outlines. Cross-adaptation occurred between full faces and features, full faces and outlines, and outlines and full faces in both FFA and OFA. The lack of cross-adaptation between features and outlines is consistent with the hypothesis that FFA and PPA contain a distributed population of independent or competing populations of face-selective, feature-selective, and outline-selective neurons, rather than a single homogeneous population of face-encoding cells.

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◆ **Endogenous control of face capture**

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Despite suggestions that faces capture visual attention, it remains unresolved whether this reflects exogenous attention mechanisms or an endogenous preference for looking at faces. To resolve this question, we examined whether attention is allocated to faces when this is counter to observers' intentions. In a visual cueing paradigm, observers responded faster to targets appearing in the location of a face cue than of a competing object cue (experiments 1a and 2a). This effect was reversed when faces were negatively predictive of the likely target location, making it beneficial to attend to the object cues (experiments 1b and 2b). It was easier still to shift attention strategically to predictive face cues (experiment 2c), indicating that the endogenous allocation of attention was augmented here by a capture effect. However, although faces delayed the voluntary deployment of attention to object cues, they could not prevent it, even at short cue-target SOAs. The results support propositions that faces draw attention, but suggest that these attention biases can be overpowered rapidly by top-down control.

◆ **Using spline curves for generating synthetic faces**

A Borji, B Esmaeili¶, Z Basseda¶, A Zadbood¶ (School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics, Tehran, Iran;

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Faces are complex and important visual stimuli for humans and are subject to many psychophysical studies (Wilson et al, 2002 *Vision Research* 42 2909–2923). A new parametric method for generating synthetic faces is proposed. Head shape and inner hairline are sampled in a polar coordinate frame, located at the center of the image at 16 and 9 equi-angular positions. Four separate frames are placed at nose tip, each eye center, and lips to sample them with 7, 20, and 24 angular points, respectively. Each eyebrow is sampled with 8 points in eye coordinate system. Augmenting feature vectors, their distance from the origin, and other facial details generates a vector of size 95. For synthesized face, intermediate points are generated with spline curves and then the whole image is filtered by a band-pass filter. Subjects participating in face-discrimination task were very successful at matching synthetic faces with their real counterparts (average performance 97%). Metric of this face space is Euclidean and the Thatcher effect is also present in it.

[Authors should thank Dr Hugh Wilson for part of code he delivered to us on his method.]

Thursday

◆ **The effect of context in face and object recognition**

I Bühlhoff, V C Quoc ¶ (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; ¶ Newcastle University, Newcastle upon Tyne, UK; e-mail: isabelle.buelthoff@tuebingen.mpg.de)

Whether recognition and categorization are parallel or serial processes remains controversial. To address this, we investigated whether face recognition is influenced by task-irrelevant face categories. We examined the recognition of a target face presented in the context of other faces of the same or different racial category using a same–different matching task. Caucasian participants were presented during learning with a set of six faces displaying one target face among different numbers of same-race faces. Participants recognized Caucasian targets better when five same-race faces rather than a single same-race face were present in the set, while this effect was absent for Asian targets. Surprisingly, participants recognized Asian targets better in sets with equal numbers of Asian and Caucasian context faces. Similar experiments, but with novel objects, were conducted in which categories were defined by similarity or expertise. These factors did not fully account for the context effects observed with faces. Overall, the results suggest that face recognition and categorization interact but other factors such as task difficulty may also affect face recognition.

◆ **Gaze adaptation: The visual representation of gaze is coded by a non-opponent multichannel system**

A J Calder, R Jenkins ¶, A Cassel, C Clifford § (Cognition and Brain Sciences Unit, Medical Research Council, Cambridge, UK; ¶ University of Glasgow, Glasgow, Scotland, UK; § University of Sydney, Sydney, Australia; e-mail: andy.calder@mrc-cbu.cam.ac.uk)

Previous adaptation research has shown that the representation of facial identity is best accounted for by an opponent-coding system. It is unclear, however, whether this framework provides a suitable method of coding all facial characteristics. In previous work we have shown that perception of gaze direction can be adapted, such that adapting to a series of faces gazing to the left causes leftward gaze test stimuli to be perceived as gazing straight ahead, and similarly for adaptation to rightward gaze. In two experiments we demonstrate that these effects are best accounted for by a multi-channel system with separate channels coding distinct gaze directions (left, direct, and right), rather than an opponent-coding system comprising two broadly-tuned pools of cells, one coding leftward gaze the other rightward gaze.

[Supported by the Medical Research Council.]

◆ **Aftereffects in the recognition of dynamic facial expressions**

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High-level aftereffects have previously been reported for the recognition of static faces. We present an experiment showing for the first time high-level aftereffects for dynamic facial expressions. Facial expressions were generated as a morph animation based on a weighted sum of 3-D shapes derived from scans of facial action units [Curio et al 2006, in *Proceedings of the 3rd Symposium on Applied Perception in Graphics and Visualization* (New York: ACM Press) pp 77–84]. With this technique we produced dynamic happy and disgust expressions. By changing the sign of the morph weights we were able to obtain ‘anti-expressions’. Participants observed dynamic anti-expressions for 8 s. Immediately after each adaptation phase, recognition performance was tested for the original expressions (2AFC, reduced expression strength). Adaptation stimuli were chosen from two identities and were shown either in forward or reverse time order. We found strong expression-related aftereffects (increased recognition for matching expression stimuli, $p < 0.05$, $N = 13$), which depended also on the match between the identities of adaptation and test face. We are currently investigating the influence of static vs dynamic representations in the observed aftereffect.

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◆ **Conspecific and human face processing in monkeys (*Macaca mulatta*): An eye movement investigation**

C D Dahl, C Wallraven, H H Bühlhoff, N K Logothetis (Department of Physiology of Cognitive Processes, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: christoph.dahl@tuebingen.mpg.de)

The perceived salience of faces and facial features can be modulated by manipulations like inversion (change in global configuration) or blurring (reduction of feature-based information).

By applying these manipulations to images of monkey and human faces, we examined the processes underlying face perception in monkeys. Eye movements were investigated during a non-reinforced passive-viewing task. The faces were either familiar or unfamiliar. We found that eye-movement patterns did not differ across familiarity, but differed across species. Conspecific faces elicited higher proportions of fixation and viewing time for eyes than any other facial feature in the upright and blurred conditions, but not in the inverted condition. In contrast, for human faces we did not find a systematic difference for both measures across facial features. These results show that conspecific faces—unlike human faces—are processed holistically as eyes attract the monkeys' gaze only in an upright context—a clear indication of a high-level influence on eye movements due to face processing.

◆ **Attention to self-referential stimuli: Can I stop looking at myself?**

C Devue, N Jamaer, S Brédart (Department of Cognitive Science, University of Liège, Liège, Belgium; e-mail: cdevue@ulg.ac.be)

Auto-referential materials (own name) have been described as particularly prone to capture attention. Some recent studies by Harris and Pashler (2004 *Psychological Science* **15** 171–178) and Gronau et al (2003 *Journal of Experimental Psychology: General* **132** 512–529) have questioned this view and showed that these own-name effects are temporary and appear only in specific conditions: when enough resources are available or when the own name is a task-irrelevant stimulus presented in the focus of attention. In the present study, a stimulus that is unique to each individual was used: the self-face. In experiment 1, the self-face produced a temporary distraction when presented at fixation during a digit-parity task. However, this distraction was not different from that triggered by another highly familiar face. In experiment 2, familiar faces failed to produce interference when presented outside the focus of attention. Experiment 3, using a less demanding task, indicated that when few resources are required, the self-face may interfere even when presented peripherally. These results confirm recent findings showing that auto-referential materials are special only in specific conditions.

[Supported by the Belgian NFSR.]

◆ **Dynamics and flexibility in mental representations of familiar faces**

T Ditye, C C Carbon (Faculty of Psychology, University of Vienna, Vienna, Austria; e-mail: thomas.ditye@univie.ac.at)

Owing to massive changes of faces over time and situations, representations of familiar faces need to be updated continuously in order to allow the faces to be identified accurately. In three experiments we investigated this mechanism that is more flexible than has often been supposed. Highly familiar faces of celebrities were used and first inspected in a configurally manipulated way. When participants had to select the veridical version out of two pictures (the original and a version slightly altered toward the previously inspected manipulated versions) the selection was biased toward these altered versions. This adaptation effect was demonstrated even for a delay of 1 week between inspection and test phase. Moreover, adaptation also concerned other images of the same person and even transferred to pictures of different identities. Thus, face-specific representations seem to underlie permanent changes that are not only identity-based but influence our perception of human faces in general.

◆ **Sensitivity to facial dynamics in recognizing emotional expressions**

C Fiorentini, P Viviani (Department of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland; e-mail: chiara.fiorentini@pse.unige.ch)

As motor behaviours determined by muscle actions, facial expressions (FEs) are intrinsically 'dynamic'. Thus, the hypothesis can be made that motion invariants associated with the actual production of an FE are important in emotion recognition. We tested observers' sensitivity to the dynamics of FEs with high-frequency (500 frames s^{-1}) recordings of naturally unfolding emotional expressions. Video clips were shown in slow motion in an identification task. In each trial participants identified the unfolding emotion as soon as they had enough information. Facial activity along each video-sequence was coded frame by frame following the Facial Action Coding System (FACS) procedure and correlated with observers' response times. Results showed that, in a proportion of cases, response times cluster in correspondence with critical facial activity along the sequence, which is sufficient to trigger correct identification of a given emotion. Asynchronies in the distribution of response times for right and wrong answers are significant, suggesting that effective emotion recognition depends to some extent on accurate appraisal of the dynamics of facial activation.

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Thursday

◆ **Left gaze bias in human infants, rhesus monkeys, and domestic dogs**

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While viewing faces, human participants often demonstrate natural gaze bias towards the left visual field, that is the right side of the person's face is often inspected first and for a longer period. With preferential-looking and eye-tracking procedures, we observed that infants as young as 7 months of age showed a left gaze bias for upright human faces and for symmetrical everyday objects. Rhesus monkeys showed left gaze bias towards both upright human and monkey faces, but not towards the inverted faces. Domestic dogs, however, demonstrated left gaze bias only towards human faces, but not towards macaque or dog faces, nor symmetrical object images. Our findings suggest that the left gaze bias towards faces is closely associated with adaptive cognitive processes, related to a predominant role of the right hemisphere for facial-information processing.

◆ **Affective negative priming in response-inhibition paradigm**

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Several studies have shown that the affective valence in previously presented stimuli can affect the time for processing of subsequent stimuli (Carroll and Young, 2005 *Quarterly Journal of Experimental Psychology A* **58** 1173–1197). What would happen if the tasks were not related to the affective properties and, as a result, observers did not attend to the affective characteristics? We investigated the affective priming effect in response-inhibition paradigm irrespective of emotion. The experiment consisted of black-and-white prime–probe sequences and the task was to judge the gender of primes and probes as quickly as possible. But half of the primes were presented as color formats to which participants were instructed not to respond. Responding for the probe was delayed in response-inhibition condition, when the prime and the probe were of the same affective valence. Our data demonstrated that facial expressions unrelated to the tasks could affect the following decision. These results imply that facial affective processing could occur to some extent automatically and without attention.

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◆ **Effects of backward dynamic change of happy and angry facial expressions on the perception of neutral faces**

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We conducted two experiments to investigate the effects of facial motions on the perceived impressions of neutral faces at the offset of a dynamic change from emotional faces. In experiment 1, we used two conditions involving changes from happy or angry expressions. In the dynamic sequence, the emotional faces were gradually changed to neutral by morphing. In the static two-frame as a control, the emotional faces were statically displayed; subsequently they were switched to neutral. The participants rated the impression of the final neutral face. Consequently, the contextual facial expressions modified the impressions of the neutral faces only in the dynamic-sequence condition, not in the static two-frame condition. In experiment 2, the participants rated the emotional intensity of the various expressions of the models used in experiment 1. By performing PCA on the data, two major PCs were obtained. We plotted the faces in the factor space and confirmed that the effects of dynamic changes in experiment 1 occurred in correspondence to the opposite polarity of the contextual facial expression.

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◆ **Transfer between pose and illumination training in face recognition**

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It remains a key issue to understand how observers learn to recognise faces across pose and illumination variations. Prior research has demonstrated detrimental effects of these variations on recognition of unfamiliar faces. However, the relationship between learning of the two types of variation is still unknown. Can exposure to one type of variation affect recognition of the face in an untrained type? To answer this question, we conducted recognition experiments where faces were trained in one type of variation but tested in another. For example, a face trained in different poses under the same illumination would be tested in the trained pose but in a new illumination. We examined whether the pose training would facilitate recognition

performance by comparing it with a control condition where the face was trained in a single pose. The effect of illumination training on pose variation was also examined by the same method. Our results revealed no transfer of training, suggesting that generalisation in face learning is limited to the trained type of variation.

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◆ **From your eyes only: Gaze adaptation from averted eyes and averted heads**

R Jenkins, J Keane ¶, A J Calder ¶ (Department of Psychology, University of Glasgow, Glasgow, Scotland, UK; ¶ Medical Research Council, Cambridge, UK; e-mail: rob@psy.gla.ac.uk)

Recent research has shown that eye-direction judgments are strongly influenced by adaptation to averted-gaze stimuli (Jenkins et al, 2006 *Psychological Science* **17** 506–514). Previous studies have suggested that the direction of another person's social attention is computed by integrating multiple direction cues, such as eye direction and head direction [Perrett et al, 1992 *Philosophical Transactions: Biological Sciences* **335**(1273) 23–30]. In light of such cue-integration models, we sought to establish whether eye-direction judgments are also influenced by adaptation to averted-head stimuli. We found that gaze-adaptation effects were largest in the case of averted-eye adaptors, smaller in the case of averted-head adaptors, and virtually eliminated when the eyes in the averted-head displays were closed or occluded. This pattern of results is discussed in relation to cue-integration models.

◆ **My face or yours? Early and late ERP correlates of self-face recognition**

H B Keyes, N P Brady (Department of Psychology, University College Dublin, Dublin, Ireland; e-mail: helen.keyes@ucd.ie)

Ways in which self-face perception is anatomically distinct from other face perception was addressed by analysing ERPs while participants monitored for repeat images of the participants own face, friend faces, stranger faces, and non-faces (flowers). Results showed characteristic P110 and N170 for faces at occipito-parietal sites, and confirmed the presence of a vertex positive potential (VPP) in central sites, which continued at frontal sites. Self/other differences occurred as early as 170 ms and became increasingly apparent later in the waveform. Contrary to previous reports of enhanced positivity to self-face viewing, self-faces elicited significantly more negativity than other faces at fronto-central sites. Although no familiarity effects reached significance, a trend at later epochs suggested the divergence of friend and stranger. Where evident, enhanced right-hemisphere responses were common to all categories of faces, questioning proposals of a right-hemisphere bias for self-face processing. Results are discussed with reference to familiarity effects and to the role of the mirror-neuron system in disambiguating self from other.

[HK was funded by the Ad Astra Scholarship.]

◆ **Temporal characteristics of face adaptation**

K Morikawa, J Seyama ¶ (School of Human Sciences, Osaka University, Suita-shi, Japan; ¶ University of Tokyo, Bunkyo-Ku, Japan; e-mail: morikawa@hus.osaka-u.ac.jp)

A number of recent studies have shown that gazing at a particular face biases subsequent perception of faces. For example, looking at a distorted face for a few minutes causes an undistorted face to appear distorted in the opposite manner. Spatial properties of this face-distortion after-effect (FDAE) have been well documented. Its temporal characteristics, however, are still largely unknown. We investigated the time course of FDAE. We used horizontally expanded/contracted faces as stimuli, and measured FDAE during, and 30 min after, adaptation. The results showed that FDAE decreases to 39% in 30 min after adaptation. The decay function of FDAE is the same regardless of whether the adapting face and the testing face are of the same identity or not. In contrast, adaptation to a downward shift of the position of one eye caused FDAE that did not decay at all after 30 min (Morikawa, 2005 *Vision Research* **45** 3180–3188). These data suggest that the temporal characteristics of FDAE depend on different types of distortion, but not on facial identity.

◆ **Age-related changes in categorical perception of facial expressions**

J E Murray, M Ryan, T Ruffman (Department of Psychology, University of Otago, Dunedin, New Zealand; e-mail: jmur@psy.otago.ac.nz)

Recent work suggests that older adults experience difficulties in recognising facial expressions of sadness, fear, and anger, but not typically of happiness and surprise. We tested for age-related differences in categorical perception of emotion in morphed faces for two nine-step continua in which the proportion of sadness and fear, and happiness and surprise was varied. For each continuum, categorical boundaries were determined and participants made same/different judgments about within-category and between-category pairs. For the happiness–surprise continuum, the results showed that older adults did not differ from younger adults in either the locus of the categorical

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boundary or the ability to discriminate within-category and between-category pairs of faces. In contrast, for the sadness–fear continuum, older adults differed from younger adults in the locus of the category boundary and were less accurate in discriminating between-category but not within-category pairs of faces. This suggests that difficulties in processing emotional expressions of fear and sadness may be caused by age-related changes in sensitivity to variation between perceptual categories.

[Supported by a University of Otago Research Grant.]

◆ **Does visual categorization really shape feature selectivity in the primate temporal cortex?**

YNajian, Sh Talehy Moineddin¶, F Sodagari¶ (Department of Basic Sciences, Nikan Health Research Institute, Tehran, Iran; ¶Iran University of Medical Sciences, Tehran, Iran; e-mail: yousef.najian@gmail.com)

Activity in the human temporal cortex is thought to be sensitive to the categorization level of the stimuli and to depend on the expertise of the observer. Sigala and Logothetis (2002 *Nature* **415** 318–320) published an article with the aim of testing whether inferior temporal cortex neurons respond selectively to object features that constitute the relevant dimensions for visual object categorization. They defined parameterized line drawings of faces each consisting of an outline and four varying features as stimuli and trained two monkeys in a categorization task. They claimed that the categories were separable along two of the four dimensions of the stimuli. On examining their stimuli again, we found that the face categories were separable along the combination of one feature with each of the remaining features. Therefore, there was only one diagnostic dimension and the monkey could optionally select the second one for categorization. Assuming that the selectivity index for the real unitary diagnostic feature was much larger than for the other three features, we find the interpretation to be different.

◆ **The hollow face illusion in infancy**

E Nakato, H Hill¶, Y Otsuka§, S Kanazawa#, M Yamaguchi (Department of Psychology, Chuo University, Hachioji, Japan; ¶University of Wollongong, Wollongong, Australia; §Tokyo Women's Medical University, Tokyo, Japan; #Shukutoku University, Chiba, Japan; e-mail: enakato@komazawa-u.ac.jp)

The hollow-face illusion is perceived on the basis of two assumptions: (i) top–down knowledge for faces, (ii) convexity preference of patterns of shading (Hill and Johnson, 2007 *Perception* 199–223). We examined the effect of the hollow-face illusion in infants aged 6–8 months. Infants were first familiarized for 80 s with a male face either in the convex or the concave condition. In both conditions each face was moved from side to side over 20°. After familiarization, infants were tested with a pair of novel convex and concave faces in two 10 s trials. If infants perceived a hollow mask as a convex face, they would show a novelty preference for the novel concave faces in test phase. The results indicated infants' preference for concave faces only in the convex condition. The results suggest that the hollow-face illusion did not appear even in 8-month-old infants.

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◆ **The effects of camera and light angles on the recognition of emotion from the face**

M Oda (Department of Psychology, Ritsumeikan University, Kyoto, Japan; e-mail: oda@lt.ritsumei.ac.jp)

The effects of camera and light angles on the recognition of facial expressions were investigated. Facial expressions and neutral faces were taken by five cameras simultaneously under four light direction conditions. The participants rated emotional intensity and reality of the stimuli. Angry faces were rated stronger in the front camera and in the front light, and weaker in the side camera and in the side light. Smiling faces were regarded as weaker in the upper camera and in the upper/side light. On the other hand, neutral faces were regarded as angry faces in the diagonal/side camera condition and upper light condition, and as smiling faces under the low light condition. These results indicate that the camera and light angles influence the facial impression, and intensity of emotion changes by the combination of emotional types, camera angles, and light angles. Moreover, the effects of camera and light angles on the neutral face and emotional expressions face could be caused by different mechanisms respectively.

◆ **The effects of adaptation duration on contrast thresholds in face identification**

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We report a novel face-adaptation paradigm in which we probe the effect of prior exposure on contrast thresholds for face identification. Each trial consisted of an adaptation period (showing a

face in the experimental trials or no stimulus for the baseline trials), a noise mask lasting 50 ms, and a test face lasting 150 ms. We examined the effects produced by variable adaptation durations, ranging from 10 ms to 6400 ms, on identifying either the same or a different face as that seen during the adaptation period. For adaptation durations greater than 500 ms, thresholds were elevated for both the same and other faces, and continued to increase with longer adaptation durations. For durations less than 500 ms, adaptation reduced thresholds for the same face, indicating a facilitation effect that was maximal at 200 ms, but continued to elevate thresholds for other faces. Similar effects were obtained with adapting faces that differed in size from the test faces, indicating that our results cannot be attributed to adaptation to low-level image properties. [Supported by CIHR grant MOP-77615, and NIMH grant 1R01 MH069898.]

◆ **Three-months recognition memory for faces in moving and static figures**

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 e-mail: yiu15793@nifty.com)

We compared infants' recognition memory for unfamiliar faces learned in a moving or a static condition. Infants aged 3 months were familiarized with a smiling woman's face either in the moving or static condition for 30 s. After familiarization, infants in both conditions were tested for the recognition of the familiarized face using a pair of novel and familiar female faces. Both faces in the test phase had static, neutral expressions. Hair was excluded so that only the internal features were visible. We found that only infants in the moving condition showed a significant preference for the novel faces. A control experiment confirmed that better performance in the moving condition was not due to the effect of seeing multiple static images contained in the movie. A novelty preference in the static condition was shown with 90 s but not with 30 s familiarization when the same image was used between the familiarization and the test. Our results suggest that learning faces in motion promotes young infants' recognition of unfamiliar faces. [Supported by RISTEX and PRESTO JST, by a Grant-in-Aid for scientific research (18000090) from JSPS.]

◆ **The impact of unilateral amygdala lesions on the detection of brief backward-masked fearful facial expressions**

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The amygdala, a grey matter structure in the anterior temporal lobe, appears to be involved in the perceptual processing of fearful facial expressions, even those that are briefly shown and backward masked so people are apparently unaware of the expression. The aim of this study was to investigate whether patients with unilateral amygdala lesions would be impaired at detecting fear from briefly presented, backward-masked faces. Fearful, happy, and neutral faces were briefly shown (20, 36, and 86 ms) and followed by a neutral face that acted as a backward mask. Participants judged whether the face was fearful or not, and rated their confidence in their response. Awareness was evaluated by signal detection analyses, including receiver operating characteristic (ROC) curves. There was little evidence that patients with right amygdala lesions were impaired at perceiving fear, whereas some patients with left amygdala lesions had difficulty reliably recognising briefly presented fearful expressions. Implications for the role of the amygdala in fear perception are discussed.

[Supported by a Macquarie University Research Fellowship.]

◆ **Processing facial expressions of emotion: Upright vs inverted images**

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We compared the perception of upright vs inverted facial expressions of emotion (FEs). Subjects made speeded *same/different* judgments about upright or inverted pairs of FEs from a male or a female poser. Each stimulus set contained seven emotion prototypes from Ekman's series, and eight intermediate morphs. The percentage of *same* judgments for each stimulus pair was taken as an index of perceptual similarity, and analyzed with multidimensional scaling. Four-dimensional solutions were obtained, similar to previous results from explicit similarity judgments (Kirkland et al, 2000 *Perception* 29 Supplement, 39). Dimensions were labeled *happy-sad*, *surprise/fear*, *anger*, *disgust*. Categorical perception is evident for stimuli containing any element of happiness,

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whether upright or inverted. Solutions for female and male posers differ significantly. However, inverting the stimuli produces smaller differences, consisting of minor changes in the salience of the dimensions. This suggests that low-level perceptual processes—treating the FEs as abstract patterns of lightness and texture—dominate the *same/different* decisions.

[We thank P Ekman for permission to use photographs. Technical assistance of S Willems is gratefully acknowledged.]

◆ **Relative importance of facial area for the complex facial expressions**

S Park, K J Cho, H R Ghim (Department of Psychology, Chungbuk National University, Cheongju, South Korea; e-mail: eulb@yonsei.ac.kr)

Our aim was to find out which facial area is most important for reading facial expressions for basic emotion and complex emotion. In experiment, a two-part image was presented with storytelling related to a special emotional state, and then four facial expressions were presented as whole face, eye area, or mouth area. Participants ranged from three-year-olds to undergraduate students. The participants' task was to select a facial expression that best described the emotional state displayed. Higher correct response ratios were found for basic emotion than for complex emotion. Correct response ratios were highest for the whole face, and better for the eye area than for the mouth area. Finding the appropriate facial expression was easier for basic emotion than for complex emotion, and the eye is more important for reading a facial expression than the mouth even for reading complex emotion.

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◆ **Abnormal adaptive face-coding mechanisms in autism**

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In low-level vision, exquisite sensitivity to stimulus variations is achieved by adaptive mechanisms that calibrate neural responses to inputs. Adaptive mechanisms in high-level vision may contribute to our remarkable ability to distinguish thousands of faces despite their similarity as visual patterns. The face-identity aftereffect, in which adaptation to a face biases perception towards the opposite identity, suggests that facial identity is adaptively coded relative to a norm that is continuously updated by experience. We investigated whether adaptive identity coding is impaired in autism, a developmental disorder characterized by social and communication deficits, in which face perception is abnormal. We measured the identity aftereffect in boys with high-functioning autism and age- and ability-matched controls, in a child-friendly 2AFC identification task. The aftereffect (shift in PSE of the identity–strength psychometric function) was significantly smaller for children with autism (mean = 10.9%, $N = 15$) than for typically developing children (mean = 18.1%, $N = 14$); $t_{27} = 2.11$, $p < 0.05$. Abnormal adaptive-coding mechanisms may therefore contribute to face-processing deficits observed in autism.

[Supported by the Australian Research Council.]

◆ **Are the neural mechanisms that underlie self-face and other-face recognition shared or separate? An adaptation study**

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The question of whether shared or separate neural processes underlie the recognition of our own face and other faces was investigated by using adaptation. Following the methods of Rhodes et al, 2006 *Psychological Science* 17 501–505 participants rated distorted faces for attractiveness after adapting to extremely distorted faces. Contingent aftereffects were obtained for highly familiar faces (own face and a friend's face) after adapting to distorted stranger faces (experiment 1) or to distorted own and friend's faces (experiment 2). In experiment 3 participants adapted to images of their own and a friend's face distorted in different directions (feature expansion or contraction) and then rated hybrid images (morphing own and friend's faces): here perceptual aftereffects cancelled. These results demonstrate that the neural code representing highly familiar faces is rapidly updated by visual experience, and suggest that shared processes underlie the representation of one's own and other faces. We conclude that self-face representation is functionally special in the brain but no more than any other non-self-face with which we are equally familiar.

◆ **Spontaneous preference for face-like displays in newborn chicks**

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There has long been a debate whether infants' preference for looking at face-like stimuli with respect to non-face-like ones is determined by the presence of an innate schematic representation of the appearance of conspecific faces (CONSPEC), or by up-down bias (that favours stimuli presenting more high-contrast elements in their upper part with respect to the lower part). We investigated the presence of an innate preference for face-like schematic stimuli in two-day-old domestic chicks, controlling for the role of the up-down bias. Subjects were completely naive with respect to the arrangement of the internal features of the face. During the test, chicks were presented with two stimuli (a face-like stimulus and a non-face-like one), both having more elements in the upper part of the figure (ie balanced with respect to the up-down bias). Chicks preferred to approach and spend more time near the face-like stimulus, showing an innate preference for a schematic face-like configuration, consistent with evidence from previous studies on infants' face perception.

[Supported by PRIN 2005 to MZ.]

◆ **Are you looking at me? Cognitive control of the gaze aftereffect**

F Schmidt, C Zang, Y Wiepen, M Persike, G Meinhardt (Institute of Psychology, Johannes Gutenberg Universität, Mainz, Germany; e-mail: franzsch@students.uni-mainz.de)

Repeated exposure to averted gaze results in a strong bias of perceived gaze towards the averted gaze direction (Jenkins et al, 2006 *Psychological Science* 17 605–613). This aftereffect evolves rapidly within seconds of exposure to averted gaze. In the present study we used different feedback configurations to modulate the magnitude of the gaze aftereffect. Feedback effectiveness was tested with a two-alternative forced-choice design, where trial by trial feedback was given. Subjects received no feedback, predominantly correct feedback, or predominantly wrong feedback, which reinforced biased judgments of perceived gaze. Statistical analysis reveals that false feedback yields a steeper formation gradient of the gaze aftereffect during bias induction. The opposite holds for correct feedback, which attenuates involvement of the gaze bias and facilitates recovery of unbiased gaze perception. On the basis of the impact of feedback on the gaze aftereffect, we argue that the involved neural mechanisms have strong cognitive overlay.

◆ **Investigation of the constructing method of the face graph reflecting the perceptual impression**

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The face graph was introduced as the visualization technique to illustrate trends in multi-dimensional data relating to facial features (Chernoff, 1973 *American Statistical Association* 18 361–368). We developed a psychologically relevant method to construct face graphs, which means that the similarity of the data is reflected in the cognitive similarity of the facial expressions. To ensure the correspondence between graphical expressions and subjective impressions, we adopted schematic faces used in the study which showed the correlations between the dimensions of the visual information and affective meanings (Yamada and Shibui, 1998 *Perception* 27 Supplement, 133). To test the effectiveness of our method, we applied it to the multidimensional data given by analyzing the academic syllabi as a practical example. Subjects rated these faces using the semantic differential method. Factor analysis of the ratings revealed two factors interpreted as 'pleasantness' and 'activity'. The configuration of faces on the factor space showed a similar pattern to that of the syllabi data themselves. This supports the usefulness of our method.

◆ **The multiple-faces phenomenon: Effects of size and eccentricity**

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In three studies we investigated effects of size and eccentricity on the multiple-faces phenomenon (Simas, 2000 *Perception* 29 1393–1394) with non-naive volunteers, 18–70 years old (50% males). The first study ($N = 80$ participants) tested the effects of sizes 17, 22, 29, and 35 deg and placed the face-stimulus contralateral to the blind spot. The second study ($N = 120$) used sizes 15, 20, 27, and 33 deg at the blind spot. A third study ($N = 192$) tested 19 and 26 deg sizes at four eccentricities, 8°, 16°, 32°, and 45°, either to the right or the left. Volunteers were requested to press either two keys in a keypad or on a mechanical counter, held in each hand, every time they saw changes in facial expression/movement (EM), or faces of different identities (DI), during 3 min for each eye. Results showed significantly higher frequencies of DI for sizes 15–17 deg

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and 20–22 deg. The right eye was the best for DI with size 20 deg at the blind spot. Size 19 deg was best for EM and 25 deg best for DI at eccentricities 32° and 32°–45°, respectively. [Supported by CNPq and FACEPE.]

◆ **Difference of the fractal dimensions of facial affect perception between photographic and line drawn faces**

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The structure of facial affect perception is represented in terms of valence and arousal dimensions. Takehara et al (2007 *Cognition and Emotion* 21 522–534) reported that the structure has a fractal property. In this research, we examined the difference of the fractal dimensions of the structure of facial affect perception by using traditionally photographic and line drawn faces; the latter type of faces had a lower amount of visual information than the former type. A statistical analysis revealed that the fractal dimension derived from line drawn faces (1.40 dimension) was higher than that derived from the photographic faces (1.34 dimension), $t_{18} = 2.73$, $p < 0.02$. As discussed in previous studies, if the difference of the fractal dimension was related to the amount of visual information from the face, the fractal dimension derived from the line drawn faces could be lower than that derived from the photographic faces. Consequently, this suggests that the fractal dimension would depend upon factors such as familiarity or novelty. [Supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Young Scientists (B).]

◆ **Investigation of the effect of an information-integration task training on face adaptation**

Sh Talehy Moineddin, A Javadiarjomand¶, R Tabesh, Y Najian§ (Department of Medicine, Iran University of Medical Sciences, Tehran, Iran; ¶ Amir Kabir University, Qazvin, Iran; § Nikan Health Research Institute, Basic Science, Tehran, Iran; e-mail: sh.talehy@gmail.com)

We used parameterized line drawings of faces, each consisting of an outline and four varying features. In the first subject eye separation and nose length and in the second subject mouth curvature and eyebrow curvature were the diagnostic features along which the face stimuli are linearly separable for the information-integration two-alternative forced-choice task of categorization training. The stimuli were presented for 200 ms with feedback of correctness. Finally the subjects' performance was 95% correct. We used adaptation paradigm before and after training. The adaptor had one feature at the extreme level that appeared randomly somewhere on the screen and moved smoothly for 5 s. Afterwards there was a 2 s blank interval, then a 200 ms test stimulus. The task for each subject was repeated without an adaptation phase. We plotted psychometric functions. Area between psychometric functions was defined as the adaptation index. Adaptation index for non-diagnostic features was 22.92 before training and 22.21 after adaptation, but for diagnostic features it changed dramatically from 15.02 to 56.65. Therefore neuronal representation of diagnostic features is much enhanced relative to non-diagnostic ones. [Supported by Faeze Sodagari, Nikan Health Research Institute.]

◆ **A bias for female face recognition in the right hemisphere?**

L Tommasi, R Parente (Department of Biomedical Sciences, University Giovanni d'Annunzio, Chieti, Italy; e-mail: luca.tommasi@unich.it)

An advantage of the right hemisphere for the recognition of the gender of faces is well established. In order to assess whether this asymmetry interacts with the observers' gender, chimeric and non-chimeric faces were presented tachistoscopically to sixteen male and sixteen female observers. Chimeric faces were created by juxtaposing left and right half-faces of different sexes (male–female and female–male), and subjects were asked to make a quick judgment about the face's gender. A laterality index was calculated to measure whether subjects relied more upon the left or the right half-face in responding. The right-hemispheric advantage for gender recognition was confirmed: judgments were significantly more based on the left hemiface. Strikingly, however, the bias was observed only for the subset of faces composed of a left female and a right male half-face but not for the other subset of faces, both in male and female observers. These results suggest that the right-hemispheric bias in gender recognition might be due to a selective advantage for recognizing female faces.

◆ **Predicting facial expression: The adaptation aftereffects of changing expressions**

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Prominent models of face processing posit that facial expressions are perceived via a neural pathway specialized for utilizing rapidly time-varying information. We investigated whether expression perception could be altered via adaptation to dynamic expressions, finding that people can use the direction of change in subtly moving faces to predict future emotional expressions, and this prediction influences perception of a target expression presented immediately afterwards. In experiment 1 we found sensitivity to the difference between predictive and non-predictive face motion, at a short ISI (50 ms), but less so at 350 ms. Experiment 2 contrasted effects of the adaptation aftereffect that heightens contrast between adaptor and target, and those of predictive change that assimilates the target into the sequence. In experiment 3 we tested whether predictive direction generalised over changes in the identity and location of the face stimuli, as predicted by similar representation-momentum effects in non-face stimuli, finding that the predictive effect survived ($F_{1,1283} = 6.24, P = 0.01$), but the adaptation aftereffect was attenuated. [Supported by the Human Frontier Science Program RGP0047/2004-C.]

◆ **The time course of processing external and internal features of unfamiliar faces**

B Veres-Injac, F Hofer, A Schwaninger[¶] (Department of Psychology, University of Zurich, Zurich, Switzerland; [¶] also Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: b.veres@psychologie.unizh.ch)

The time course of processing internal and external features was studied in a face-matching task in which participants had to match target and test faces, which differed in their external (hair and face outlines) or internal features (eyes, nose, mouth), or both. To this end, three different definitions of 'same' were used: same trials were defined as full congruency between target and test faces or as congruency in external or in internal features only. The results of three experiments provide an evidence for very fast matching of faces on the basis of external or internal features. Maximal performance is achieved already with 90 ms exposure time and longer exposure (120 ms, 150 ms, self-determined) time did not improve accuracy. The study suggests that unfamiliar faces can be matched more accurately on the basis of external vs internal features. There is no inversion effect for facial features, while matching of whole faces is impaired by orientation. [Supported by the Swiss National Science Foundation, grant no. PMCD1114398/1 given to BV.]

◆ **Semantic dimensions related to facial structural variables involved in the recognition of facial expressions of emotion**

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In our previous study (Yamada and Shibui, 1998 *Perception* 27 Supplement, 133) we examined the relationship between facial structural variables ('slantedness' and 'curvedness/openness') and semantic dimensions ('pleasantness' and 'activity') involved in the recognition of emotion from facial expressions. Our subsequent studies (Watanabe et al, 2003 *Japanese Journal of Cognitive Psychology* 3 167–179) revealed that there are not two but three facial structural variables ('curvedness/openness,' 'slantedness of lips', and 'slantedness of eyebrows and eyes'). Here, we investigated which semantic dimensions relate to those structural variables. Participants ($N = 145$) rated 12 facial images and 6 schematic faces representing facial expressions in terms of 20 semantic differential scales. Factor analyses with both varimax and promax rotations yielded three factors: 'pleasantness', 'activity', and 'potency'. The results implied that it would be better to think that those dimensions were orthogonal. A canonical correlation analysis on the factor scores with three facial structural variables, scored from the displacements of facial characteristic points, showed about a one-to-one relationship between each of the semantic dimensions and the three facial structural variables.

◆ **Are you looking at me? Characteristics and time course of induced gaze perception**

Y Wiepen, M Persike, C Zang, F Schmidt, G Meinhardt (Methods Section, Johannes-Gutenberg-Universität, Mainz, Germany; e-mail: yvonnewiepen@web.de)

Jenkins et al (2006 *Psychological Science* 17 506–513) found that adapting to averted gaze induces a strong bias of perceived gaze towards the averted-gaze direction. We replicate the adaptation effect, but also demonstrate that adaptation is not necessary to produce the gaze-direction bias. Showing displays with averted gaze just for 8 s before the gaze-direction probes ('top-up displays') induces a similar bias of perceived gaze. The bias evolves rapidly in the first three trials of alternating gaze exposure (approx. 30 s), and has a similar time course of extinction after refreshment by top-up displays is switched off. Further, we varied the presentation time of the top-up

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displays in settings of 2 s, 4 s, and 8 s. The results show that the duration of the top-up display moderates the time course of evolvment and the magnitude of the gaze-direction bias. On the basis of the rapid evolvment we argue that fast adaptation and reference-frame setting rather than cell-response fatigue is involved.

◆ **Yang's eye illusion**

J Yang, A Schwaninger¶ (Department of Psychology, University of Zurich, Zurich, Switzerland; ¶ University of Zurich and Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: j.yang@psychologie.unizh.ch)

A new visual illusion in face perception is demonstrated. Faces were mirrored and combined so that the distance between the resulting four irises were equal. In experiment 1, Caucasian and Asian face stimuli were used. Dot stimuli were created by deleting all face areas except the irises. Participants from two different ethnic groups (Swiss and Taiwanese) were asked to judge whether the distance between the middle two irises is larger, shorter, or equal to the distance between the left two or right two irises. Participants perceived the distance between the middle two irises as shorter than the other distances regardless of orientation and participant race. The illusion was found in face stimuli but not in dot stimuli. Interestingly, the illusion magnitude was larger for Asian than for Caucasian faces. In experiment 2, the face stimuli were replaced by line drawings of the eyes and irises. Similar results were obtained suggesting that the illusion is caused only by the shape of the eyes, and is independent of facial context.

◆ **Mapping the behavioral affordances of face stimuli**

Y Zhang, L Zebrowitz (Department of Psychology, Brandeis University, Waltham, USA; e-mail: yizhang@brandeis.edu)

The human face provides visual information not only about its structure, color, or identity, but also about its behavioral affordances. Affordance, according to the Gibsonian view, is defined as the interaction opportunity an object provides to the perceiver. In the present study we used perceivers' approach-avoidance arm movements (pulling toward the self vs pushing away from the self) when viewing different types of faces and their self-reported behavioral intentions to assess the faces' perceived affordances. Fifty-two Caucasian participants pulled or pushed a joystick to indicate the category membership of each face before they filled out ratings on affordances. We found that anomalous faces elicited faster avoidance tendencies than either attractive faces or average attractive faces. Asian faces elicited faster approach tendencies than Caucasian faces, whereas Black faces elicited faster avoidance tendencies. Ratings of behavioral intentions were consistent with behavioral measures except for Black faces, where they were rated higher on approach and lower on avoidance than Caucasian faces. The importance of using an implicit behavioral measure is discussed.

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◆ **Face aftereffects improve discriminability for similar faces**

C Zhao, P Hancock¶ (School of Informatics, Neuroinformatics DTC, University of Edinburgh, Edinburgh, Scotland, UK; ¶ University of Stirling, Stirling, Scotland, UK; e-mail: C.Zhao-3@sms.ed.ac.uk)

Previous studies have demonstrated a face-identity aftereffect that facilitates face-identification performance (Leopold et al, 2001 *Nature Neuroscience* 4 89-94). Adaptation should improve discrimination between faces in the region of the adapting stimulus, but this has not previously been demonstrated. We report an investigation on face discrimination, using faces distorted with Photoshop spherize function making them either expanded or compressed. We did psychophysical experiments on thirteen participants using an adaptive Bayesian method in order to present stimuli efficiently and effectively. The participants were adapted to systematically distorted faces (-60% or +60%) and then tested on discrimination sensitivity around both +60% and -60%. The results show that discrimination is facilitated at -60% after repetitive adaptation to -60% faces, but not significantly facilitated at +60% following adaptation to +60%. Overall, there is a significant shift in discriminability with adaptation condition. We conclude that face discrimination can be facilitated at the point of adaptation but that demonstrating such an improvement will require a more tightly controlled stimulus presentation protocol.

NATURAL IMAGES

◆ **Contour curvature in natural images: Statistical analysis and psychophysics**

J Cham, S Khuu, A Hayes (Department of Psychology, University of Hong Kong, Hong Kong, China; e-mail: joeycham@gmail.com)

We examined the statistics of natural images to determine the pattern of occurrence of curved contours, where both curvature sign and angle are constant. Templates of curved contours of

different curvatures were mapped for 472 linearized natural images. The results of this analysis revealed a tendency for contour fragments that are curved to propagate at a constant rate of curvature. Two psychophysical experiments were conducted to examine human response to constant-curvature contours. In the first experiment, observers were required to detect contours of different curvatures in a field of randomly orientated elements. We found greater sensitivity to constantly curved contours. In the second experiment, observers were required to judge the spatial orientation of the last element of a contour. We found that the last element is judged to be biased in the direction of curvature when it is a part of a curved contour. These results show that human visual system is sensitive to the regularity observed in natural images.
[Supported by grants HKU7409/06H and HKU7426/05H.]

◆ **Modelling natural scene dipper functions**

M Chirimuuta, Z Jiwa ¶, D J Tolhurst ¶ (School of Philosophy and Bioethics, Monash University, Clayton, Australia; ¶ University of Cambridge, Cambridge, UK; e-mail: mazviita.chirimuuta@arts.monash.edu.au)

Chirimuuta and Tolhurst (2004 *Perception* **33** Supplement, 176) showed that contrast discrimination of natural-image and $1/f$ filtered random-luminance stimuli produces low-contrast facilitation and high-contrast masking (dipper functions). Here we model these dippers with a V1 model including untuned contrast normalisation (Watson and Solomon 1997 *Journal of the Optical Society of America A* **14** 2379–2391) and orientation-tuned surround suppression. The model successfully fits dippers for the random image and several band-pass variants. With slightly different best-fitting parameters, it also fits dippers for 2 unfiltered and band-passed photographs of natural scenes. The averaged best parameters give acceptable fits to all data sets (error 3.4 dB² per point). Hence the model seems internally consistent for images with roughly $1/f$ statistics. However, when the same model is applied to data from dipper experiments with classical grating and Gabor stimuli, the best-fitting parameters are significantly changed from the natural and $1/f$ stimuli. These best-fitting parameters for the sinusoidal stimuli produce a poor fit for the $1/f$ and natural-scene data (error 8.1 dB² per point).
[Supported by the Medical Research Council UK DERA.]

◆ **Cat – dog categorization in natural images**

R Daliri, S A Kondra, W Vanzella, V Torre (Neurobiology Sector, SISSA, Trieste, Italy; e-mail: daliri@sissa.it)

We present a cat – dog categorization based on the shape extracted from our bottom – up segmentations of side views of both categories with a variety of backgrounds. We collected 100 images of each category using Google search. We did manual segmentation of each image as ground truth. The recognition rate on manual segmentation was 83% with leave-one-out procedure. The automatic-segmentation method uses a watershed algorithm and a new merging procedure of color and scale information. The shape-matching algorithm is based on dynamic programming to find the correspondence between point sets over the contour of the model and the testing shape, removing the outliers and aligning with procrustean analysis. Comparing each of segmented shape with the models, we obtain a global match for that image. We further want to increase the number of classes by collecting a database of mammals like cows and sheep.

[Supported by the EU project MRTN-CT-2004-005439 “VISIONTRAIN”]

◆ **Visual-difference predictor models for human suprathreshold ratings of differences between natural images: Complex-cell models outperform simple-cell models**

M To, P Lovell ¶, T Troscianko ¶, D Tolhurst (Department of Physiology, Development and Neuroscience, University of Cambridge, Cambridge, UK; ¶ University of Bristol, Bristol, UK; e-mail: mpst2@cam.ac.uk)

Observers viewed 900 pairs of coloured natural images and rated the perceived difference between each pair, which differed in eg the degree of blur, the colour, location or presence of objects (To et al, 2006 *Perception* **35** Supplement, 106). The ratings were compared with predictions of various simple-cell models: a basic visual-difference predictor model (Párraga et al, 2005 *Perception* **34** Supplement, 155) gave a correlation of 0.45 with the ratings, while a more realistic V1 model (optimised through a neural network) comprising surround-suppression, non-specific normalization and elongated receptive fields gave a correlation of 0.57. We found a consistent pattern of outliers on the correlations whereby the model predictions either greatly overestimated or underestimated observers' ratings. The models consistently underpredicted ratings for blur and objects appearing/disappearing, but overpredicted ratings for textural differences and small movement. The latter was partly remedied by a modified model that replaced the Gabor simple cells with 'complex cells' (rms of the responses of quadrature pairs of simple cells); the overall correlation coefficient rose up to 0.63.

[Supported by EPSRC/Dstl (GR/S56399/01 & GR/S56405/01).]

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READING◆ **Multi-factorial deficits in developmental dyslexia**

M Benassi, S Vicari ¶, A Facoetti §, A Finzi ¶, D Menghini ¶, M Ruffino §, S Giovagnoli, R Bolzani (Department of Psychology, University of Bologna, Bologna, Italy; ¶ IRCCS, Children's Hospital Bambino Gesù, Rome, Italy; § University of Padova, Padua, Italy; e-mail: mariagrazia.benassi@unibo.it)

We investigated the role of some specific neuropsychological functions in the aetiology of developmental dyslexia. Sixty dyslexics and sixty-five age-matched controls were compared on their performance in dorsal–visual processing, visuo-spatial attention, implicit learning, frontal processing, and phonological short-term memory. Dorsal–visual processing was measured by means of a random-dot motion task; visuo-spatial attention was evaluated by a serial visual search task; as implicit learning measure, a serial reaction time task was used; frontal processing was analysed by means of the Wisconsin Card Sort task; to evaluate the phonological short-term memory, a non-word repetition task was used. Results showed that the dyslexics had lower performances in comparison to the controls in dorsal–visual processing, visuo-spatial attention, and phonological short-term memory, and that these functions were significantly correlated with each other. These findings are in accordance with the hypothesis that developmental dyslexia is a multi-factorial deficit involving specifically dorsal–visual functions, spatial attention, and phonological processing.

◆ **Vertical interline spacing is not a major limiting factor of reading speed with a central artificial scotoma**

J-B Bernard, A-C Scherlen ¶, E Castet (CNRS, INCM, 13402 Marseilles Cedex, France; ¶ ENISE, St-Etienne, France; e-mail: bernard@incm.cnrs-mrs.fr)

We used a gaze-contingent display to examine reading performance in subjects with an artificial central scotoma (size: 6° or 10°). Seven normally-sighted subjects read aloud MNREAD-like French sentences. In experiments 1 and 2, letter size (x-height) varied from 0.52 to 2 deg and interline spacing was 0.85×, 1×, or 1.25× the standard spacing. In experiment 3, letter size was kept constant (80% of the critical print size calculated in experiment 1) and interline spacing was 0.72× (null leading), 1× or 2×, the standard spacing. We find that modulation of reading speed as a function of character and scotoma size has the same characteristics as those reported in clinical literature. Interline spacing only slightly affects reading speed (8% increase from 1× to 2× spacing), in contrast with a recent RSVP study (100% increase from 1× to 2× spacing). This suggests that interline spacing is not a major limiting factor of reading speed when the eyes are free to move.

◆ **'Pure alexia': a disorder of visual processing**

D Caine, S S Baker, E H Lacey ¶, S Eshan, E Jefferies, M A Lambon Ralph (Neuroscience and Aphasia Research Unit, University of Manchester, Manchester, UK; ¶ Georgetown University, Washington, DC; e-mail: Diana.Caine@manchester.ac.uk)

'Pure alexia' describes an acquired reading disorder, characterised by pathologically high word-length effect on reading times. Whether 'pure alexia' is a specific disorder of reading per se, or instead a manifestation of a more generalised visual impairment, remains highly contentious. The latter hypothesis predicts: (a) that degraded visual input will induce a word-length effect in normal readers; and (b) that patients with 'pure alexia' will also be impaired on non-reading visual tasks. We tested these predictions in a series of experiments with 'pure alexic' patients and normal readers. Distortion to word shape (alternating letter size) and letter identity (low-pass spatial-frequency filtering) induced both length effects in normal readers, as well as visual reading errors—another feature of 'pure alexia'. Patients were impaired at face and object recognition, as well as word recognition, especially on measures of RT. The results suggest that word length is an emergent effect of degraded visual input; and, concomitantly, that the disorder of 'pure alexia' results from a subtle, but generalised and pervasive, impairment to visual processing.

◆ **Learning to read in Italian: An eye-movement single-case study**

M De Luca, F Zeri ¶, D Spinelli §, P Zoccolotti ¶ (IRCCS Fondazione Santa Lucia, Rome, Italy; ¶ Università di Roma 'La Sapienza', Rome, Italy; § Istituto Universitario di Scienze Motorie, Rome, Italy; e-mail: maria.deluca@uniroma1.it)

Eye movements (EMs) and vocal reaction times (RTs) were recorded in the 1st (beginning and end), 2nd, and 5th grade in an Italian girl with normal development in reading, intelligence, and optometric tests. RTs to single words showed a marked length effect, disappearing by the end of the 2nd grade. At the beginning of the 1st grade, EMs (while reading passages and lists of words and non-words) showed many fixations and small saccades with total inspection time heavily depending upon word length. By the end of the 1st grade, the number of fixations

decreased by a factor of three (saccade amplitude and gaze duration changed by one of two). Consequently, total inspection time showed a five-fold decrease. Similar, but much smaller, changes were present in the 2nd and 5th grade. Discrimination between function and content words (and words and non-words) was clear by the end of the 1st grade and increased thereafter. These longitudinal observations indicate that main EM and RT changes were concentrated during the 1st grade, indicating rapid acquisition of reading in a transparent orthography.

◆ **The relevance of colour in web page readability**

A Farini, C Gheri, R Arrighi (Istituto Nazionale di Ottica Applicata, Florence, Italy);
e-mail: alessandro.farini@inoa.it)

Readability can be defined as the measure of how easy it is to read and comprehend a document. Unfortunately, in the web world, the main colour guidelines given by W3C are not completely informative and they are based on the colour system used by NTSC used in the US television and not valid everywhere (<http://www.w3.org/TR/AERT#color-contrast>). In order to better determine when a colour combination is readable we fixed a font and a size of the text and then we varied the colour of the strings (evaluated in the CIElab colour system) on a constant background. Once we individuated the variables determining a good foreground/background colour combination, we carried out an accurate experiment that took into account the comprehension of the text. We varied the time presentation for different string/background colour couples and then measured the observer reaction times for answering a question. We defined the best trade-off for a readable foreground/background combination and we measured reaction-time variations given a background with strings of different colours.

◆ **The detection and discrimination of linguistic stimuli in foveal and peripheral vision**

C-H Kao, C-C Chen (Department of Psychology, National Taiwan University, Taipei, Taiwan; e-mail: d92227011@ntu.edu.tw)

We investigated linguistic stimulus processing in foveal and peripheral vision by measuring the contrast threshold for detecting and discriminating linguistic and non-linguistic stimuli. The stimulus size varied from 0.8 to 9.2 deg and eccentricity from 1° to 8° with 100 ms duration. We used a 2AFC paradigm and PSI adaptive procedure to measure contrast threshold at 75% correct level. The observers were to indicate which one of two intervals contained stimuli in the detection task and which one of two intervals contained real characters in the discrimination task. The detection threshold decreased with target size with a slope $-\frac{1}{2}$ on log-log coordinates at all eccentricities and for all stimulus types. The discrimination threshold decreased with target size with a slope -1 up to a critical size that depended on stimulus type and eccentricity. This suggests that mechanisms for analyzing character-specific information have a larger receptive field than those for analyzing lines.

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◆ **Is horizontally extended text array optimal for reading?**

O Levashov, E Kononenko, (Education Centre 556, Moscow, Russia);
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Ten adults were presented with different text arrays over a short time (100–600 ms). The task of the subjects was to read as many words as possible. Text arrays varied from the simplest (one sentence) to more complex. We used three text array formats: (i) horizontally extended (8–9 items in a string); (ii) square matrix (3 × 3 or 4 × 4 words); (iii) a vertical column of words. At 100 ms presentation all subjects recognized more words in the case of the second format (square matrix). This tendency retained at 600 ms exposition in seven subjects. For the other three subjects the routine format was more readable. These three subjects used an analytical (serial) strategy of text recognition; others used a holistic one. On average, holistics recognized twice as many words as analytics. The majority of holistics showed a similar score in reading vertical and horizontally extended texts. We propose that holistics have a stronger word recognition system than analytics and that square matrix format of a text is more readable in learning.

SCENE PERCEPTION

◆ **Order/disorder and perceptual segmentation**

B J Gillam, B L Anderson, P M Grove ¶ (Department of Psychology, University of New South Wales, Sydney, Australia; ¶ University of Queensland, Brisbane, Australia);
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The only common quality always possessed by occluded objects is their alignment at the occluding edge. Alignment for unrelated objects is statistically strong evidence for occlusion and Gillam and Chan (2002 *Psychological Science* **13** 279–283) showed that illusory contours were far stronger along the terminators of figures with different lengths, orientations, and spacings

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(disordered) than for rows of similar figures of identical length and spacing, perpendicular to the aligned edge (ordered). Here we use two new measures (the second one, objective) confirming the order-within-disorder principle. Using paired comparison, 6 rectangles, each containing 8 contours, were ordered with respect to appearing to be a hole. This appearance increased monotonically with the orientation range of the contours. Second, some of Gillam and Chan's figures were presented binocularly with disparity at an oblique alignment producing an illusory contour in depth. Depth thresholds were lowest for the disordered condition, showing cooperation between disorder and disparity cues to occlusion depth. The disorder principle, which has major ecological significance, needs to be incorporated into models of segmentation. [Supported by ARC DP0559897 to BG and BA.]

◆ **Ultra-rapid object detection in natural scenes: How fast is it in non-human primates?**

P Girard, H Kirchner (CNRS-UMR 5549, Toulouse, France;
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In a choice saccade task, in which two scenes are flashed simultaneously for a short time period, human subjects can initiate a first reliable saccadic eye-movement response to the side of the target object with a minimum reaction time of 120 ms (Kirchner and Thorpe, 2006 *Vision Research* **46** 1762-1776). How fast can this task be performed by non-human primates? Macaque monkeys were trained to perform the same forced-choice categorization task as the one used in humans. To test the generalization process, new pairs of target and distractor images were introduced every day. Accuracy levels were comparable both with new and well-known images (75% vs 88%). More importantly, one of the monkeys had a minimum reaction time of 100 ms. Given that onset times in IT are about as long as this behavioural response time, we conclude that visual processing involved in performing the task might be based on rather simple shape and form processing as can be seen in area V4.

◆ **What really happens to illusory contour figures in heterogeneous contexts?**

P Guardini (Department of General Psychology, University of Padua, Padua, Italy;
e-mail: pietro.guardini@unipd.it)

Illusory contour figures have been widely researched against homogenous backgrounds. Many studies demonstrated that illusory contour clarity and brightness enhancement may be separately influenced by manipulating the position and aspect of inducers. Very little is known, however, about the third phenomenal attribute: depth stratification. This percept, quite ephemeral in common conditions (ie against a homogeneous background), can be significantly enhanced when the inducers are seen against a heterogeneous background (Purghé, 1998 *Perception* **27** 337-340). Here, Gaussian-noise textures were employed in two rating-scale experiments to explore how observers' judgments on the three aspects are affected by the use of a heterogeneous background. In experiment 1, depth stratification was reported more strongly in heterogeneous than in homogenous conditions. In experiment 2, texture coarseness was manipulated to determine how depth stratification is affected by linear elements of different sizes in the background, and to relate the variation to contour clarity and brightness enhancement. Results suggest that depth stratification is independent from contour clarity and brightness enhancement.

◆ **What might have been is an abstraction, a perpetual possibility, in a world of speculation: We are not aware of what we did not see in an ambiguous figure**

M Kubovy (Department of Psychology, University of Virginia, Charlottesville, USA;
e-mail: kubovy@virginia.edu)

Considerable evidence supports the idea that perceptual organization happens late. This paper undermines this view and provides evidence that perceptual organization happens at an early stage of information processing. I report on six experiments in which a second-choice paradigm borrowed from early studies of signal detection was used (and provided strong evidence against high-threshold theories of detection) and apply it to the forced-choice phenomenological psychophysics of perceptual organization. These experiments show that when observers report one organization of an ambiguous pattern (a 300 ms masked dot lattice), they have no information about what they did not see, even when they know that they will be asked to provide information about organizations that are not the most probable. The experiments also reveal that in the face of this dearth of information about what they did not see, observers use a strategy to confabulate: they choose the answer most different from the one that corresponds to what they saw. [Supported by USPH grant from the National Eye Institute and the National Institute of Deafness and Communicative Disorders.]

- ◆ **The role of large structural regions of different luminance in rapid scene identification**
J Li, J-P Gaillard, N Portolan[¶], B Marquet[¶] (Department of Psychology, University of Rennes 2, Cesson-Sévigné, France; [¶] France Telecom R&D, Cesson-Sévigné, France; e-mail: jingqiang.li@orange-ftgroup.com)

Neural imaging results suggest that there may be separate cortical areas supporting object and scene identification (Epstein and Kanwisher, 1998 *Nature* **392** 598–601). Therefore, rapid scene identification could be based directly on certain scene-level features without requiring the identification of any of the specific objects. These features include large volumetric shapes (geons) or other similar large-scale image features. Studies on eye movements in scene perception suggest that the local contrast of luminance is related to fixation sites (Reinagel and Zador, 1999 *Network: Computer and Neural Systems* **10** 341–350). In our study, the scenes are transformed into images with only certain structural regions of different luminance (without any information about the objects). Those images were used in a go/no-go paradigm of rapid scene identification, where each subject's answer (true or false) and reaction time were recorded. The results suggest that in rapid scene identification there might be a pre-identification mechanism based on structural regions of different luminance.

- ◆ **Maybe they are all ellipses: Uncertainty about the assumptions influences cues' weights**
C M P Muller, E Brenner, J Smeets (Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; e-mail: c.muller@fbw.vu.nl)

Humans judge surface slant from a weighted average of cues, with more reliable cues receiving more weight. Cues that provide more precise estimates are obviously more reliable, but many cues also rely on assumptions about the statistics of the world. For instance, many monocular slant cues rely on the assumption that the surface in question is isotropic. Is the possibility that this assumption is incorrect considered when assigning weights to the cues? Are only the statistics of scenes in general considered, or also specific information from the scene in question? We asked subjects to match the slant of an elliptical target (with monocular and binocular cues indicating slightly different slants) by setting the slant of a large surrounding surface. To strengthen the assumption that the (textured) target was isotropic (circular) it was rotating without its outline changing and the surrounding surface consisted of rotating circles. For comparison, we presented static targets surrounded by rotating ellipses with various aspect ratios. In none of the conditions we found that changing the assumption about the aspect ratios significantly influenced the monocular cue weights.

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- ◆ **Shadow processing: Top – down or bottom – up?**
G Porter, A Tales, T Troscianko, U Leonards (Department of Experimental Psychology, University of Bristol, Bristol, UK; e-mail: Gillian.Porter@bristol.ac.uk)

The existence of an automatic shadow discounting mechanism in the visual system (Rensink and Cavanagh, 2004 *Perception* **33** 1339–1358) is still under debate (eg Elder et al, 2004 *Perception* **33** 1319–1338). Revisiting Rensink and Cavanagh's search task, we found that, independently of the exact task requirements (target-present/target-absent or target-present only), search was slowed for upright shadow stimuli relative to inverted, but not for a control condition in which neither stimulus orientation could be interpreted as shadows. Differences emerged consistently in absolute reaction times but not search slopes. Similarly, only the number of eye movements but not fixation durations increased in the shadow-like condition. Taken together, our data are in line with Rensink and Cavanagh's observation that shadow-like images are difficult to process. However, rather than an automatic bottom–up driven mechanism to discount shadows, our data suggest the existence of a top–down mechanism that leads to delayed processing of shadow-like stimuli.

[Supported by the BRACE Charity.]

TEMPORAL VISION

- ◆ **Impairment of in-stream target identification when stream items appear perceptually individuated as an invariant, static stimulus token**

T Bachmann, K Hommuk (Center for Behavioural and Health Sciences, University of Tartu, Tallinn, Estonia; e-mail: talis.bachmann@ut.ee)

When successive targets are presented within a stream of spatially overlapping, formally invariant items, 20-Hz condition involving perceived flicker allows higher rate of correct target identification than 60-Hz condition without flicker (Bachmann and Sikka, 2005 *Acta Psychologica* **120** 19–34). This effect can be related to higher apparent contrast of stream items in the 60-Hz condition or to static appearance of stream-item tokens. Here, we normalised the stream-item

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contrast so that stream items in the 60-Hz condition appeared as having equal apparent contrast to those of the 20-Hz condition. Target-identification rate in the 60-Hz condition with normalised contrast-level increased compared to high-contrast-level condition, but it remained lower than in the 20-Hz condition of flickering presentation of stream items. Results show a difficulty in target identification when stream-item tokens appear subjectively as a static, invariant object extended in time. Difficulty of target token individuation in stream impairs type identification. When targets are presented within the first epoch of stream (50–80 ms from onset), first target unusually prevails over second target.

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◆ **Large contrast effects in the discrimination of short temporal intervals**

E della Rocca, D C Burr (Dipartimento di Psicologia, Università degli studi di Firenze, Florence, Italy; e-mail: leonoradr@gmail.com)

Several studies suggest that the mechanisms involved in coding short, sub-second durations are different from those in encoding longer durations. We examined the effect of temporal distractors on interval discrimination. Subjects compared the duration of the second interval in a three-flash sequence with the interval between a two-flash sequence. For short durations, the presence of the irrelevant distractor interval affected the apparent duration of the test duration in a contrasting manner: short distractors caused it to appear longer, and vice versa. For very short probe durations (< 100 ms) the effect was large, changing perceived duration by up to a factor of two. For longer probe durations the effect of distractors reduced steadily, to no effect for durations greater than 500 ms. The results for visual flashes, auditory tones, and brief vibrations were similar, implying the existence of two mechanisms for timing brief events, one for short intervals (less than 500 ms), and another for longer intervals, and that the transition between the two is gradual.

◆ **Does flat mean slow? LCD monitors and their temporal precision for visual experiments**

T Elze, T Lochmann, T G Tanner ¶ (Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany; ¶ Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: Tobias.Elze@mis.mpg.de)

Up to now, the vast majority of psychophysical experiments requiring a high precision of visual stimuli are performed on cathode-ray-tube (CRT) monitors. These devices have been standard computer monitors for decades, and their temporal characteristics are well known. However, the production of most CRT monitors lines has been discontinued owing to the wide adoption of flat liquid-crystal-display (LCD) panels for most applications. On the other hand, many experimenters still avoid using LCD monitors as their display characteristics have not yet been assessed for psychophysical purposes. This work, based on systematic measurements of different LCD panels, assesses the usability of LCD monitors in vision research with regard to their temporal precision. We compared the signals of CRT monitors with those of current LCD technologies. While timing precision and controllability of LCD monitors still lags behind those of CRT devices, technologies such as 'Overdrive' allow performing visual experiments with tolerably high precision if certain conditions are taken into account. Advice is given on selecting the best-matching technology.

◆ **Temporal lighting modulation and visual information coding mechanisms**

M E Jaén (Departamento de Luz y Vision, Universidad Nacional de Tucumán, San Miguel de Tucumán, Argentina; e-mail: mjaen@herrera.unt.edu.ar)

Temporal lighting modulations at frequencies just above the critical flicker frequency can modify some characteristics of saccadic movements. Besides, they can also interfere with micro-movements whose spectrum extends up to 100 cycles s^{-1} . In sensitive people (especially autistics), the added noise, synchronous with the signal, interferes with neural segregation processes which would explain the obtained psychophysical data. Results confirm that temporal lighting modulation of this frequency therefore affects the visual efficiency. Two experiments were carried out, one under laboratory conditions, with high illuminance levels, and the other under more ecological conditions of an office lit with fluorescent lamps. In both cases, heavily temporally modulated light, the fundamental component of which—100 Hz—has a modulation percentage of 32%, results in an increase of the task time in visual-search tests (where errors were not allowed) compared to the results obtained under lighting with low modulation percentage (3%) for the 100 Hz component and 64 kHz main frequency. These differences are statistically significant, especially in the second experiment, in which a sample of fifty students was used.

[Supported by CIUNT and ANPCyT, Argentina.]

◆ **Comparable visual temporal-order-judgment abilities in profoundly deaf and normal-hearing individuals**

E Nava, D Bottari, M Zampini, F Pavani (Centre for Mind and Brain Sciences, Università degli Studi di Trento, Rovereto, Italy; e-mail: elena.nava@unitn.it)

In several studies different types of visual abilities following profound deafness have been examined, but these studies failed to investigate temporal processing in this population as a possible emerging change after long-term sensory deprivation. Here, we tested the ability to make temporal-order judgments (TOJs) for pairs of visual stimuli in ten profoundly deaf participants and twelve normal-hearing controls. Participants judged the order of two visual stimuli appearing on a screen on opposite sides with respect to central fixation, and gave unspeeded responses. Stimuli were presented at 10 different stimulus-onset asynchronies (SOAs), in four different spatial arrangements on the azimuth. The two groups showed comparable performance in the visual TOJ task, but performed better for central than peripheral pair of stimuli, and when the first stimulus appeared at central locations in asymmetrical pairs. These findings challenge the notion that auditory deprivation affects temporal-processing abilities in other sensory modalities and reveal that visual processing is not enhanced at peripheral over perifoveal locations in the deaf group.

[Supported by Prin 2007.]

◆ **On principles of short time interval estimation by human subjects**

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A study is reported of the characteristics of the process of human perception of short time intervals. The stimuli were intervals between two thin stripes of low intensity, presented on a PC screen. The subjects were asked to estimate the intervals from the three ranges: 0.03–1.93 s (20 intervals), 0.13–3.93 s (20 intervals), and 0.03–2.97 s (50 intervals). The dependencies between subjective and physical durations were obtained for the three ranges: the dependence was approximately linear for the 0.03–1.93 range and a power function for the two other ranges. The analysis of subjects' estimation errors showed that each range included four or five intervals that were estimated more precisely than the others; the values of these durations from one range were close to the ones from the other ranges. Thus, it may be assumed that during time-interval estimation subjects create subjective discrete scales including four or five points. Such scales may agree with Miller's law (magic number 7 ± 2). Possible neuronal organization of short-time-interval perception system is proposed.

[Supported by the Department of Biological Sciences of Russian Academy of Sciences.]

◆ **Duration discrimination thresholds for brief bimodal events follow a dipper function**

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Little is known about mechanisms that time brief sensory events within and between modalities. We measured duration discrimination thresholds as a function of base duration (0–400 ms) for unimodal (auditory – auditory, visual – visual) and bimodal stimuli (auditory – visual and vice versa). The visual stimuli were 5-ms, 7-deg disks, and the auditory ones were 15-ms bursts of white noise. For both unimodal and bimodal presentations, discrimination thresholds followed a dipper function, improving with base duration up to a point of maximum facilitation, then deteriorating with the square-root of base duration. The point of maximum facilitation was around 5 ms for acoustic stimuli, 20 ms for visual stimuli, and 70 ms for bimodal stimuli. Simultaneity thresholds were also measured with a periodic unimodal or bimodal series, yielding similar values to those for a single event. The presence of facilitation for bimodal events indicates that such events are combined by a nonlinear mechanism, and that the mechanism is more sluggish than that operating with the individual senses.

[Supported by European Commission Sixth Framework Program (New and Emerging Science and Technology grant 'MEMORY').]

VISUAL SEARCH

◆ **Less is more: Visual search behaviour depends on percentage of to-be-ignored non-targets**

J S Benjamins, I Hooge, J van Elst, L Wertheim, F Verstraten (Department of Experimental Psychology, Utrecht University, Utrecht, The Netherlands; e-mail: j.s.benjamins@uu.nl)

In visual search, selecting one set of items that differs in only one feature from target (a 1-D set), while ignoring another set of items that differs in two features from target (a 2-D set) yields mixed results. We systematically varied the percentage of 2-D non-targets to determine the

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contribution of these non-targets to search behaviour. Increasing the percentage of the to-be-ignored 2-D non-targets is expected to result in increasingly faster search, since it decreases the size of the to-be-searched 1-D set. Four observers searched large displays (96–600 set size) with a percentage of 0%, 5%, 50%, or 95% 2-D non-targets (different in size and colour as opposed to 1-D non-targets differing only in size from the target). Surprisingly, the presence of 5% 2-D non-targets yields the longest search time per item. This effect of 2-D non-targets on performance is constant and independent of set size. Apparently, visual-search behaviour critically depends on the percentage of to-be-ignored 2-D non-targets.

◆ **Analyzing an SDT model of search through the joint use of classification images and magnitude estimation**

F Campanella, C Avarino ¶, M Mastrilli ¶, S Baldassi ¶ (Dipartimento di Informatica Sistemistica e Telematica [DIST], University of Genoa, Genoa, Italy; ¶ University of Florence, Florence, Italy; e-mail: ingrid@liralab.it)

The Signed-Max model of search explains set-size effect in two-tailed visual-search task, assuming an opponent integration rule of information coming from independent noisy detectors. In a series of experiments we adopted classification-images (CI) and magnitude-estimation (ME) techniques to characterize this model in tilt identification and localization tasks of an oriented target embedded among vertical distractors, with regard to high magnitude errors in visual search. CI analysis shows that templates used in the identification task, always more tilted in absolute value than the effective tilt of the target, were proportionally more tilted with increasing set size for both correct and wrong identifications, as predicted by the Signed-Max model. The data derived from ME also show this trend, but the mean reported tilt is lower than template inclination. Moreover, the Signed-Max model predicts the distribution of localization responses across locations. We conclude that CI and ME provide evidences for the Signed-Max model, though they characterize internal processes underlying, respectively, the sensory and decisional phases of visual search. [Supported by a MIUR PRIN grant to SB.]

◆ **Visual search as a real-world task: Effects of expertise on scanning**

J Keillor, J Jarmasz, N Pavlovic, M Lamb (Defence Research & Development Canada [DRDC], Toronto, Canada; e-mail: judy.smith@drdc-rddc.gc.ca)

We conducted experiments in Search and Rescue (SAR), and scanning for Improvised Explosive Device (IED) and found evidence that experience affects how visual scanning is carried out. Effects of expertise on tasks involving visual search of large areas are often elusive and it has been suggested that it may be difficult to improve performance through training. We compared experienced soldiers to novices, and observed a significant difference in eye-movement parameters in two groups as they scanned videotapes of roadsides for IEDs. Those who conducted visual search as part of their jobs carried out a more strategic search. Similarly, we found evidence in a simulated SAR task that those who were familiar with an area exhibited more strategic search patterns and were less likely than novices to designate the same targets as new. These findings indicate that experience leads to changes in how visual search is carried out.

[Supported partially by a Canadian National Search and Rescue Secretariat grant. Thanks to Elena Scourtoudis.]

◆ **Contextual effects in search for simple and superimposed-feature targets**

A Pavan, C Alberti, C Casco (Department of General Psychology, Università degli Studi di Padova, Padua, Italy; e-mail: andrea.pavan.1@unipd.it)

When an element of a static global configuration (background) moves, it can be interpreted either as local change or as a change that maintains shape invariance despite local motion. We show visual-search asymmetries resulting from background configuration that may reveal the underlying process. Search efficiency (d') for both single- (orientation or motion) and superimposed-feature contrast (motion parallel to orientation, ie iso) was generally improved by collinearity of static distractors, a global effect confirming that collinearity grouping facilitates pop-out of background discontinuity. Conversely, search for a target moving orthogonally to orientation (ortho) not only was more efficient than search for a single-feature and iso-target, reflecting joint-ortho-feature tuning (Casco et al, 2006 *Vision Research* **46** 1091–1098) but also was further improved by distractor misalignment at large set sizes. To explain the novel finding that misalignment facilitates pop-out, we suggest that aligned distractors are captured by salient local ortho motion into a global one and this may underlie perception of global invariance of contours underlying local change.

◆ **Eye dominance in visual search for a conjunction of features**

E Shneur, S Hochstein (Department of Neurobiology, Hebrew University, Jerusalem, Israel; e-mail: eshneur@hotmail.com)

We previously found a perceptual advantage for the dominant eye in feature search (Shneur and Hochstein, 2006 *Vision Research* **46** 4258–4269). We now ask if this advantage extends to conjunction search which is known to be more difficult, requiring the use of focused attention, and may depend on different levels of the cortical hierarchy (Hochstein and Ahissar, 2002 *Neuron* **36** 791–804). We determined the dominant eye of nine subjects using the Hole-in-the-Card test. Subjects viewed a briefly presented (4×4 , 6×4 , or 6×6) array of spotted squares and filled circles, followed by a masking stimulus. On half of the trials, one spotted square was replaced by a filled square—the target. Squares and circles were both distributed half red and half green so that, viewed through red–green glasses, the halves appeared to different eyes. We tested performance when the target was red vs green and subjects saw it with the dominant vs non-dominant eye. There was significantly better performance when the target was seen by the dominant eye. [Supported by US–Israel Binational Science Foundation and Israel Science Foundation Center of Excellence.]

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ORAL PRESENTATIONS

BASIC MECHANISMS

◆ Pursuit response to tritanopic stimuli

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Tritanopic stimuli (visible only to S cones) appear markedly different from generic stimuli. Motion at higher temporal frequencies is often invisible, suggesting that the S-cone pathway has little involvement in the computation of visual motion. Using a dual-Purkinje image eye tracker with stimulus deflectors, we have introduced artificial delays in the visual consequences of eye movements (transient stabilization). For delays in excess of 100 ms, this results in spontaneous oscillations of the eye, the period of which varies linearly with delay. Extrapolating the period vs delay function to its x -intercept (corresponding to a period of 0) allows estimation of the internal processing delay. The slope of the function is indicative of the control mechanism, with velocity-based control of eye acceleration predicting a slope of 4, while position-based control predicts a slope of 1. Empirically, we observe slopes near 1.5 for most stimuli tested to date (both tritanopic and achromatic). The results are consistent with an S-cone-based motion computation that drives eye movements but not perception.

[Supported by NASA's Aviation Safety Program.]

◆ Level of adaptation in the M- and L-cones regulates the S-cone input to the luminance pathway

C Ripamonti, E Crowther, A Stockman (Institute of Ophthalmology, University College

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When their signals are enhanced by intense long-wavelength adaptation, the S-cones make a small, but robust contribution to luminance, as defined by heterochromatic flicker photometry. Whether this contribution persists under other conditions of adaptation, however, remains unclear. Here, by using chromatic adaptation and/or tritanopic metamers to isolate the S-cone response, we investigate the dependence of the S-cone luminance input on adaptation. Remarkably, we find that the S-cone luminance input disappears completely when no adapting background is present, even though the same S-cone stimulus makes a clear contribution to luminance in the presence of a long-wavelength background. The dependence of the S-cone luminance input on the wavelength and radiance of the adapting background is also surprising: We find that the S-cone signal can only be measured on fields of 543 nm and longer that exceed a criterion background radiance. The S-cone luminance input is apparently silent unless the M- and L-cones are also adapted, a finding that is reminiscent of the silent chromatic surrounds demonstrated by Ingling and his coworkers.

[Supported by Fight for Sight.]

◆ Comparison of responses of retinal ganglion cells to natural and artificial images

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We recorded the rabbit's retinal responses to either classical artificial stimuli or back-and-forth transitions from homogeneous gray images to different natural scenes. Responses to natural images showed properties that one could not easily predict from responses to artificial stimuli. We describe three examples: (i) Cells were ON or OFF according to responses to luminance modulation in their receptive-field centers regardless whether the image was natural or artificial. However, ON cells responded mainly to gray-to-natural-image transitions, whereas OFF cells preferred natural-image-to-gray transitions. (ii) Some cells were sustained with natural images but transient with artificial stimuli. (iii) Surround inhibition was weak for most cells for all but a few outlier natural images. Therefore, although surround inhibition was nonlinear (division-like), cells' Volterra receptive-field models from natural images were mostly, but not always, linear. These linear models had little or no surround inhibition, but accounted well for responses to novel back-and-forth gray-to-natural-image transitions. These results emphasize the necessity to study visual cells with natural images.

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◆ **Multiresolution wavelet framework reproduces induction effects**

X Otazu, M Vanrell, C A Párraga ¶ (Computer Vision Center, Bellaterra [¶ Cerdanyola del Vallès], Spain; e-mail: ainhoa@cvc.uab.es)

Induction effects have been classified depending on the interactions between central stimuli and surroundings. When the brightness of the stimuli shifts away from the surroundings it is called contrast induction and when it shifts towards its surroundings it is called brightness assimilation. There have been attempts to model these effects with different modeling frameworks such as multiresolution decompositions based on difference-of-Gaussians (DoG). However, these results are limited to some effects while others remain unaccounted for. Here, we present a wavelet-based multiresolution computational framework, which incorporates the observer's CSF function, the target's distance, and some known nonlinearities of the human visual system, and can reproduce assimilation and contrast effects as two particular cases of a more general unified formulation. Moreover, some previously accounted for effects (such as the White effect, Mach bands, Chevreul effect) are predicted alongside the Duneon illusion, the Adelson–Logvinenko tile, and the Todorović effect. We compare the predictions of our method with existing psychophysical data. Other existing models (such as the ODOG model) are also considered.

◆ **Orientation tuning of LGN neurons and its contrast invariance**

T Naito, H Osaki ¶, O Sadakane §, M Okamoto ¶, H Sato (Graduate School of Medicine, Osaka University, Toyonaka, Japan; ¶ Medical School, Osaka University, Suita, Japan; § National Institute of Basic Biology, Okazaki, Japan; e-mail: naito@vision.hss.osaka-u.ac.jp)

It is generally thought that the orientation-selective neuron first appears at the primary visual cortex (V1). In this study, we measured orientation tuning of neurons in the lateral geniculate nucleus (LGN) in an anesthetized and paralysed cat. We found that more than 90% of LGN neurons exhibited significant orientation tuning under the stimulus condition with high spatial frequency and larger size. Next, we measured area-summation tuning curves of responses with stimuli of the optimal and null orientation and found that the significantly orientation-tuned surround suppression was observed under the high spatial-frequency condition. Our results suggest that the orientation-tuned surround suppression causes orientation selectivity in LGN. In V1, the tuning width of orientation selectivity was independent of stimulus contrast. This phenomenon is known as the contrast invariance of orientation selectivity. We also report that the contrast invariance of orientation selectivity was also observed in LGN. These results suggest a possibility that the orientation selectivity in LGN is one of the sources of orientation selectivity in the V1.

◆ **Colour coding in LGN and V1 revealed by fMRI pattern classification**

S M Wuerger, D Oxley, J-B Marsman, L Parkes (School of Psychology, University of Liverpool, Liverpool, UK; e-mail: s.m.wuerger@liverpool.ac.uk)

Pattern classification algorithms applied to fMRI brain activation patterns have recently confirmed orientation columns in the human visual cortex (Kamitani and Tong, 2005 *Nature Neuroscience* 8 679–685). We used this approach to investigate chromatic tuning at different levels of the visual processing stream. In session 1 we presented colour modulations (red–green, lime–violet, black–white) that are known to differentially stimulate neurons in the lateral geniculate nucleus (LGN-colours). In session 2 we presented observers with colours that are more closely aligned with what we perceive as focal colours, ie red, green, yellow, and blue (perceptual hues). Support vector machines were used to classify the fMRI activation patterns according to the colour stimulus applied. We find above-chance classification (about 60%) for LGN-colours and chance performance for the perceptual hues in the LGN. The data in V1 show no classification for the LGN-colours but significant classification for the perceptual hues, suggesting that V1 contains a substantial number of neurons with chromatic tuning similar to perceptual hues. [Supported by the Research Development Fund, University of Liverpool.]

HISTORY AND ART

◆ **How would Helmholtz explain Emmert's law?**

R L Gregory (Department of Experimental Psychology, University of Bristol, Bristol, UK; e-mail: Richard.Gregory@bristol.ac.uk)

A recent fMRI study finds that illusory changes of size in the Ponzo illusion correspond with changes of size of activity in the primary visual area V1 (Murray et al, 2006 *Nature Neuroscience* 9 429–434). This throws new light on functions of V1 and on the physiological basis of scaling. But does it apply to Emmert's law? If Emmert's law was represented by corresponding areas of cortical activity, it would use up the whole brain! Helmholtz suggested a general principle, which might be summarised as follows: objects are seen that would generally be assigned to the sensory

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input, modified by probabilities from the context. The suggestion is that Emmert's law is not due to size scaling, but rather to Helmholtz's principle of trading size for distance. We would expect no change of the representation in V1, if indeed Emmert's law is due to assigning size for a given distance. The law should hold over the full range of seen distances, with small deviations due to constancy scaling, as in the Moon illusion.

[Supported by the Gatsby Foundation.]

◆ **The visual physiology and sensory philosophy of Galileo Galilei**

M Piccolino, N Wade ¶ (Dipartimento di Biologia ed Evoluzione, Università di Ferrara, Ferrara, Italy; ¶ University of Dundee, Scotland, UK; e-mail: marco.piccolino@unife.it)

An important, though poorly investigated, aspect of the scientific revolution promoted by Galileo is his critical reflection on sensory physiology and particularly on vision. In spite of the importance he attributed to both experimentation and direct observation of phenomena, Galileo had a clear grasp of the fact that the senses are adapted to the basic needs of life and are not by themselves a sure path to scientific knowledge. This is particularly evident in his interpretation of telescopic observations concerning structures on the surface of the Moon, of the 'secondary light' of the Moon, of the appearance of Venus, of sunspots, and of the visibility of 'fixed stars'. Galileo drew attention to the possible fallacies of immediate visual appearances by making recourse to a series of extraordinary thought experiments; these can be seen as anticipating modern psychophysics. The epistemological foundation of Galileo's sensory physiology involved a revolutionary (Copernican) shift away from Aristotle's finalistic conception of the human senses and their communication with Nature.

◆ **Optical-geometrical illusions: The nomenclature**

G B Vicario (Department of Philosophy, University of Udine, Udine, Italy; e-mail: vicario.gb@for.uniud.it)

The various inaccuracies of the current nomenclature of optical-geometrical illusions are set forth. The Oppel–Kundt display cannot be found either in the 1855 Oppel or in the 1863 Kundt article: it has first been described by Bourdon in 1902; the Poggendorff illusion was first depicted in 1861 by Hering; Loeb's 1892 illusion is ignored in the cases of misalignment; the current Müller-Lyer display was outlined in 1892 by Brentano; Baldwin never presented an illusion of his own; Ebbinghaus (or Titchener) illusion is by Thiéry; Münsterberg simply reported a figure found in the 1897 paper by Heymans; Ponzo illusion, in its current form, cannot be found in his 1912 and 1928 works. Besides, current nomenclature, based on authors names, neglects the fact that some authors presented many and different illusive figures (for instance: Delboeuf: 108; Müller-Lyer: 83; Lipps: 192), so that any reference to the authors is useless. A nomenclature centred on figures, and not on authors, is suggested: name of the author of publication, year of publication, number of the figure (or page of the paper).

◆ **Ferruccio Tartuferi (1852–1925) and histology of the retina in Golgi's school**

N J Wade, M Piccolino ¶, P Mazzarello § (Department of Psychology, University of Dundee, Dundee, Scotland, UK; ¶ University degli Studi di Ferrara, Pisa, Italy; § University of Pavia, Pavia, Italy; e-mail: n.j.wade@dundee.ac.uk)

The cellular structure of the retina has been scrutinized since the development of achromatic microscopes in the 1820s. Receptors were differentiated and named on the basis of their morphology and the intricate connections between neural layers were slowly bared to the gaze. A major early obstacle was the difficulty of discerning the retinal structures under the microscope. The invention of the silver staining method, by Camillo Golgi (1843–1926) in 1873, transformed the studies of the nervous system. In 1887 Golgi's student, Ferruccio Tartuferi (1852–1925), applied the technique to the retina and presented beautiful illustrations of its structure. The rods, cones, bipolar, horizontal, and amacrine cells are clearly represented. Despite these clear depictions, Tartuferi retained his teacher's view that the nervous system was a connected and continuous unit by assuming that nerve signals circulated laterally in the retina through netlike structures. We have examined the work of Tartuferi and other researchers in Golgi's laboratory, particularly Giovanni Marengi (1868–1903), and contrast it with the retinal studies of Santiago Ramón y Cajal (1852–1934).

◆ **Art perception and understanding**

H Leder (Faculty of Psychology, University of Vienna, Vienna, Austria; e-mail: helmut.leder@univie.ac.at)

Art provides the prototypical material for examining aesthetic processes. Recently, we proposed an information-processing stage model that explains perceptual, cognitive, and emotional processes involved in aesthetic experiences, particularly of modern art (Leder et al, 2004 *British*

Journal of Psychology **95** 489–508). Essential is a processing stage of cognitive mastering in which it is claimed that perceivers aim to understand what they see. Cognitive challenges of both abstract art and other conceptual, complex, and multidimensional stimuli require an extension of previous approaches to empirical aesthetics, and a particular focus on the process of finding meaning in art. With respect to our model, I present studies in which the restriction of time that artworks are perceived (Leder et al, 2006 *Acta Psychologica* **121** 176–198) or the presentation of extra-information on stylistic features (Belke et al, 2006 *Psychological Science* **48** 115–135) enable the examination of the processes involved in acquiring meaning through perception.

◆ **Inconsistent perspective and emotional expression in art works**

B Kersten, R Belton ¶ (Department of Psychology, University of Bern, Bern, Switzerland; ¶ University of British Columbia Okanagan, Kelowna, BC, Canada; e-mail: bernd.kersten@psy.unibe.ch)

In this presentation we argue that an unorthodox way of using vanishing points has subtle and fascinating aesthetic effects in Renaissance art (cf Kubovy and Tyler, online at <http://webexhibits.org/arrowintheeye/index.html>). While the incorrectness of perspective is often noted, there is not a great deal of research about the emotional effect of discordant vanishing points. We tested different paintings with different subject matter in which the perspective was noticeably incorrect. We compared the respective original art work with a 'corrected' version using semantic differential scales for the affective responses and a judgment of the aesthetic value of the variants. The conflicting depth cues were registered by the visual system and, overall, we found that there were significant differences in the affective judgments. In addition, the aesthetic judgments are explained to a great extent by the emotional responses and different emotional responses were responsible for the respective aesthetic value. We conclude that inconsistent perspective deflects viewers' affective reactions and understanding of the meaning of the art work.

VISUOMOTOR INTERACTIONS

◆ **Perceived visual speed while walking: Adding to subtraction**

J L Souman, I Frissen, M O Ernst (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: jan.souman@tuebingen.mpg.de)

Perceived visual speed has been reported to be reduced during walking compared to standing still. This effect has been attributed to an automatic subtraction of part of the walking speed from the visual speed (Durgin et al, 2005 *Journal of Experimental Psychology: Human Perception and Performance* **31** 339–353). Here, we show that both the magnitude and the direction of this 'reduction' depend on visual speed. Observers compared visual speed of a simulated ground plane (presented through an HMD) while standing and walking (1.1 m s^{-1}). PSEs, estimated for three standard speeds during walking ($1.0, 2.0, 3.0 \text{ m s}^{-1}$ simulated speed), increased approximately linearly with the standard speed, with a slope > 1 . For the lowest standard speed, the PSEs were lower than the standard speed, whereas they were higher for the highest standard speed. The latter is clearly incompatible with an automatic subtraction effect. The results suggest that, contrary to what Durgin et al (2005) claim, the effect of walking on perceived visual speed is not independent of the visual speed and raise questions regarding the functional role of the subtraction effect.

◆ **New evidence against a perceptual – motor dissociation**

A Gorea, P Cardoso-Leite (Laboratoire de Psychologie de la Perception, CNRS–Paris Descartes University, Paris, France; e-mail: Andrei.Gorea@univ-paris5.fr)

The perceptual–motor dissociation is re-examined with a 2AFC detection task combined with a speeded simple and choice response-time (sRT and cRT) task. Two supraliminal annuli (S2) displayed $\pm 6^\circ$ horizontally and $\pm 2^\circ$ vertically from fixation were preceded (50 ms) by one liminal Gaussian blob (S1) displayed either within (masked condition, M) or $\pm 4^\circ$ below/above one of the two S2-annuli (not-masked condition, nM). Observers first reacted to the S1 + S2 complex by pressing one (sRT), or one of two button(s) contingent on S1 location (cRT), and then confirmed/refuted their choice (perceptual 2AFC). Under both M and nM conditions, sRT and cRT were shorter for correct than for incorrect perceptual responses (10 ms, 30 ms, respectively), with sRT for incorrect responses equal to sRT measured in the absence of S1. Hence, motor responses do not profit from non-detected targets disproving the perceptual–motor dissociation. A stochastic race model positing that the two processes operate on the same internal response but are based on distinct decision variables nicely accounts for the data.

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◆ **Automatic inhibition of sensorimotor priming by medial frontal cortex**

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Visual stimuli can rapidly and automatically activate motor plans associated with them, but it remains unclear how such priming is controlled to allow flexible behaviour. It is possible that automatic suppression mechanisms keep sensorimotor priming in check to allow alternative behavioural responses to occur. Here, we test the hypothesis that such automatic inhibition may be an important role of medial frontal areas traditionally associated with volitional control. We studied two extremely rare patients with microlesions of the supplementary eye field (SEF) and supplementary motor area (SMA), employing a masked-prime task that evoked automatic inhibition in healthy people. Our SEF/SMA patients showed a complete reversal of the normal inhibitory effect—ocular or manual—corresponding to the functional subregion lesioned. Control patients with lateral premotor or pre-SMA damage showed normal inhibition. These findings imply that the SEF and SMA normally mediate automatic effector-specific suppression of motor plans. Thus an automatic mechanism may contribute to the participation of these areas in the voluntary control of action.

[Supported by BBRSC, The Wellcome Trust.]

◆ **Does knowledge of object mass affect interception of a free-falling object?**

R Baurès, N Benguigui, M-A Amorim (Department of Motor Control and Perception,
 University Paris-Sud XI, Orsay, France; e-mail: robin.baures@u-psud.fr)

Several studies have recently provided data supporting the view that gravity can be embodied in a quantitative internal model. The internalization of the exact value of gravitational acceleration would permit to access the exact time-to-contact (TTC) when intercepting free-falling objects. However, on Earth, free-falling objects are both accelerated by gravity but also decelerated by air resistance decreasing acceleration of the object until it reaches a limit velocity. The latter depends, among other parameters, on objects mass. We tested if knowledge of ball mass helps to estimate the kinematic consequences of air resistance on the timing of the fall. Participants manipulated a light ball before intercepting it (consistent pre-information condition) or manipulated a heavy ball before intercepting the light one (inconsistent pre-information condition). Results showed no difference in performance nor in interception rate. Movement parameters (initiation, movement time, and maximum velocity) were not affected by the pre-information. Our results show that the mass of the ball is not taken into account in the execution and timing of interceptive actions.

◆ **Dissociation of visual information used for rapid manual or saccadic responses**

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In contrast to the luminance signals, signals from short-wave cones (S cones) do not project directly to the superior colliculus via the retinotectal route, and neither do they make a strong contribution to the magnocellular pathway. Therefore, comparing responses to luminance and S-cone stimuli permits us to address the role of these pathways, often assumed to play a central role in the triggering of fast reflexive eye saccades. We compared the saccade latencies and manual detection times for luminance and S-cone stimuli that were presented on the left or right of fixation. Importantly, these stimuli were equated in detectability for each participant. Our results show that both manual and saccadic detections are slower for S cone stimuli. Interestingly, this reaction time difference was found to be approximately 20 ms higher for saccadic responses (40 ms on average) than for manual responses (20 ms). This difference shows that manual and saccadic responses rely on different combinations of visual signals. In particular, this could suggest that different response outputs rely on dissociated routes.

[Research funded by the BBRSC.]

◆ **Control of reaction time variability by consequences**

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Studies of reaction time-distributions provide a useful quantitative approach to the understanding of decision processes at the neural level and at the behavioral level. Here we test the ability to independently control the median and variability in reaction times. Saccadic and manual latencies were measured in four human subjects in a 2AFC discrimination task. Subjects were trained to produce four different reaction-time distributions using an operant procedure. When low variability was reinforced, the standard deviation (SD) of latency distributions was reduced by a factor

of two and when high variability was reinforced the SD returned to baseline level. Our procedure independently affected the spread and the median of the distribution patterns. Using the LATER model, we found that changing the distribution of the noise affecting the decision process could account for these effects. Our results demonstrate that learned contingencies can affect reaction-time variability and support the view that the so-called noise level in decision processes can undergo long-term changes.

CROSSMODAL INTEGRATION

◆ Auditory – visual integration for biological motion

G Meyer, S M Wuerger (School of Psychology, University of Liverpool, Liverpool, UK; e-mail: georg@liv.ac.uk)

Recent behavioural evidence suggest that humans are particularly effective in integrating multi-sensorial biological motion (Brooks et al, 2007 *Neuropsychologia* **45** 523–530). We further tested this hypothesis by measuring reaction times and sensitivity for motion discrimination using either a point-light walker (PLW) or a scrambled PLW together with consistent or inconsistent auditory footsteps. Both signals, auditory footsteps and the PLW, could either convey a looming or a receding motion. Our main finding is that motion congruency has a differential effect on biological versus scrambled motion: congruent auditory and visual motion (both looming or both receding) yields significantly shorter reaction times than incongruent motion for the biological-motion stimuli only; no effect of congruency was found for scrambled visual motion. These differential effects are also mirrored in sensitivity changes (d'). Our results suggest that different physical constraints govern the multisensorial integration of biological and non-biological motion signals; only the integration mechanisms for biologically meaningful motion signals are direction-selective.

◆ Streaming or bouncing? Attention does not explain the audiovisual bounce-inducing effect

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Two identical discs moving from opposite points in space, overlapping and stopping at the other's disc starting point can be seen as either bouncing or streaming through each other. For silent displays, the streaming percept predominates whereas, if a sound is played when the discs touch, the bouncing percept predominates (Sekuler et al, 1997 *Nature* **385** 308). The origin of the switch from streaming to bouncing percept is not yet known. In fact, the sound can either modulate perception towards an impact-elastic event, or alternatively, distract the observer from the disc motion display. In two experiments, we used either impact-similar sounds or impact-dissimilar sounds and found that the first induce the bouncing percept whereas the latter, although as much distracting as the first (eg 20 dB more intense), render streaming and bouncing percepts equally frequent at most. We interpret the switch from streaming to bouncing percept in audiovisual displays as resulting from attention that induces a bistable percept and from perception that turns the bistable percept into a stable, bouncing percept.

◆ Effects of auditory pitch on vertical-line bisection: Bottom – up or top – down processing?

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Auditory pitch is known to influence visual spatial localisation (Mudd, 1963 *Journal of Experimental Psychology* **66** 347–352). Here, we investigated whether a similar effect is found for visual spatial attention. Subjects bisected vertical lines presented on a touch-screen monitor at different spatial locations while touch coordinates and eye movements were recorded. Lines were presented on their own or simultaneously with one of three tones (440 Hz, 880 Hz, or 1760 Hz). For no-tone conditions, a classic vertical-line bisection bias was observed. This bias decreased for the low-pitch tone and increased for the higher-pitch tones. Effects were strongest for low tones in the lower left visual field and for higher tones in the upper right visual field. First saccade landing positions also reflected a vertical-line bisection bias. However, this bias was not modulated by auditory pitch. We conclude that visual spatial attention is influenced by auditory pitch in a top–down manner, possibly due to learned associations, rather than by bottom–up multimodal integration.

◆ Effects of musical expertise on perceived audiovisual synchrony

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Psychophysical and neurophysiological evidence suggests that professional music training influences audiovisual perception. However, Miner and Caudell (1998 *Presence* **7** 396–409) point out how this

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hypothesis needs further investigation for the case of perceiving audiovisual synchrony. For this purpose, we investigated the effect of expertise on the audiovisual integration window by measuring the effects of changes in tempo and accent of a simple music pattern. Eighty-one point-light movies of a drummer performing swing groove on a drumhead (3 tempos \times 3 accents \times 9 audiovisual delays) were created. Four jazz-drummer experts and four novices were recruited for participating in the experiment. Twenty-one repetitions of each movie were presented in three separate sessions of 7 blocks, during which participants gave forced-choice judgments of audiovisual synchrony. Our results show a clear effect of expertise on perceived synchrony, as well as a negative correlation between tempo and the delay size which produced the best perceived synchrony (Arrighi et al, 2006 *Journal of Vision* **6** 260–268), though this correlation varied with accent condition.

[Supported by the British Academy.]

◆ **Altering cue reliability changes visual – auditory perception within seconds**

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Multimodal (visual–auditory) information is combined by weighting unimodal signals by their relative reliabilities. Reliability in real-world stimuli, however, does not remain constant. Here we ask whether the system adjusts the weights online in the McGurk effect. Subjects were presented with an audiovisual recording of an actor's face producing a series of syllables. Such syllables were composed either by consistent multimodal information, or by auditory /ba/ and lip movement of /ga/. Subjects' task was to continuously report the perceived syllable. We varied the reliability of the visual information by changing the visibility of the face. With inconsistent multimodal information, increased reliability of the visual signal biased perception towards the illusory /da/ percept whereas decreased reliability biased perception towards the auditory /ba/. However, changes in reliability had perceptual consequences only after 3–4 s. Therefore, the reliability estimate of the sensory signals is not instantaneous but continuously updated with a time-constant of a few seconds. [Supported by EU grant 27141 "ImmerSense", SFB 550-A11, and the Max Planck Society.]

◆ **Audio-visual integration in the perception of tap dancing**

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We measured thresholds for discriminating light-point tap dancing scenes using visual, auditory, and combined information. A dance sequence was filmed with three distinct visual markers positioned on each foot. Both the visual and audio sequences were then thresholded, and the visual markers and auditory taps substituted with circular disks and a stereotyped tap, to produce controlled light-point sequences. Subjects were required to discriminate in forced-choice which of two 3 s noise-embedded intervals contained a light-point dance sequence (rather than a scrambled sequence). Sensitivity was defined as the noise level corresponding to 75% correct discrimination. After equating visual and auditory sensitivity with unimodal measurements, sensitivity was measured bimodally with the auditory sequence in-phase and out-of-phase. The in-phase presentation improved thresholds substantially, by a factor of about 2, while the out-of-phase presentation only by a quarter of this value, more consistent with probability summation. The results suggest that, unlike simple translational motion, biological motion shows complete audio-visual integration.

COLOUR

◆ **Improved colour sensitivity during smooth-pursuit eye movements**

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Contrast sensitivity for peripheral, luminance-modulated stimuli is attenuated during smooth-pursuit eye movements compared to fixation. Since analogous suppression effects during saccadic eye movements were shown to be specific to stimuli mediated by the parvocellular system, we wanted to explore whether this is true for pursuit as well. We therefore measured the sensitivity for colour and luminance stimuli during pursuit and fixation. Subjects had to track a spot that was stationary (fixation) or moved horizontally (pursuit) with a velocity of 10.57 deg s^{-1} . Contrast sensitivity was measured by means of a blurred 0.3 deg wide horizontal line that appeared for 10 ms 2 deg above or below the pursuit trajectory. The line was defined by an increment or decrement in luminance or in isoluminant red–green colour. The subjects had to indicate whether the line appeared black, white, red, or green. The results show that contrast sensitivity

for luminance stimuli is reduced by 22% during pursuit. For colour stimuli the pattern is reversed, showing a 22% increased sensitivity during pursuit.

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◆ **Chromatic contrast responses in LGN and superior colliculi studied with high-field fMRI at 7 T**

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Chromatic signals are transmitted into cortex via the lateral geniculate nucleus (LGN) and the superior colliculi (SC); these subcortical structures have not been studied in humans with cone-contrast controlled stimuli. We investigated the BOLD responses in these subcortical regions using various cone-contrast levels. Sixteen axial slices covering cortical, tegmental, and thalamic regions were measured with a Siemens 7 T MR scanner (in plane resolution 1.38 mm × 1.38 mm), slice thickness 1.5 mm (gap 0.3 mm). Visual stimuli were checkerboards containing a central fixation marker ($\pm 18^\circ$). Two directions in cone-contrast space were employed with four contrast levels each (L – M: 1.75%, 3.5%, 7%, 14%; L + M: 7%, 14%, 28%, 56%). Contrast sensitivity was found to be higher in the SC as compared to LGN responses. Hemodynamic responses in the superior colliculi exhibited predominantly a luminance (L + M) preference, while LGN responses appeared more heterogenous. However, throughout the LGN, clusters preferring color-opponent stimuli were intermingled with clusters preferring luminance stimuli. Hemodynamic response amplitude is substantially higher in cortical regions than in subcortical regions at equal cone contrast. In conclusion, chromatic preferences differ substantially between the LGN and SC.

◆ **Colour appearance influenced by naturalness of a scene**

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We usually recognize colour of objects with no difficulty because we can easily recognize the structure of a space and illumination in a natural environment. If we were thrown into an unnatural environment, we would not be able to construct those recognitions correctly and fail to have good colour constancy. To show the importance of naturalness to colour constancy, we studied how colour appearance was affected by an unnatural viewing condition where a spatial structure was distorted. Observers judged the colour of a test patch placed in the center of a small room illuminated by white or reddish lights. In a natural viewing condition an observer saw the room through a viewing window, whereas in an unnatural condition the scene structure was jumbled by a kaleidoscope-type viewing box. The immediate surround of the patch was the same in both conditions. The degree of colour constancy decreased in the unnatural viewing condition, suggesting that naturalness and spatial factors play an important role in colour constancy in a complex environment.

◆ **Modelling with flying colours: The application of the RadGrad model to chromatic Hermann grids**

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It is known that illusory spots are chromatic in chromatic Hermann grids. So far, no model has accounted for the colour of spots in Hermann grids comprising any arbitrary colour pairs. We present an overall theoretical model for the chromatic Hermann-grid illusion by introducing an additional principle to the RadGrad model (Geier et al, 2007 *Perception* in press): Hermann grids are split into RGB channels, resulting in three separate images. The RadGrad simulation is run on each of them. Finally, the three outputs are rejoined into one, resulting in spots of definite colour in the intersections. In order to compare the simulation results with perception, subjects ($N = 31$) adjusted the colour of real spots until they were the same colour as the illusory ones. We found that the colour of the spots is aptly predicted by the model (except for iso-luminant cases, where further investigation is needed). Consequently, the RadGrad model, supplemented by the principle of separate processing on RGB channels, is an adequate theoretical model for the Hermann-grid phenomena.

◆ **Lateralisation of colour categorical perception: A cross-cultural study**

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Categorical perception (CP) of colour is shown when discrimination is faster and more accurate for two colours from different colour categories than for two colours from the same category,

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even when chromatic separation sizes are equated. This effect is stronger for the left than the right hemisphere (Drivonikou et al, 2007 *Proceedings of the National Academy of Sciences of the USA* **104** 1097–1102). Here we assess the involvement of language in CP and its lateralisation. Using a target detection task where coloured targets were presented on same- or different-category backgrounds, we tested for CP in English, Greek, and African speakers. These languages segment the colour space in different ways. For example, Greek has two basic blue terms (ble and galazio), and many African languages have one term that includes blue and green. CP was shown by faster detection of targets on different- than same-category backgrounds. However, lateralisation of CP was only found when category boundaries were marked by the language. The findings are related to the debate about the nature and origin of colour CP.

◆ **Colour slew-rate: Chromatic pathways are limited by a maximum rate at which they can signal changes in colour**

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At low to moderate flicker frequencies (4 to 10 Hz), the overall mean colour appearances of M- and L-cone-isolating sawtooth stimuli depend on whether the direction of the sawtooth is rapid-on (|\\|\\|\\|) or rapid-off (/|/|/|/). Rapid-on-L-cone and rapid-off-M-cone sawtooth stimuli appear greener, while rapid-off-L-cone and rapid-on-M-cone sawtooth stimuli appear redder, even though they have the same mean chromaticities. These changes can be explained by supposing that chromatic mechanisms are better able to track the slowly changing phase of the sawtooth than its fast phase. Thus, their mean output will always be skewed in the direction of the slow change. By investigating how colour appearance depends on the slopes and amplitudes of the sawtooth waveforms we can determine the temporal properties of the underlying chromatic mechanisms. Our results are consistent with a simple model of red–green colour-opponent processing that is limited by a maximum rate of change in the colour signal from red to green or vice versa (the colour ‘slew-rate’).

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VISUAL COGNITION

◆ **Ultra-rapid categorization in pigeons**

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Rapidly flashed images may encourage subjects to make rapid instinctive decisions on the basis of the first rapid pass through the visual system. Humans and monkeys are known to detect targets in pictures with a high rate of success in such tasks. Here, we investigated the ability of pigeons to solve a series of categorization tasks within time spans ranging from 100 ms to 10 000 ms. Therefore, pigeons were trained in a modified go/no-go procedure to discriminate between both simple geometrical stimuli (experiment 1) and colour photographs (experiment 2). Each session comprised the whole range of presentation times, and response rates associated with the individual times spans were measured. Although there was some impairing effect of shorter presentation times on discrimination performance, the pigeons were, for the most part, able to correctly classify the presented stimuli even when flashed very briefly. Furthermore, discrimination of stimuli differing only in shape was found to be more difficult than that of stimuli differing in colour. This effect was particularly obvious at very short presentation times.

◆ **PPA and OFC correlates of beauty and ugliness: An event-related fMRI study**

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We tested the hypothesis that neural correlates of beauty and ugliness may have different brain function. Subjects ($N = 14$) viewed and rated a large number of Japanese paintings (3 categories: landscape, still life, and portrait). Regardless of category, the paintings were judged to be beautiful or ugly prior to fMRI session. Based on the rating, selected stimuli in the 3 categories were viewed in the scanner. Each stimulus was presented for 2 s with an ITI of 3–4 s during which the subject fixated a central cross. The subjects were asked to press one of three buttons in the scanner for each painting corresponding to ugly, neutral, or beautiful. Results showed major differential activation in the brain: the right orbitofrontal and the right amygdala for ugly paintings; the left parahippocampal place area for beautiful paintings. Both ugly and beautiful pictures shared common activation area in the anterior cingulate cortex, frontal pole, and medial

prefrontal cortex. These findings confirm the validity of our hypothesis on distinct neural correlates of beauty and ugliness.

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◆ **The development of category learning strategies**

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One fundamental aspect of human development is the broadening and refining of conceptual knowledge, which enables better understanding of objects and scenes. Concepts can be learned and refined by either identifying attributes shared by objects within specific categories, identifying the attributes discriminating objects from different categories, or both. In a recent study we found that some adults fail to learn categorization rules when presented only with pairs of exemplars known to be from different categories, even when the objective information provided is sufficient. Following these findings, in the current study we compared the performance of adults with that of children. We discovered that, when presented only with objects known to be from the same category, children learned the categorization rules as well as adults. However, when presented only with exemplars from different categories, most children, unlike adults, failed to learn the categorization rules. This difference between learning from pairs of the same vs different categories may explain known developmental phenomena related to the acquisition of concepts.

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◆ **Ambiguous patterns doubly thrilling: Memory of appearance diverges from appearance**

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The phenomenal appearance of an ambiguous pattern typically persists across lapses in stimulation: earlier appearance leaves a memory trace favouring identical appearance once stimulation resumes (Leopold et al, 2002 *Nature Neuroscience* 5 605–609). Having previously characterized the time scales on which this memory builds and fades, we simultaneously monitored spontaneous reversals of phenomenal appearance and the time evolution of memory states. Observers reported the instantaneous appearance of an ambiguous pattern, which was interrupted occasionally but mostly present continuously. After each interruption, initial appearance reflected memory state: whether appearance ‘stayed’ or ‘changed’ depended on recent history and, in particular, on the relative duration of recent dominance periods. Surprisingly, the inferred memory state was highly stable and reversed only after markedly unbalanced dominance episodes. In consequence, memory and perceptual state (instantaneous appearance) frequently diverged. This dissociation suggests that ambiguous patterns engage two representations which reverse independently: one controls instantaneous appearance and the other holds a cumulative memory of past appearance. Thus, multi-stability is even more complex and thrilling than suspected!

◆ **Count your eggs before they hatch: Enumerating static and dynamic visual stimuli**

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An extensive literature on the enumeration of static visually presented objects reports that, below five items, the time taken to enumerate them rises relatively slowly with their number; above this limit, the time taken rises far more quickly. In the former case, subjects are said to be subitizing, whilst in the latter they are counting. We used three types of dot field to reveal the effect of motion on human enumeration performance: (i) static, (ii) moving with an interstimulus interval, (iii) moving without an interstimulus interval. Reaction times for condition (i) were similar to condition (ii), replicating previous findings (Trick et al, 2003 *Memory and Cognition* 31 1229–1237), but longer in condition (iii) for stimuli with more than two dots, covering both subitizing and counting ranges. We hypothesise a common enumeration process for static [condition (i)] and long-range motion stimuli [condition (2)], and a less efficient process for short-range motion stimuli [condition (3)]. These data address the ongoing debate between pattern recognition and attentional theories of enumeration.

◆ **Reasoning by exclusion in pigeons, dogs, and humans**

U Aust, F Range, M Steurer, L Huber (Department of Neurobiology and Cognition Research, University of Vienna, Vienna, Austria; e-mail: ulrike.aust@univie.ac.at)

Exclusion learning in six pigeons, six dogs, six students, and eight children was investigated, for the first time, under almost identical experimental conditions. The subjects were trained in a computer-controlled forced two-choice procedure to discriminate between photographs of eight

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everyday objects (4 S+, 4 S−), and were then tested with displays consisting of one S− and one novel (ie undefined) stimulus (S′). One pigeon, three dogs, and almost all humans preferentially chose the S′, thereby showing evidence of choice by either exclusion or novelty. To decide between the two strategies, these subjects were then tested with displays consisting of one of the S′ and one novel stimulus (S′′). Whereas the pigeons preferentially chose S′ and thus by novelty, dogs and humans maintained their preference for S′, thereby showing evidence for reasoning by exclusion. The results suggest that dogs and humans, but not the pigeons, were able to infer by exclusion class membership of the undefined stimuli, a process also known as ‘fast mapping’.
[Supported by the Austrian Science Fund (FWF).]

ACTION AND VISION

◆ **Bluffing bodies: Inferring intentions from actions**

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Recent findings suggest that a close link between perception and action allows us to infer others’ action goals by observing their actions. The degree to which observed actions are part of one’s own action repertoire should affect how well action outcomes can be inferred. To test this idea, we showed expert basketball players and novices short video clips and static images of a basketball player. The player was either making a pass or a fake, and the displays did not show the final part of the action. Participants judged whether the player would make a pass or a fake. Both experts and novices showed some prediction abilities for static images. For movies, expertise determined how accurate the predictions were, experts showing significantly better performance than novices. Further experiments revealed that, when only dynamic information was presented (point-light displays), experts’ performance resembled their performance for videos, whereas novices’ predictions were at chance. These findings suggest that one’s own action repertoire plays a crucial role in using dynamical action cues for prediction.

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◆ **How archer fish hunt freely moving objects**

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Archer fish are renowned for their specialized hunting technique: they use streams of water to shoot down airborne prey, even if this prey moves rapidly. As we know from recent literature (eg Schuster et al, 2006 *Current Biology* 16 378–383), training with horizontally moving objects suffices to succeed in this three-dimensional task. Additionally, archer fish can learn to hit moving objects by watching successful conspecifics. In this study, a group of 17 fish was presented with free-moving flies, and their behaviour was filmed for detailed analyses. Results showed that shooting archer fish directly target their prey’s position. But the fish were unable to hit flying objects because the flies moved away from their position during their flights; the flies took irregular trajectories and the fish had no training opportunities with gradually increasing velocities. However, the fish improved their accuracy through learning: they managed to hit sitting flies immediately after their landing. By shooting first, more active fish successfully prevented conspecifics from practicing. Crawling flies elicited no learning effect.

◆ **Perception and understanding of others’ actions and brain connectivity**

M A Pavlova, A N Sokolov ¶, I Krägeloh-Mann (Developmental Cognitive and Social Neuroscience Unit, Children’s Hospital, University of Tübingen Medical School, Tübingen, Germany; ¶ University of Ulm Medical School, Ulm, Germany; e-mail: marina.pavlova@uni-tuebingen.de)

Perception and understanding of dispositions and intentions of others through their actions is of immense importance for adaptive behaviour and social communication. We ask whether, and, if so, how this ability is impaired in adolescents with periventricular leukomalacia (PVL) that affects brain connectivity. Visual event arrangement (EA) task was administered to PVL patients and two control groups: premature-born and term-born adolescents without brain abnormalities. Performance on the EA task was significantly lower in PVL patients. It was inversely related to the extent of parieto-occipital PVL bilaterally, and to the right temporal PVL. Whereas impairments in biological motion processing and visual navigation in PVL patients are associated with parieto-occipital lesions, difficulties in the EA task are specifically linked to the right temporal PVL. For the first time, we show that the severity of the right temporal PVL can serve as a predictor of the ability for perception of others’ actions. We assume that impairments in this ability are caused by disrupted brain connectivity to the right temporal cortex, social region.

[Supported by the German Research Foundation (DFG).]

◆ **Does perception of escalator initiate a habitual motor program even before stepping on a stopped escalator?**

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When we step on a stopped escalator, we feel a weird sensation (eg imbalance of posture). This phenomenon is widely known, but exact behavioural property during this action remains unclear. To reveal this point, we compared the performance to stopped escalator (SE) with those to moving escalator (ME) and to wooden stairs (WS) which duplicated the structure of stopped escalator (ie the first step is shorter than other steps). We found the following results. First, while walking velocity in ME condition before stepping is increased to step on a moving step, the velocity in SE condition did not increase and was similar to that in WS condition. Second, once stepped on, drastic posture forward sway was observed in SE condition, but not in WS condition. These results suggest that we correctly recognize the state of the escalator before stepping on, and that the forward-sway posture which would be assumed to link with weird sensation is not due to the structural nonuniformity but to the actual interaction with stopped escalator. [Supported by JST ERATO Shimajo Implicit Brain Function Project.]

◆ **Aging of action: A problem of slowing not of execution in both automatic and inhibitory pointing movements in the elderly**

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The online correction of a reaching movement in response to a target displacement has been named automatic pilot for the hand. It has been previously shown in young subjects, that these online corrections still occur despite a stop instruction, but surprisingly there has been no study of the degree to which the capacity to inhibit this type of automatic response declines with age. Here, for the first time, we compared young adults with an elderly group in their ability to either adapt their pointing trajectory or interrupt their movement in response to a target location shift. Interestingly, we found no accuracy decrease with aging on both tasks, as the elderly group was as good as the younger when correcting or stopping their ongoing reach. However, the older sample was found to be significantly slower both when initiating and executing these two types of movement. We interpret these results as being evidence for a general slowing in the elderly of both automatic and inhibitory processes of goal-directed movements.

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◆ **Assessing postural reactivity to dynamic visual information as a function of age: A fully immersive virtual reality study**

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We assessed the development of postural reactivity to a dynamic visual environment using an FIVR environment. Thirty-one typically developing participants of different ages (5–7 through 20–25 years) were asked to stand within a virtual tunnel that oscillated (antero-posterior) at three different frequencies (0.125, 0.25, and 0.5 Hz). Body sway (displacement relative to oscillation frequency) and instability index (total displacement) were measured. Most 5–6 year old participants were unable to remain standing during the dynamic conditions. For older participants, sway decreased significantly with age for all frequencies. Instability decreased significantly from the 8–11 through 16–19 year age groups (greatest decreases for 0.5 Hz, followed by 0.25 and 0.125 Hz conditions). No difference of frequency or instability was found between the 16–19 and 20–25 year old groups. Results suggest an over-reliance of visual input relative to proprioceptive and vestibular systems on postural regulation at young ages (5–7 years). The finding that postural instability decreased significantly with age before stabilizing between 16 and 19 years suggests a critical period for sensorimotor development.

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◆ **Visual processing of human walking after left cerebellar lesion removal**

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Brain imaging indicates involvement of the cerebellum in visual processing of human locomotion. Here we present psychophysical findings in neurosurgical patients with left cerebellar lesions. The data reveal that, in comparison to healthy controls, cerebellar patients exhibit a lower sensitivity to a point-light walker. Detectability of human locomotion by patients with left lateral

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lesions is worse than detectability by patients with midline lesions. We also report a patient SLO with an extensive left cerebellar lesion. Her pre-operative sensitivity to point-light displays representing human locomotion was at a chance level. Post-operative assessment conducted eight months after neurosurgery revealed substantial improvement of the visual sensitivity so that it approached the level of healthy controls. Two years after neurosurgery, her visual sensitivity had reached the level of controls. The findings contribute to a better understanding of the role of the cerebellum beyond a purely motor domain, and its functional plasticity. Combination of psychophysical and brain imaging is required for precise determination of cerebellar regions engaged in the network subserving biological motion processing.
[Supported by the German Research Foundation (DFG).]

APPLIED VISION

◆ **Service and return in table tennis: Visual cues and selection of the right information**

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Table tennis is a fast ball game and players must make immediate decisions in order to perform a correct motor action later. In this sport, the different skill levels are extremely evident. For example, in squash (Abernethy, 1990 *Perception* **19** 63–77) expert players use visual cues provided by the opponent player to predict with more accuracy and in advance where the ball will arrive. For these reasons correct anticipation before the ball is struck is the basis for an accurate motor response later. In this experiment, we compared two groups of table tennis players having different levels of expertise in a video task focused on the prediction of the location of arrival and the trajectory of a table tennis ball. Results show that expert players more accurately predict the trajectory of the ball by recognizing the right visual cues from body, bat, and ball trajectory of the opponent player. Data are interpreted within the perception and action model.

◆ **Analysis of the perceptual processes activated by tennis players in responding to the service**

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Visual processes and their influence in cognitive and motor activities have a determinant role in ball sports; in fact, the possibility to anticipate the trajectory by means of observation strategies will inevitably result in time and energy saving for the athlete. In this research, the importance of anticipating the response to the service was analysed; in particular, we decided to observe if a difference existed in the directional anticipation of the service among tennis players of different expertise. Results demonstrated how the experimental study of the perceptual activity of the athletes is at the base of the development of cognitive strategies to optimize their performance. Therefore, the visual stimulus and the perceptive methodology used are elements that allow study of the performance of the athletes as well as the development of their training, based on the consolidation of their cognitive capabilities.

◆ **Surveillance video assessment in visible and infrared displays by scanpath analysis**

T D Dixon, S Nikolov, T Troscianko, J Noyes (Department of Experimental Psychology, University of Bristol, Bristol, UK; e-mail: Timothy.Dixon@bristol.ac.uk)

The use of visible as well as infrared surveillance videos is now commonplace, and combining such inputs to create a composite sequence has been shown by the authors to improve accuracy in simple tracking tasks. In the current study, participants were asked to track visually a human target in two separate scenarios using three separate displays: visible; infrared; and 'video + infrared' side-by-side (SBS). In the 'simple' scenario participants visually tracked a lone person, whilst in the 'complex' scenario they tracked a person moving around amongst a group of people, with both scenarios shown in two natural luminance levels. Participants also made key-press responses when predefined events occurred in the video. Results showed that infrared display generally allowed more accurate tracking of human targets, although within the 'complex' scenario SBS results the visible display led to higher accuracy, in contrast to the 'simple' scenario. A range of other findings are also discussed, including relating recent results to previous research, and future directions involving the use of CCTV camera footage.

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◆ **The impact of expertise on the processing of 2-D and 3-D images: The case of minimal invasive surgery**

A Blavier, A-S Nyssen (Cognitive Ergonomics, University of Liège, Liège, Belgium; e-mail: Adelaide.Blavier@ulg.ac.be)

Although 3-D images lead to better performances than 2-D ones in reaching and grasping tasks, the effect of subject expertise on this difference has never been investigated. In order to answer this question in a natural and meaningful setting, we compared the performance of twelve novices (medical students) with that of twelve laparoscopic (2-D view) surgeons and four robotic surgeons, using a new robotic system that allows 2-D and 3-D view. Our results showed a trivial effect of expertise (surgeons generally performed better than novices). Furthermore, we showed that the effect of 2-D and 3-D view was influenced by expertise level: the performance of novices was strongly influenced by 2-D–3-D difference (they performed significantly better in 3-D than in 2-D), whereas laparoscopic surgeons accurately compensated for the loss of depth perception in 2-D view and achieved similar performance in 2-D and 3-D. Robotic surgeons, used to manipulating robotic system in 3-D, were also influenced by 2-D–3-D difference (they achieved the same performance as laparoscopic surgeons in 2-D view and a significantly better performance in 3-D). [Supported by grants from the National Fund of Scientific Research.]

◆ **Scientific presentations: What we like vs what's best**

N Stucchi, M Greco, V Graci ¶, Z Daniele (Department of Psychology, University of Milano-Bicocca, Milan, Italy; ¶ University of Bradford, Bradford, UK; e-mail: natale.stucchi@unimib.it)

The present work was driven by the observation that conference presentations by professionals of visual facts (architects, designers, and indeed visual scientists) are often poorly rated in terms of their readability. We investigated one aspect, the choice of colours employed for text and backgrounds (T&B), in two experiments. Experiment 1 was designed to test what are observers' preferences either in terms of readability or pleasantness when presented with T&Bs on a laptop: two groups of subjects (thirty per group) were presented with 702 stimuli created by combining two colours from a matrix of 27 colours. Observers rated stimuli either in terms of readability or pleasantness. Dark texts on bright backgrounds received the highest rankings for both features. Experiment 2 consisted of large projections of 364 highly ranked stimuli from experiment 1 on a white surface with 3 different environmental illuminations (dark, bright, half-light). The task was to rate stimuli according to readability. Again, only dark texts on bright backgrounds received high rankings in all 3 conditions.

◆ **Are visual models the best models to learn a specific task in sport training?**

G Righi, E Ferletic, D Furlan, A Pin, A Gherzil (Department of Psychology, University of Trieste, Trieste, Italy; e-mail: giovanni.righi@inwind.it)

Visual models are used as training strategies in sport. Usually, the athlete is shown a standard performance in a video simulation of her/his or another athlete's performance. Experimental sport-psychology research suggests the relevance of an acoustic representation of action as a model for the performance, and also that the actual performance of the athlete herself/himself should be used as a model. We investigated the effect of the use of different kinds of self-models where we manipulated the perceptual information available (visual, acoustic, visuo-acoustic) as training strategy on 20 young tennis players engaged in a serve task. Results show that there are significant differences in the learning rate among athletes trained with different kinds of model. The best result was obtained after acoustic stimulation, the worst one with a visual model, while the visuo-acoustic model led to intermediate results. Therefore, the use of a self-model in a training based on acoustic stimulation seems to help the athlete to standardise the timing of the performance.

DEPTH AND 3-D

◆ **Sensitivity to the stereoscopic depth of a moving surface in the human MT complex measured with fMRI adaptation**

A Smith, M B Wall (Department of Psychology, Royal Holloway University of London, Egham, Surrey, UK; e-mail: a.t.smith@rhul.ac.uk)

We used fMRI adaptation to examine sensitivity to stereoscopic depth in the human MT complex. On each trial, two brief, rotating dot patterns were presented sequentially. These had either the same or opposite directions of motion and were presented in either the same or different depth planes (± 1 deg disparity). There were no monocular cues to depth. In both MT and MST, the compound response was smaller (adapted) when the two had the same depth than when they were different, suggesting the presence of separate neural populations sensitive to near and far motion. The magnitude of the depth effect was similar to that of motion direction, suggesting

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equally pronounced tuning. Attention was controlled by a demanding task at fixation and control trials in which stimulus salience was manipulated, which confirmed that there was no modulation by attention. Our results suggest strong tuning for stereoscopic depth in both MT and MST, consistent with physiological results in macaques. Varying degrees of stereoscopic depth tuning were also seen in earlier visual areas.

[Supported by The Wellcome Trust.]

◆ **Calibration of the centre of projection in linear perspective**

P Mamassian (Laboratoire de Psychologie de la Perception, CNRS and Université Paris 5, Paris, France; e-mail: pascal.mamassian@univ-paris5.fr)

We rarely notice distortions of the depicted scene in a movie even though we are almost never watching the movie from the point of view of the camera. How do human observers calibrate themselves to the correct centre of projection (CoP)? An experiment is reported where participants were tested for their mislocalisation of the CoP before and after an adaptation period that provided strong information about the correct CoP. The observer's representation of the CoP was estimated with a task involving a length comparison of two sides of a rectangular parallelepiped. When observers are placed behind the correct CoP, they typically underestimate the viewing distance—they over-compensate (Mamassian, 1998 *Perception* 27 Supplement, 34). After an adaptation period where participants were presented with a rotating parallelepiped that strongly constrained the correct CoP when the object was seen as rigid, their representation of the CoP was significantly displaced. These results suggest that the rigidity assumption can help observers calibrate to the correct viewpoint in a movie theatre.

[Supported by Chaire of Excellence, France.]

◆ **Partial perceptual invariance for pictures viewed at different positions**

M S Banks, A Girshick, A Alvarez (Vision Science Program, University of California at Berkeley, Berkeley, USA; e-mail: martybanks@berkeley.edu)

Pictures viewed from the center of projection (CoP) generate the same retinal image as the original scene, so the perceived and original layouts are similar. When pictures are viewed from other locations, the retinal image specifies different layouts, but we normally do not notice the changes. We investigated the mechanism underlying this perceptual invariance, using pictured hinges. When viewers looked at the pictures monocularly through a pinhole and could not determine the orientation of the picture surface, perceptual invariance was not observed. When viewers looked binocularly without pinholes, partial invariance was observed. The amount of invariance was critically dependent on the orientation of the picture contents relative to the picture surface: less invariance when the contents were perpendicular to the surface. We also investigated how the partial invariance was achieved and found that the perceived orientation of the picture surface was critical. We discuss the relevance of these findings to several aspects of perceiving information in visual displays.

[Supported by NSF.]

◆ **Configural cues, disparity, and depth perception: internalization of natural scene statistics**

J Burge, C C Fowlkes, M S Banks (Vision Science Program, University of California at Berkeley, Berkeley, USA; e-mail: jburge@berkeley.edu)

Configural cues, like convexity, are thought to provide ordinal depth information. Yet those cues, when paired with binocular disparity, affect the magnitude of perceived depth (Burge et al, 2005 *Journal of Vision* 5 534–542). We conducted an experiment to determine whether humans integrate convexity and disparity in Bayesian fashion. Observers viewed stereograms with depth edges of varying curvature. For a given disparity, observers perceived greater depth when the edge was convex rather than concave. These data are predicted by a model in which the distribution of depth change across curved contours is skewed such that the convex side of the contour is more likely to be near than the concave side. To see if a similar relationship characterizes the natural environment, we measured the joint statistics of convexity and depth from numerous luminance-and-range images of natural scenes. The likelihoods derived from subjects and scene statistics were quite similar, suggesting that configural cues provide metric depth information and that the associated ecological statistics have been internalized by the visual system.

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◆ **Dominance of ground stimuli in vection induction**

T Sato, T Seno, H Kanaya, H Fukazawa (Department of Psychology, University of Tokyo, Bunkyo-ku, Japan; e-mail: Lsato@mail.ecc.u-tokyo.ac.jp)

It has been known that 3-D stimulus structures strongly affect vection. We compared the effectiveness of optic flows presented on the ground and ceiling planes by using random-dot motions

simulating retinal motions generated by forward motion of the observers. Subjects were exposed for 60 s to stimuli simulating motion either on the ground or on the ceiling, and subjective strength (magnitude estimation), latency, and duration were measured. We found that the ground stimuli induced significantly stronger vection than the ceiling stimuli. Similar results were obtained with horizontal motions, with motions from homogenized retinal dot-densities, or even when the ground stimuli were presented on the upper part of the screen. However, no such effect was obtained when the upper half or the lower half of the stimulus simulating dotted volume (3-D space filled with random dots) in front of the observer was presented. These results demonstrate the importance of the existence of a surface as well as the dominance of the ground in vection.

◆ **Temporal dynamics of the Venetian-blind effect**

W W Stine, J J Dobiás, R S Hetley, A L Noyce (Department of Psychology, University of New Hampshire, Durham, USA; e-mail: bill.stine@unh.edu)

When binocularly viewed with luminance or contrast disparity, individual bars of a square-wave grating appear to rotate (the Venetian-blind effect—Cibis and Haber, 1951 *Journal of the Optical Society of America* **41** 676–683; Filley and Stine, 1998 *Perception* **27** Supplement, 99). Binocularly displayed square-wave gratings with constant overall luminance (approximately 30 cd m⁻²) and modulating contrast disparities (0.1 to 1.4 Hz) were presented to produce a Venetian-blind effect rotating in a sine-wave motion (three observers). Observers were asked to judge rotation and movement of individual bars. Frequency was adjustable up to approximately 1.1 Hz without disruption of movement or depth. At frequencies above 1.1 to 1.4 Hz, the ability to judge depth and/or movement was disrupted. Regan and Beverley (1973 *Vision Research* **13** 2369–2379), on the contrary, found that when viewing stereoscopically displayed vertical bars undergoing suprathreshold sine-wave depth oscillations, movement of bars in depth was visible up to approximately 4–5 Hz. This difference suggests the recruitment of more processing in the Venetian-blind effect.

◆ **Interposition, perspective, and the principle of minimal depth**

W Gerbino, C Fantoni (Department of Psychology and B.R.A.I.N. Centre for Neuroscience, University of Trieste, Trieste, Italy; e-mail: gerbino@units.it)

Depth perception in pictorial displays depends on a set of separable cues. When interposition and perspective are the only cues, a peculiar indeterminacy problem arises. Consider a display that simulates a floating bar crossing an open box, such that the front face of the box occludes the bar, which in turn occludes the back face of the box. In such a case the depth of the bar is underspecified: the bar might be glued to the front face, floating in mid-air, or glued to the back face. However, for most observers the bar appears located just behind the occluding surface in the foreground. The effect is strong and can be observed also in 3-D objects in which the crossing bar is actually glued on the back face of the open box. Pictorial space is governed by minimal depth. Surfaces appear as close as possible to the observer. Interposition provides information about the signed order in depth (ie from the foreground to the background) of homogeneous surfaces otherwise perceived as coplanar.

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POSTER SESSION

3-D VISION

◆ **Orientation of planar cuts affects the perceived shape of 3-D objects**

N B Bocheva (Department of Sensory Neurobiology, Institute of Neurobiology, Sofia, Bulgaria; e-mail: nadya@percept.bas.bg)

The effect of the orientation of planar cuts on the perceived characteristics of objects was studied for line drawings representing 3-D objects. The stimuli were three opaque spherical objects whose shape was perturbed by adding randomly positioned peaks of equal height. Only the surface markings formed by the intersection of the object's surface with a set of parallel planes were visible. Ten different orientations of the cutting planes were obtained by rotating them about vertical and horizontal axes at angles in the range -40° to $+40^\circ$. The results showed that changes in the orientation of the cutting planes modified the perceived elongation and orientation of the objects in depth with respect to the observer. These effects depended on the direction of the orientation flow created by the surface markings, but not on their curvature. The magnitude of these effects varied among the objects studied. These variations do not appear related to variations in surface curvature, but may be related to the shapes of the occluding contours produced by the planar cuts.

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◆ **Motion noise removes the effect of visual path information on human heading estimation**
 J C K Cheng, S Khuu, L Li (Department of Psychology, University of Hong Kong, Hong Kong, China; e-mail: josephck@hkucc.hku.hk)

We have shown that visual path information helps heading estimation when the display does not contain sufficient optic flow cues (see Li et al, 2007 *Perception* 36 Supplement, this issue). Here, we investigate whether adding motion noise, which disrupts the reliability of path information, to environment points similarly affects heading perception in displays with or without path information. The display (110 deg × 94 deg) simulated motion on a circular path and observers used a joystick to rotate their line of sight until deemed aligned with true heading. Motion noise, as assigned random velocities of environmental points, was introduced to the display at levels of 0%, 25%, 33%, and 50%. Heading precision decreased monotonically with increasing motion noise in a similar manner for displays with and without visual path information (mean heading precision ± SE across six observers: 2.9 ± 0.4 deg vs 3.0 ± 0.2 deg at 0%, 4.1 ± 0 deg vs 5.5 ± 0.6 deg at 25%, 6.4 ± 0.4 deg vs 7.3 ± 0.8 deg at 33%, and 12.8 ± 0.8 deg vs 13.4 ± 0.5 deg at 50%). Motion noise is effective in removing the influence of path information on human heading estimation.

[Supported by Hong Kong Research Grant Council, HKU 7471/06H.]

◆ **An fMRI study of the pictorial cues (perspective lines, shading, shadows) contributing to depth perception in the reverse-perspective illusion**

N D Cook, T Hayashi, M Murata, N Fujimoto (Department of Informatics, Kansai University, Takatsuki, Japan; e-mail: cook@res.kutc.kansai-u.ac.jp)

We have measured brain activation in an fMRI experiment on sixteen normal subjects viewing the reverse-perspective (depth-inversion) illusion. The illusion produces a false sense of motion in a static picture as a consequence of a conflict between motion parallax and pictorial depth cues. Six stimuli were used: (i) a 140 cm × 42 cm × 17 cm reverse-perspective painting that included perspective lines, shadows, and shading (producing a reliable illusion when viewed binocularly at a distance of 3 meters), (ii) a similar painting lacking perspective lines, (iii) a similar painting lacking shading and shadows, (iv) a similar painting lacking shading, shadows, and perspective lines, (v) an unpainted wooden structure of the same dimensions, and (vi) a normal-perspective shadow box painting similar to (i) but built without depth inversion. Stimuli were presented in both static and slowly rotating conditions. Contrast between the rotating and static conditions showed activations of cortical regions involved in motion detection, mental rotation, and depth perception.

[Supported by a grant from the Japanese Society for the Promotion of Science (JSPS.KAKENHI, Grant No. 16300085).]

◆ **Head-mounted display calibration using camera calibration techniques**

S J Gilson, A W Fitzgibbon[¶], A Glennerster[§] (Department of Physiology, Anatomy and Genetics, University of Oxford, Oxford, UK; [¶]Microsoft Research Ltd, Cambridge, UK; [§]University of Reading, Reading, UK; e-mail: stuart.gilson@dpag.ox.ac.uk)

Head-mounted displays (HMDs) require accurate calibration to be used in psychophysical experiments. We calibrated an nVision DV80 head-mounted display which has an optical see-through mode. A camera mounted inside the stationary HMD recorded images of a calibration grid at different orientations. The camera also recorded a superimposed regular array of dots generated by the HMD, allowing the location of the grid corners to be re-expressed in the coordinate frame of the HMD image. We used standard camera calibration techniques to recover the optical parameters of the HMD (not the camera) and hence derive an appropriate software frustum for rendering virtual scenes in the HMD. We quantified the improvement in calibration by measuring re-projection errors between real-world and virtual points rendered to appear at the same location.

[Supported by the Wellcome Trust and the Royal Society.]

◆ **Evaluation of pictorial cues contributing to depth inversion in the reverse-perspective illusion**

T Hayashi, N D Cook, A Shiraiwa (Department of Informatics, Kansai University, Takatsuki, Japan; e-mail: hayashi@res.kutc.kansai-u.ac.jp)

The reverse-perspective illusion is a powerful visual illusion similar to the hollow-mask illusion, but more interesting in producing the perception of an illusory motion in a static picture. It is caused by conflict between motion parallax and pictorial depth cues painted on the 3-D relief. We investigated the effects of the pictorial cues contributing to depth perception in the reverse-perspective illusion. Computer-generated stereo graphics images were used as stimuli instead of real objects. To evaluate the strength of the illusion, the binocular disparity was gradually altered and the value at which the depth inversion takes place was recorded. Stereo images which contained

(i) perspective lines, (ii) shading, and (iii) shadows were prepared and the contribution of these cues to the reverse-perspective illusion was evaluated quantitatively.

[Supported by a grant from the Japanese Society for the Promotion of Science (JSPS.KAKENHI, Grant No.16300085).]

◆ **3-D illusory object perception from alternately displayed pair of pictures with slight disparity**

M Idesawa, Q Wang (Graduate School of Information Systems, University of Electro-Communications, Chofu-shi, Japan; e-mail: idesawa@is.uec.ac.jp)

We reported earlier 3-D illusory object perception with binocular viewing (Idesawa, 1991 *Japanese Journal of Applied Physics* **30** L751–L754, L1289–L1292; 1993 *Japanese Journal of Applied Physics* **32** L75–L78): illusory surfaces (planar and curved, opaque and transparent), illusory volumetric objects, and the interaction between them could be observed. We alternately displayed a pair of pictures with slight disparity in various directions and observed 3-D illusory objects almost the same as with horizontal disparity with binocular fusion. Suitable alternating periods ($0.05 \text{ s} < T < 0.5 \text{ s}$) were almost coincided with those in apparent motion perception. Surprisingly, we found that the existence of unpaired parts in the pair of images was indispensable; this was proved by using the Poggendorff probe of surface perception (Wang et al, 2004 *Japanese Journal of Applied Physics* **43** L11–L14). Alternation of a pair of pictures partially compatible and equivalent with both binocular disparity and motion parallax provides a new clue to the 3-D perceptual mechanism in the human visual system.

◆ **Learning a continuous novel depth cue to motion in depth**

H Kaneko, R Uemura, S Mukaida ¶ (Imaging Science and Engineering Laboratory, Tokyo Institute of Technology, Midori-ku, Japan; ¶ Hokkaido Information University, Ebetsu, Japan; e-mail: kaneko@isl.titech.ac.jp)

It has been shown that visual system can recruit novel cues by learning to disambiguate bistable depth perception even though the cues are uninformative geometrically (Haijiang et al, 2006 *Proceedings of the National Academy of Sciences of the USA* **103** 483–488). We investigated whether continuous change of a factor in visual pattern can be learned to be a novel cue to continuous depth. An experimental session consisted of pre-learning-test, learning, and post-learning-test phases. In the learning phase, observer moved an LCD display back and forth while viewing the stimulus presented on it. A specific factor in the stimulus (position, degree of randomness, or expression) changed systematically and continuously according to the distance from the observer. In the test phases, observer responded with perceived depth changes for the stimulus presented at a fixed distance. Results showed that changing position and expression produced depth changes after the learning phase in some observers and conditions, suggesting that the visual system of adults has enough plasticity to recruit a new continuous depth cue to changing depth.

◆ **Training in interception increases sensitivity to time-to-contact**

J T Karanka, S K Rushton, T C A Freeman (School of Psychology, Cardiff University, Cardiff, Wales, UK; e-mail: karankajt@cardiff.ac.uk)

Previous research has shown that training can improve performance in simulated interception tasks and actual catching. The ability to judge time to contact (TTC) is considered to be critical for the timing of these actions. We therefore asked whether sensitivity to TTC improves with training in a simulated interception task. Sensitivity to TTC was measured on two consecutive days using a standard 2IFC discrimination task. Inbetween these measurements, the observers were trained on a simulated interception task in which they estimated the arrival time of an approaching object while receiving feedback of the real arrival time. The range of TTCs was 0.3–0.82 s in both tasks. Five out of seven observers increased their sensitivity to TTC and the remaining two were unable to judge TTC at all. Only one of these seven observers performed in the range of three expert observers that had extensive training on the interception task. We discuss these findings, and further work on individual differences in interceptive timing. [JTK is funded by the School of Psychology, Cardiff University.]

◆ **Direct measurement of sensuous depth imaged by 3-D display observer**

H Kuribayashi, M Date ¶, H Takada ¶, S Suyama ¶, T Hatada (Department of Media and Image Technology, Tokyo Polytechnic University, Atsugi-shi, Japan; ¶ NTT Corporation, Musashino-shi, Japan; e-mail: hidekuri@mega.t-kougei.ac.jp)

The quantitative measuring method of the imaging depth using sensuous distance expression of a human is proposed. With the adjustment method, it is difficult to measure psychically perceived depth of 3-D images, because the observer can compare precisely the physical distances by optical triangulation information when he watches two targets at the same time. In our proposed method, observer presents the perceived depth as distance between forefinger and thumb. The measured

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depth agreed well with the actual depth, when observer imaged distance between two real objects aligned in depth direction. The effect of monocular depth cues (relative size, contrast, color difference) could be also confirmed. Then we measured the perceived depth when observer saw a 3-D image displayed by a DFD display, in which an apparent 3-D image was produced by only overlapping two 2-D images displayed at different depths. The results showed that DFD display can produce accurate depth as well as real objects. Moreover, the perceived depth tended to be enhanced when monocular depth cues were added synergistically.

◆ **Influence of field-of-view (FOV) size and depth range on heading perception with or without visual path information**

L Li, J Chen, X Peng (Department of Psychology, University of Hong Kong, Hong Kong, China; e-mail: lili@hku.hk)

We have previously shown that humans can perceive heading without visual path information (Li et al, 2006 *Journal of Vision* 6 874–881). Here we examine how varying two key parameters for estimating heading from optic flow, FOV size, and depth range of environmental points, influences human heading perception with or without visual path information. The display simulated an observer travelling on a circular path. Observers used a joystick to rotate their line of sight until deemed aligned with true heading. Four FOV sizes (110 deg × 94 deg, 48 deg × 41 deg, 16 deg × 14 deg, 8 deg × 7 deg) and depth ranges (6–50 m, 6–25 m, 6–12.5 m, 6–9 m) were tested. Heading bias increased with the reduction of FOV size or depth range when the display did not contain visual path information relative to when the display did contain such information (mean heading-bias ± SE: 4.8° ± 1.0° vs 2.2° ± 0.8° and 3.9° ± 0.3° vs 2.2° ± 0.5° for FOV size with $N = 5$ and depth range with $N = 6$, respectively). Human heading and path perception are independent. Path helps heading perception when the display does not contain enough optic flow information.

[Supported by Hong Kong Research Grant Council, HKU 7471//06H.]

◆ **Does the blue – yellow contrast contribute to stereo vision?**

M Ozolinsh, K Desmitniece (Department of Optometry and Vision Science, University of Latvia, Riga, Latvia; e-mail: ozoma@latnet.lv)

The contribution of the blue–yellow visual pathway neural activity in stereopsis is still under discussion. We present experimental data for real depth sensation studies with two vertical bars (one of them movable) emitting white, yellow, red, green, or blue light. Emission was produced by different-colour LED set inside the bars, that allowed varying the presentation time in millisecond range. The bars were placed in the front of LCD display; thus such setup allowed to create various colour contrast stereo stimuli and to select only red–green, blue–yellow, or luminance channel contributing to formation of stereo sense. We observed stereopsis for subjects participating in studies for all colour-contrast stereo stimuli. The lowest stereoacuity was revealed for pairs of blue-emitting bars on black background and for yellow bars on isoluminant achromatic background. The latter presents a scene where mainly the short wavelength (blue) light intensity spatial modulation contributes to the stereo disparity. We discuss stereopsis time responses induced by achromatic and different colour-contrast stimuli and analyze specific contributions of luminance, red–green, and blue–yellow pathway neural activity acting in stereopsis.

◆ **The effects of head tilt on perceived geometry of visual space**

O Tosković (Department of Psychology, Faculty of Philosophy Kosovska Mitrovica; and Laboratory for Experimental Psychology, Belgrade, Serbia; e-mail: otoskovi@f.bg.ac.yu)

In previous research it was shown that in darkness physically shorter distances towards the zenith are seen as equal to physically longer distances towards the horizon. It was also shown that different angular turns of the eye correspond to different perceived shapes of the visual space. The aim of the present research was to investigate whether the elliptical shape of perceived space is due to the head turn. Fifteen participants had the task to equalize perceived distances of three stimuli in three directions (horizontal, tilted 24.26° relative to the horizon, and vertical) while sitting on the floor, in a dark room. Customized equipment was used to present stimuli and special glasses were used to prevent subjects' eye and body movements. (i) Horizontal estimates and estimates in the 24.26° direction were longer than the standard, and (ii) estimates towards the zenith were shorter than the standard. These results suggest that, as the head tilts upwards, perceived space is being elongated, which coincides with results from previous research.

◆ **Interpretation of optic flow synchronized with self-hand movement**

H Umemura, H Watanabe (AIST, HSBE, Ikeda, Japan; e-mail: h.umemura@aist.go.jp)

We investigated the effect of a novel motor action on 3-D perception and its formation process. A stimulus was a slanted plane formed by white dots. The stimulus synchronously moved and rotated

in depth with subjects' hand movement on a tablet panel. Subjects answered the direction of its axis of rotation. The optic flow of the stimulus had ambiguity and could generally give two interpretations: one was a rotation with depth movement synchronized with the subject's hand movement, and the other was no depth movement with rotation whose axis of rotation was orthogonal to that with depth movement (Wexler et al, 2001 *Vision Research* **41** 3023–3037). We inserted training sessions among experimental sessions in which subjects manually moved the stimuli onto an instructed position. The results showed that the frequency of perception with depth movement was increased as sessions proceeded, and indicate that the visual system used the association between manual movements and object movements formed during the experiment. [Supported by JSPS grant 19500231.]

◆ **Curvature contrast governed by spatial proximity, not depth cue**

K van der Kooij, S te Pas (Department of Experimental Psychology, Helmholtz Institute, Utrecht University, Amsterdam, The Netherlands; e-mail: k.vanderkooij@fss.uu.nl)

The general geometry of a scene influences shape perception, as is demonstrated in shape contrast effects. We investigated whether spatial proximity or the nature of the depth cue is more important in inducing a curvature contrast effect. A central disparity-defined paraboloid was flanked by two inner and outer inducing paraboloids. The inner and outer inducers could be presented by different cues: disparity and structure-from-motion, or by disparity only, depending on condition. We varied the curvature difference between inducers in the reference and test interval. Observers had to decide which of the two intervals contained the central paraboloid with the highest curvature. This way, we could determine the curvature contrast effect. We found a consistent contrast effect invoked by the inner paraboloids, while the effect caused by the outer flankers was small, if any. There were no large differences between the different cue combination conditions. The main factor influencing curvature contrast seems to be spatial proximity, regardless of the depth cue that induces the effect.

◆ **Poggendorff configuration probing the temporal properties of surface perception**

Q Wang, M Idesawa (Graduate School of Information Systems, University of Electro-Communications, Chofu-shi, Japan; e-mail: wang@is.uec.ac.jp)

Opaque-surface perception could be probed from the occurrence of the Poggendorff illusion (Wang et al, 2005 *Perception* **34** Supplement, 187; 2004 *Japanese Journal of Applied Physics* **43** 1A/B, L11–L14); we investigated temporal properties of surface perception with this probe. Lines and testing opaque illusory surface composing the Poggendorff configuration were used in which the illusory or real lines were displayed continuously and the testing surfaces were displayed periodically with various durations and intervals. The duration time for the occurrence of the Poggendorff illusion needed > 280 ms (illusory lines) and > 360 ms (real lines); the interval time for obliterating the Poggendorff illusion needed > 80 ms (illusory lines) and > 60 ms (real lines). We inferred that these duration times and interval times were the reflection of the required time for surface perception and the decaying time of perceived surface. The Poggendorff configuration could be used effectively for probing temporal properties of surface perception and expected to reveal forming time and remaining time of perceptual surfaces.

COGNITION

◆ **Lateralization of social learning in the domestic chick (*Gallus gallus*)**

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Social learning allows individuals to acquire information about their environment whilst reducing the risks associated with engaging in novel experiences. At least some social behaviours (social recognition and other skills involved in establishing hierarchies) are influenced by cerebral lateralization (eg Deng and Rogers, 2002 *Animal Behaviour* **63** 697–706). Because of the asymmetric positioning of the embryos, light stimulation of eggs before hatching is giving rise to behavioural asymmetries in domestic chicks for several visual tasks. We presented 3-day old chicks, coming from eggs maintained in the light ('lateralized') or in the dark ('non-lateralized') with a social demonstrator. This was a motorized arm used to represent the hen's pecking motion which is spontaneously imitated by chicks (ie 'tidbitting'). The demonstrator signalled one bead as the target within two differently coloured beads. The chicks' response, ie pecks at the target as compared to the non-target beads, demonstrated that such a discrimination task was differently acquired by lateralized as compared to non-lateralized birds. Further experiments are required to better clarify the function of this lateralized behaviour.

[Supported by EU Project 'Evolution and Development of Cognitive, Behavioural and Neural Lateralization']

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- ◆ **Perceiving affordances in virtual environments: visual guidance of virtual stair climbing**
L L Di Stasi, P Guardini ¶, (Department of Experimental Psychology, University of Granada, Granada, Spain; ¶ University of Padua, Padua, Italy; e-mail: distasi@correo.ugr.es)
It has been argued that perceptual preferences correspond to optimal points in the animal–environment system (Warren, 1987 *Journal of Experimental Psychology: Human Perception and Performance* **10** 683–703). In particular, Warren showed that the visual preference for the riser height of the steps in a flight of stairs corresponds the energetically optimal riser, according to a minimum-energy-expenditure model. Here, we tested these findings using immersive virtual reality. In a rating-scale experiment, subjects were asked to judge the ‘climbability’ of six different stairways, with riser height varying from 12.7 to 25.4 cm. Judgments were collected in three virtual rooms where the floor was set at different height levels: 0 and ± 20 cm. Rooms were connected with long inclined corridors to keep subjects unaware of the change in their eye height. Results are in agreement with previous findings: observers gave highest ratings to the riser height predicted by the minimum-energy-expenditure model. Moreover, floor manipulation could affect judgments, suggesting a stronger role of visual input over physical height.
- ◆ **Interactions between mental rotation and different types of manual movements**
I Fasiello, M Wexler ¶ (ENS Cachan, CMLA, Cachan, France; ¶ CNRS and University of Paris Descartes, LPP, Paris, France; e-mail: irene.fasiello@cmla.ens-cachan.fr)
Mental rotation has been suggested to rely on the visuomotor anticipation of covert motor actions. We investigated the interaction between visual and motor systems using a dual-task paradigm, in which subjects performed a mental rotation task while executing an unseen rotation movement, and measuring the specific effect of manual on mental rotation. We used three types of manual rotation relying differently on the premotor, primary motor, and parietal areas: active motion in a freely chosen direction, active motion in a given direction, and passive replay of a previously recorded trajectory. We predict that the more the motor task activates premotor areas, the stronger will be its effect on mental rotation performance. Our results confirm previous findings that when motor and mental rotation directions are compatible, mental rotation is facilitated; and suggest that the compatibility effect is attenuated in the case of passive movement. Therefore, the locus of the interaction seems to be the motor planning and anticipation systems, most likely located in premotor and posterior parietal cortex.
- ◆ **Effects of cueing attention on representational momentum**
T L Hubbard, A M Kumar (Department of Psychology, Texas Christian University, Fort Worth, USA; e-mail: t.hubbard@tcu.edu)
An observer’s allocation of attention has been related to halting (Hayes and Freyd, 2002 *Visual Cognition* **9** 8–27) or maintaining (Kerzel, 2003 *Cognition* **88** 109–131) representational momentum (RM). Effects of attention on RM were examined by cueing direction or final position of moving targets. In experiment 1, arrow cues indicated target direction; in experiments 2 and 3, plus sign cues indicated where targets vanished. In experiments 1 and 2, cues were presented before targets appeared; in experiment 3, cues were presented just before targets vanished or during the retention interval. In experiments 1 and 2, cues did not influence RM. In experiment 3, cues diminished RM, although RM occurred even when cues were presented. Experiment 3 partially reconciles results of Hayes and Freyd (RM decreased when more attention was directed to the final target position) and of Kerzel (RM decreased when a nontarget stimulus appeared during the retention interval); however, experiments 1 and 2 suggest that usefulness of cueing attention has limited duration.
- ◆ **“Me” in the moving video picture**
T Kayahara (School of Project Design, Miyagi University, Kurokawa-gun, Japan; e-mail: kayahara@myu.ac.jp)
Does visual input tell us about ourselves in addition to our status in the external space? In particular, do dynamic aspects of the visual input (eg scene shake by walking) make it possible to distinguish “my” vision from others? To examine this question, subjects were asked to distinguish a movie taken by a CCD camera situated at his/her head (near the viewpoint of natural eyes) from a movie taken at the head of others. Before experiment, all subjects walked through a corridor whose visual condition was kept constant between subjects to take a movie as experimental material. Any episodic visual event was eliminated from the content of the movie. In the result, the performance of distinguishing the movie from “my” viewpoint from others is significantly higher than that of control experiment in which subjects’ judgments were based on a still image from a CCD at their heads.

◆ **Visibility of fonts used in new signposts of the Metropolitan Expressway in Tokyo**

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The visibility of candidate fonts in new signposts of the Metropolitan Expressway was measured. Japanese signposts have alphabetic expressions as well as Japanese place names in limited space, so that designers puzzle over their layout. Nonsense syllables using Shin-Go M for Japanese and Vialog LT M for alphabet were examined. The height of Japanese characters was 500, 450, 400, 350, or 300 mm, and that of alphabet was 400, 350, 300, 250, or 200 mm. The stimulus was suspended 5 m above ground level. Thirty-four participants, from 20 to 63 years old, reported the distances at which they probably could understand the spelling and when they certainly read it. As regards the probable visibility, about 60% of participants incorrectly read the stimuli. The cumulative relative frequency of the visible distance of the Japanese 500 mm font was closely similar to that of the Japanese 450 mm font. The alphabetic font could be read from a greater distance than Japanese. This suggests that 68% height of alphabetic font could have similar visibility as the Japanese 500 mm font.

◆ **Compensation mechanisms in mediated communication**

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Mediated communication, such as in telephone calls, reduces information in the diverse sensory channels and affects coordination and adaptation processes among subjects ('alignment') with respect to visual attention, speech, or gestures. By contrasting face-to-face conversation with mediated conversation where subjects could not see each other, we studied the strategies they employ in order to compensate for the reduced alignment possibilities. Specifically, we hypothesise that gestures used to illustrate object features such as size, orientation, or typicality in face-to-face situations are being substituted by more detailed verbal descriptions in mediated communication. In a collaborative visual-search task, subjects had to identify a mismatch between their otherwise identical displays. Preliminary data hint at analogous processing of gestures and corresponding verbal descriptions: the analysis of eye movements shows similarities in the visual scan path in both conditions: verbal descriptions seem to guide visual attention equivalently to gestures for the given task. The substitution might thus be an efficient compensation mechanism, supporting alignment processes in mediated communication when only restricted information is available.

◆ **Perception of rotating objects by pigeons**

J Kramer, U Aust, M Steurer, L Huber (Department of Neurobiology and Cognition Research, University of Vienna, Vienna, Austria; e-mail: johanna-kramer@gmx.at)

It has been suggested that dynamic change of perspective helps to integrate individual views of an object into 3-D images. Here, we investigated whether the ability of pigeons to discriminate virtual dynamic computer-generated 2-D projections of 3-D objects was primarily based on the use of generalized 3-D representations of them. Pigeons were first trained in a go/no-go procedure to discriminate between projections of a cube and a pyramid, presented as static or dynamically rotating around different axes. When the pigeons had acquired the discrimination, they were subjected to a series of transfer tests with new modified projections, involving diverse featural and rotational transformations. In contrast to a study by Cook and Katz (1999 *Journal of Experimental Psychology: Animal Behavior Processes* 25 194–210) who used a similar experimental design, we found almost no indication of a 'dynamic superiority effect', ie discrimination performance was not improved by dynamic as compared to static presentation. The results suggest that discrimination may have been based on stored 2-D featural information rather than on object-like 3-D images.

◆ **The influence of stylistic information on the perception of modern art: A DC-EEG study on aesthetic experience**

P G Lengger, F P S Fischmeister, H Leder, H Bauer (University of Vienna, Vienna, Austria; e-mail: petra.lengger@univie.ac.at)

Slow cortical potentials (SCPs) were used to establish the functional neuroanatomical correlates of aesthetic processing of abstract and representational paintings dating from the 20th and 21st century. In order to encourage aesthetic processing, participants without any particular background in the fine arts were presented with stylistic information in some cases. Behavioural data were obtained by having the participants rate the artworks on the basis of understanding and aesthetics qualities. The neural data revealed that the comparison of representational and abstract paintings led to significantly higher activation for representational artworks in several regions of the brain, predominantly bilaterally in the temporal lobes, in the left frontal lobe, and bilaterally in the parietal and limbic lobes. Without stylistic information, the stimuli evoked

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higher activation mainly in the left frontal lobe; further activation was found within the parietal lobe and the insula. Stylistic information led to a better understanding of the paintings and resulted in reduced cortical activation in the left hemisphere. These findings may indicate that the information facilitated processing of the stimuli.

◆ **Amodal completion unveils number discrimination competences of animals**

L Regolin, R Rugani, E Simoni, M De Matthaeis, G Vallortigara ¶ (Department of General Psychology, University of Padua, Padua, Italy; ¶ University of Trieste and B.R.A.I.N. Centre for Neuroscience, Trieste, Italy; e-mail: lucia.regolin@unipd.it)

Partly occluded objects are regarded as whole objects by animal species which, like humans, seem to complete perceptually the missing parts. This phenomenon can be exploited to investigate numerical competences of animals. In experiment 1, young domestic chicks were trained to discriminate one versus two items, and then required to choose between such stimuli when partly occluded by a bar. We wondered whether two visible halves would be treated as representing two separate elements even though their overall surface was congruent with that of a single, whole, object. Chicks correctly regarded such stimulus as two separate objects even when the spatial disposition of the items was changed from trial to trial. In experiment 2, chicks showed that they were able to discriminate two versus three items when contour length and area of the elements were controlled as well as when the objects were partly occluded. Overall, the ability to discriminate groups of up to three elements seems to be fully available in the young chick.

◆ **Does rapid processing of numeric information depend on number notation?**

N Sakuma, E Kimura, K Goryo ¶ (Chiba University, Chiba, Japan; ¶ Kyoto Women's University, Kyoto, Japan; e-mail: n-sakuma@graduate.chiba-u.jp)

It has been demonstrated that numeric meaning is one of statistical properties that are rapidly extracted from visual displays (Corbett et al, 2006 *Vision Research* **46** 1559–1573). When viewing brief displays of numerals, observers could rapidly and accurately indicate which side of the displays contained the largest average value. To further elucidate the nature of rapid processing of numeric displays, we investigated whether the numeric information could also be rapidly processed when the displays were composed of Japanese Kanji numbers. Our results showed that the advantage of numerals over letters could be obtained in Japanese observers regardless of number notation; that is, the rapid processing was observed with Kanji as well as Arabic numerals. The present results indicate that the numeric advantage cannot be accounted for by properties specific to certain types of number notation, but more abstract properties are rapidly extracted from numeric displays. We are further exploring whether the observers actually conduct a numerical operation such as averaging numbers before they respond.

◆ **Eye fixation patterns partially predict equilibrium judgments of composite objects**

F Samuel, D Kerzel (FPSE, University of Geneva, Geneva, Switzerland; e-mail: Francoise.Samuel@pse.unige.ch)

In a previous study, we asked observers to adjust the orientation of two-dimensional, composite objects until the objects seemed to be in equilibrium (ie the objects would neither fall to the left nor to the right). We found considerable inter-observer variability and substantial within-observer consistency. Our results indicated that observers base their equilibrium judgments on very different visual cues. Some observers used the object's centre of mass, others the object's base, or the object's summit. The present study aimed at corroborating the use of differential visual cues by monitoring observers' eye fixations while they performed a forced-choice judgment of equilibrium (would the object fall to the right or to the left?) Our analysis confirmed individually distinct but classifiable patterns of eye fixations. Further, the pattern of eye fixations partially predicted the judgment of equilibrium orientation. For example, when the object's base was preferentially fixated, observers relied on identical angles at the object's base, even though asymmetric angles were needed to establish equilibrium.

◆ **Effects of threat perception on cognitive task performance**

F L K Tey, G Davis (Department of Experimental Psychology, University of Cambridge, Cambridge, UK; e-mail: flkt2@cam.ac.uk)

Many previous studies of the relationship between threat perception and other aspects of cognition and action have focused solely on the role of visual attention in perceived threat and maintenance of anxiety. In contrast, the big picture of changes to the human cognitive profile following threat has received relatively little investigation. In several new experiments we have investigated the effects of perceived threat on performance of three types of cognitive tasks. We found robust effects of threat in two of these three tasks and then employed manipulations of these tasks to isolate candidate components of cognition that we propose are particularly susceptible to threat perception. We discuss the likely adaptive value of these effects.

COLOUR

◆ **When it works it is beautiful: The effect of web page text – background colour combinations on readability, legibility, and subjective preference**

R Actis-Grosso, M Landoni, E Rabolini (Department of Psychology, University of Milano-Bicocca, Milan, Italy; e-mail: rossana.actis@unimib.it)

In two experiments we tested the effect of text – background-colour combinations on readability, legibility, and subjective preference in web design and navigation. In experiment 1 participants saw 324 combinations of coloured texts/backgrounds obtained by combining 18 widely used web-page colours. Texts consisted of automatically generated pseudo-words: participants' task was to count the number of occurrence of a specified character. Objective measures (session 1) included answers on accuracy and response times (RTs); subjective measures (session 2) included preference-, intention to use-, and readability-ratings (PR, IR, and RR). ANOVAs indicated that colours with greater contrast ratios and preferred colours (eg blues) significantly affected performance. Both accuracy and RT correlate with participants' ratings. In experiment 2, twelve webmasters gave PR and RR to a web page with 47 links to text – background combinations obtained with (a) preferred colours found in experiment 1, and (b) colours derived from participants' personal web pages. Major finding was that PR and RR correlate only for the highest PRs. Data are consistent with the statement that attractive things work better.

◆ **Robust short-term memory for surface colours in natural scenes**

K Amano, D H Foster (School of Electrical and Electronic Engineering, University of Manchester, Manchester, UK; e-mail: k.amano@manchester.ac.uk)

Judgments about surface colours in natural scenes may be made quickly and reliably, but how well can surface colours be memorized? A computer-controlled colour display system was used to present images of a natural scene under two different daylights, of correlated colour temperatures 25 000 K and 6500 K, each lasting 1 s and separated by a variable interval of 0, 0.1, 0.2, 0.5, 1, 2, or 5 s. Observers had to decide whether a test sphere in the scene had constant or variable surface colour. Performance declined gradually with interval duration. As a control, the experiment was repeated with Mondrian-like coloured patterns with a single fixed patch or 25 randomly selected patches serving as the test surface. With the fixed test patch, performance also declined gradually with increasing interval, but, with the random test patches, much more rapidly, suggesting a loss in a separate transient cue. Despite changes in memory for perceived colours in some tasks, memory for surface colours seems relatively robust.

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◆ **Dichoptic studies of instantaneous colour constancy in human vision**

J L Barbur, M Fahle¶, K Spang¶ (Applied Vision Research Centre, City University, London, UK; ¶ Bremen University, Bremen, Germany; e-mail: johnb@city.ac.uk)

The contribution the primary visual cortex and extrastriate visual areas make to instantaneous colour constancy (ICC) was investigated in dynamic colour-matching experiments under sequential changes of illuminant using monocular, binocular, and dichoptic Mondrian stimuli. The importance of immediate surround was investigated in both binocular and dichoptic conditions. Localisation of brain activity for stimulus conditions that drive ICC mechanisms was also measured using fMRI. We wanted to establish the extent to which ICC depends only on the monocular processing of chromatic context (that precedes the conscious perception of colour). The latter condition was achieved in dichoptic viewing by producing changes of illuminant that could be either in phase or in counterphase in the two eyes. The counterphase modulation condition is perceptually equivalent to the Mondrian being illuminated by a steady, unchanging illuminant. The strength of the ICC index achieved in such dichoptic, colour-fusing experiments remains completely independent of the perceived changes of illuminant colour in the Mondrian surround and depends only on local, monocular processing of chromatic context.

◆ **An explanation of the AMBEGUJAS phenomenon?**

S S Bergström (Department of Psychology, Umeå University, Umeå, Sweden; e-mail: stens@skatboet.se)

The AMBEGUJAS phenomenon (Jakobsson et al, 1997 *Perception* 26 531–541) is a reversible figure shifting spontaneously between two apparent 3-D shapes, A and B. A appears as a yellow and blue chromatic object in white light. Shape B appears grey but in a yellowish illumination and a blue shadow. This appears whether the stimulus is a chromatic display or a grey display in two coloured illuminations. Both A and B shapes reverse spontaneously in a 'convex' and a 'concave' alternative (a 2nd-order ambiguity). When A shifts between these alternatives its inter-reflectance situation does not change. When B shifts from its concave to its convex shape the inter-reflectance (yellow–blue) disappears, which should change its colours. As stimulus is

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constant (and flat) such a colour shift would not be logical. The perceptual solution seems to be a transfer of the surface colours to an illumination mode of appearance.

◆ **Study of colour categorical perception with equal discriminability stimuli**

V Bonnardel, C van Leeuwen¶, J Flintham§ (Department of Psychology, University of Winchester, Winchester, UK; ¶Riken Brain Science Institute, Saitama, Japan; §University of Utrecht, Utrecht, The Netherlands; e-mail: valerie.bonnardel@winchester.ac.uk)

Categorical perception (CP) effects occur when performance to between-category discriminations are better than equally spaced within-category discriminations. Evidence for CP effects is often obtained in successive as opposed to simultaneous discriminations and for emulated Munsell samples whose spacing might not correspond to equal discriminability between stimuli. We investigated CP effects using emulated Munsell samples for which the inter-stimulus discriminability, assessed by reaction time, was equivalent. CP effects were subsequently tested in temporal discrimination task. The chromaticity of the within-category stimulus (starting with 5 BG) was adjusted until it produced equivalent simultaneous discrimination RTs from 10 BG as did 5 B (cross-category stimulus). Cross- and within-category pairs were then tested in temporal discrimination with two delays (50 and 500 ms). Equivalent simultaneous discrimination RTs were obtained at 6.5 BG–10 BG (within-category) and 5 B–10 BG (cross-category). CP effects were subsequently observed in successive discrimination for the two delays. Results suggest two different types of discrimination mechanisms for simultaneous and successive presentations, with the influence of the stimulus category membership in the later case.

◆ **Kirschmann's fourth law**

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How does the magnitude of colour contrast vary with the saturation of the inducing field? The literature gives conflicting accounts (eg Kinney, 1962 *Vision Research* 2 503–525; Valberg, 1974 *Journal of the Optical Society of America* 64 1531–1540). We have measured colour contrast as a function of the saturation of inducing fields that varied either along the cardinal axes of MacLeod–Boynton chromaticity space or along intermediate axes. On one side of the display, a 2 deg target patch (of chromaticity equivalent to equal-energy white) was embedded in a 12 deg coloured surround. The subject compared the target patch to a variable comparison patch presented on a black surround on the other side of the display. Although colour induction increases rapidly as the reference first becomes discriminable from the inducing background, further increase in the saturation of the inducing field brings either no change in induced saturation, or only a small increase, depending on axis. We have found striking individual differences in the magnitude of colour induction, consistent across different axes.

◆ **Impairment of colour contrast sensitivity in cases of optic nerve head drusen**

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The type and degree of colour contrast thresholds has been computed by measuring the zones of colour confusion. Twenty patients with optic nerve head drusen and twenty age-matched controls were examined. The diagnosis has been confirmed by ultrasound and computer tomography. Visual acuity of subjects was 20/20 and visual field was normal. All subjects were 20 to 45 years old. The mean values of colour determination thresholds of healthy persons were 1.6 and those of persons with optic nerve head drusen were 2.33. Colour contrast thresholds in patients with optic nerve head drusen were 1.5 times worse than those of the healthy persons ($p < 0.01$). These results lead to the hypothesis that optic nerve head drusen may affect perception of colours because the test performance results are significantly worse for patients diagnosed with optic nerve head drusen.

◆ **Visual capacities in adult and hatchling leatherback sea turtles**

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Leatherback turtles are behaviourally and ethologically unique. They are also internationally listed as endangered. Anthropogenic light sources are implicated in the population's demise. Leatherback turtles have not been maintained successfully in captivity. Consequently, there is a paucity of knowledge about the extent and development of their visual capacities. We measured spectral and temporal sensitivity in both hatchling and adult leatherbacks. We employed flicker

electroretinography and anesthetized leatherbacks on a nesting beach in Trinidad. The temporal sensitivity of leatherbacks was poor in comparison to that of green and loggerhead turtles and low-pass in shape. Spectral sensitivities of leatherbacks differ from those of green and loggerhead turtles, having greater sensitivity in the short wavelengths and clear evidence for more than one photoreceptor class. Hatchling spectral sensitivities were similar to those of adults, while temporal sensitivity of hatchlings was superior. These results suggest that efforts to mitigate the demise of sea turtle populations need to carefully consider species and ontogeny.

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◆ **Comparison of relative L-cone and M-cone sensitivities measured with a recognition task and with a minimal flicker method**

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Two tasks were used to estimate the relative sensitivities of L and M cones in the periphery: (a) Landolt Cs were presented either to L- or to M-cones and observers indicated the test orientation for target sizes from 0.7 to 4 deg; (b) The Webster–Mollon method of minimum flicker detection (1993 *Journal of the Optical Society of America A* **10** 1332–1340) was adapted for peripheral targets: counterphasing rectangular gratings were created using the red and green monitor guns and observers indicated which of two simultaneous gratings gave the stronger flicker. For both tasks, stimuli were centred at 5 deg. In the recognition task, the L/M threshold ratio increased with decreasing target diameter on average from 1.2 to 4, ie L cones enjoy a greater advantage at high spatial frequencies. The minimal-flicker method gave relative sensitivities to red and green phosphors of 1.14–1.2. Relative excitations of L- and M-cones, reconstructed from these data, were in the range of 4, which corresponds to the relative sensitivities measured with the smallest Landolt Cs.

◆ **The spatiotemporal properties of the achromatic and chromatic Craik–O'Brien–Cornsweet effect**

F Devinck, T Hansen, K Gegenfurtner (Department of Psychology, University of Giessen, Giessen, Germany; e-mail: Frederic.Devinck@psychol.uni-giessen.de)

In the Craik–O'Brien–Cornsweet effect (COCE), two isoluminant surfaces appear to be different in brightness or in color because of the contrast border between them. It has been hypothesized that the COCE is mediated by a cortical filling-in process. Consequently, the COCE should proceed at finite speed, and exhibit some temporal tuning as a function of the width of the area enclosed by the contours. Observers varied the temporal frequency of a COCE grating, at three spatial frequencies, to determine the maximum temporal frequency at which temporal brightness or color modulation is perceived. The contours were determined along the luminance, the L-, M-, or S-cone axis of the DKL color space. For the achromatic condition, the temporal frequency for an induction effect increased with increasing spatial frequency. For both chromatic COCEs, the modulation in chromaticity decreased when the spatial frequency increased. Our results are consistent with the spatial filtering properties of the luminance and chromatic systems, but they suggest that temporal filling-in may not operate under all conditions.

◆ **Red and green detection contours and hue equilibria redux**

R T Eskew Jr, D Richters, S Gabree (Department of Psychology, Northeastern University, Boston, USA; e-mail: eskew@neu.edu)

The primary inputs of the 'R' and 'G' chromatic detection mechanisms are the subtraction of signals from the long-wavelength (L) and medium-wavelength (M) cones. It is not clear, however, how these detection mechanisms are related to the chromatic mechanisms that mediate colour-appearance judgments. Here we compare hue classification judgments ('red' vs 'green') and R and G detection contours. Observers were presented with suprathreshold incremental ('yellowish', 45°) or decremental ('bluish', 225°) 'pedestal' stimuli in the (L, M) plane; on each trial, a small 135° or 315° test vector was added, and the observer classified the resultant as 'reddish' or 'greenish'. Psychometric functions were fit to the classification proportions and the 50% equilibrium hue was extracted. These equilibria lie along a line through the white origin of slope of about 0.9, slightly flatter than the 1.0 slope of the detection contour. This flattening is consistent with the mechanisms mediating red vs green colour appearance having more S cone input than those mediating detection, which may have none.

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◆ **Colour appearance: The gamut expansion effect does not depend on chromatic variance in the surround**

F Faul, V Ekroll, G Wendt (Institut für Psychologie, Universität Kiel, Kiel, Germany; e-mail: ffaul@psychologie.uni-kiel.de)

Brown and MacLeod (1997 *Current Biology* 7 844–849) observed that chromatic patches appear much more saturated against an equiluminant, uniform gray surround than against a chromatically variegated surround with the same space-averaged colour. That is, the perceived colours in the uniform surround are 'expanded' in all directions about the neutral gray. One explanation proposed for this 'gamut expansion effect' is that the sensitivity of colour-opponent cells adapts to the variance of the colour distribution in the surround. Our results show, however, that chromatic variance plays only a secondary and unspecific role. Instead, the interesting thing happens in uniform surrounds: A uniform patch with a very low chromatic contrast to an equiluminant uniform surround appears highly saturated. This 'saturation enhancement' seems to depend on colour scission. It vanishes rapidly if one deviates in any way from the above mentioned specific condition, eg by increasing the chromatic contrast or the luminance contrast to the surround, by separating central patch and uniform surround by a small black ring, or by using a variegated surround.

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◆ **Elevated thresholds along the S – (L + M) chromatic axis in women taking the contraceptive pill**

A Franklin, L Notman (Department of Psychology, University of Surrey, Guildford, UK; e-mail: a.franklin@surrey.ac.uk)

Studies in the 1970s reported a high incidence of tritanomaly in clinical colour-vision tests for women taking the contraceptive pill. Since then the dosage of oestrogen in the pill has been reduced from 50 to 20–30 µg and there has been little report of the effect of the pill on colour vision, with only one study reporting changes in one individual's colour vision when she started to take the contraceptive pill (Eisner et al, 2004 *Visual Neuroscience* 21 513–531). Here, we tested the colour discrimination of women taking the pill and an age matched sample of women not taking the pill. We estimated discrimination thresholds along S – (L + M) and L – M chromatic axes, using a ZEST procedure. Participants indicated whether a colour-defined line was sloping left or right. Women taking the pill had significantly higher thresholds than women not taking the pill, but only along the S – (L + M) axis, with elevated thresholds along this axis for over half of the sample taking the pill.

◆ **Visual perception of gradients: The role of direct and mutual illumination**

L Garcia-Suarez, A Ruppertsberg, A Hurlbert ¶, M Bloj (Department of Optometry, University of Bradford, Bradford, UK; ¶ Newcastle University, Newcastle upon Tyne, UK; e-mail: m.bloj@brad.ac.uk)

Shading and mutual illumination (MI; light reflected between surfaces) manifest themselves as smooth spatial variations ('gradients') in image luminance and chromaticity. A monitor controlled by a 42-bit graphics card was used to display a computer-rendered 3-D scene. The observer viewed an almost frontoparallel white card, on which gradients arose due to the combination of direct illumination from the light source and indirect illumination from MI. Observers performed a gradient-discrimination task, in which we manipulated the gradient by varying the light-source position and measured the contributions to sensitivity from direct and indirect illumination, as well as from chromaticity and luminance variations separately. For all observers, luminance variations were the main contribution to gradient-discrimination sensitivity. Discrimination based on variations solely in chromaticity was unreliable across observers; that based solely on indirect illumination was impossible. Yet, for three out of four observers, performance improved either when chromaticity variations were added to luminance variations or when indirect was added to direct illumination. The fourth observer's performance was unaffected by either combination.

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◆ **Neon-colour-spreading dynamics investigated by subthreshold summation**

A V Garusev (Department of Psychology, Lomonosov Moscow State University, Moscow, Russia; e-mail: percept5@mail.ru)

Colouration dynamics are judged by magnitude of interaction between real coloured test stimulus and neon colours. The magnitude of interaction was estimated by the subthreshold summation method. Neon colour spreading was induced on a PC monitor by four sets of concentric black circumferences with inner coloured arcs, that created a neon-tinted square. These weakly coloured inner arcs that cannot create the illusory tinted square were used as the subthreshold stimuli. The real coloured square, exactly coinciding with the illusory one in shape, served as the

test stimulus and was delayed in relation to the subthreshold stimulus. At delays of 70–250 ms, interactions are inverse to standard interactions between real colours, as if the subthreshold colours were complementary. At delays greater than 500 ms, the interaction is similar to the standard case, but much smaller in magnitude. This fact implies that neon colours at the early stage of illusion formation behave as illusory colours in simultaneous colour contrast. For the latter illusion, a similar experiment was carried out for comparison.

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◆ **Chromatic and luminance edges in natural scenes**

T Hansen, K R Gegenfurtner (Department of Psychology, University of Giessen, Giessen, Germany; e-mail: Thorsten.Hansen@psychol.uni-giessen.de)

We analyzed the statistical distribution of luminance and chromatic edges in natural scenes. Images from the McGill calibrated colour image database (Olmos and Kingdom, 2004 *Perception* 33 1463–1473) were converted to the DKL colour space, edges were computed in two chromatic planes and an achromatic plane, and the joint histograms of edge strengths were computed. The vast majority of edges combine luminance and chromatic information. In some images object boundaries were signalled only by chromatic edges. The joint histograms differ between categories: strong chromatic edges occurred for fruits, flowers, and man-made scenes, in contrast to snow and land/water scenes. Analyzing the edges at a larger scale revealed essentially the same pattern, suggesting that the lower spatial resolution of the chromatic system is not reflected by a similar pattern in nature. We also compared DKL edge responses to human segmented edges. We found a larger agreement with the human response for a combination of chromatic and achromatic edges than for achromatic edges alone. Overall, this suggests that colour facilitates the detection of object boundaries.

[Supported by German Science Foundation grant Ge 879/5.]

◆ **Colour perception in 2-D and 3-D**

M Hedrich, M Bloj, A Ruppertsberg (University of Bradford, Bradford, UK; e-mail: m.hedrich@bradford.ac.uk)

We studied colour constancy with real-surface stimuli in 2-D and 3-D setups. Our hypothesis was that colour-constancy performance in a 3-D scene should be better than in a flat 2-D scene due to the increased visual cues available. Ten female observers learned a target colour under daylight (a) as part of a 2-D palette with 16 coloured paper swatches, and (b) as part of a 3-D setup, which consisted of several geometrical volumes. After learning, observers selected the remembered colour from a 16-swatch palette, which was presented under tungsten light. Selection was done either immediately or after a 2 min delay. We tested two target colours from three colour groups (red, yellow, and blue). Observers selected the correct colour swatch in significantly more cases in the 3-D than in the 2-D setup and hit rate increased significantly after the 2 min delay due to adaptation. A control experiment showed that memory was not a confounding factor in the experiment. Colour-constancy performance was significantly improved in the 3-D scene.

[MH is supported by a studentship of the Division of Optometry, University of Bradford, and the Francis R Hudson Memorial Fund.]

◆ **Perception of saturation of colours and dominant wavelength discrimination in central and peripheral retina**

V Karitans, M Ozolinsh (Department of Optometry and Vision Science, University of Latvia, Riga, Latvia; e-mail: variskaritans@gmail.com)

Perception of colour saturation in central and peripheral retina was studied by two kinds of psychophysical methods. The method of constant stimuli, in which pairs of stimuli with different saturation are presented, was used. Shift of the saturation perception equality was found: peripheral stimuli were perceived to be less saturated than the central one when the observer was not adapted before answer was given. In a step-by-step method, the observer was asked to find equilibrium by adjusting saturation of the peripheral stimulus. Hysteresis of the shift of the perception of saturation equality was observed: the shift depended on whether the initial saturation of the peripheral stimuli was maximal or zero. Results can be explained in terms of saturation adaptation. After adaptation to saturated stimulus, sensitivity to saturation of the eye is reduced. After adaptation to unsaturated stimulus, the sensitivity is increased. The method of constant stimuli with adaptation phase was also used. There was strong time dependence of the shift of the saturation perception. In a step-by-step method, the observer was asked to find equilibrium by adjusting saturation of the peripheral stimulus. The two methods were compared by keeping saturation of peripheral stimulus constant but varying the saturation of the central stimulus. This shows that adaptation occurs at retinal level.

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◆ **A failure to reveal sensitivity to illumination-like boundaries in complex scenes**

J M Kraft, Y Ouyang (Faculty of Life Sciences, University of Manchester, Manchester, UK; e-mail: j.kraft@manchester.ac.uk)

Numerous studies have shown that abstract visual configurations which are consistent with real illumination boundaries produce stronger simultaneous contrast effects than do similar configurations which are not consistent with real illumination boundaries. We made a relatively focused investigation of whether the visual system is sensitive to the precise form of a boundary between areas of different predominant colours. We presented coloured stimuli in which the outer boundaries of circular annuli of two different sizes were either: (i) illumination-like (smooth, having X-junctions consistent with an illumination boundary); (ii) jagged (contiguous but without X-junctions); or (iii) probabilistic (spatially extended, not contiguous). Data from two observers failed to show the predicted increase in simultaneous contrast for annuli having illumination-like boundaries. The absence of sensitivity to boundary form suggests camera-like visual processing which ignores object and illumination boundaries. It is also possible that our stimuli did not successfully simulate illumination boundaries.

[Supported by EPSRC grant GR/S95558.]

◆ **L:M cone ratios estimated by colour appearance, ERG, and adaptive optics methods**

J Krauskopf, J Carroll ¶ (Center for Neural Science, New York University, New York, USA; ¶ Medical College of Wisconsin, Milwaukee, USA; e-mail: jkr@cns.nyu.edu)

At the 2006 meeting of the ECVF a method was presented (Krauskopf, 2006 *Perception* 35 Supplement, 175) for estimating the numerical ratio of L and M cones in the fovea from a combination of the Stiles two-colour increment threshold procedure and the statistics of the colour appearance of small flashes of light. Preliminary results were presented to illustrate the method. We have made further measurements on a larger population of people including some for whom there are estimates of the L:M ratio derived from flicker ERG and adaptive optics methods. We found variability among observers in the colour appearance data, and compare this with variability in L:M ratio and cone pigment λ_{\max} .

◆ **Are the short-wave cones slow to respond?**

T H Land, Z E Blake, J D Mollon (Department of Experimental Psychology, University of Cambridge, Cambridge, UK; e-mail: th28@cam.ac.uk)

Tradition holds that the short-wave cones, or the pathways carrying their signals, respond with long latency. Sometimes taken as evidence is an illusion described by Mollon and Polden (1975, *Journal of Physiology* 254 1P–2P): when a vertical bar, with a blue upper part and a red lower part, is moved across a yellow field, observers report that the blue half lags the red and is more persistent. Using a Maxwellian-view system in which an optical scanner is conjugate with the pupil, we have made quantitative measurements of this effect, finding an average delay of 17.9 ms for the leading edge, and 48.3 ms for the trailing edge. However, the original conditions place the short-wave and long-wave cones in different adaptive states. When the background field elevates both cone types equally relative to their absolute thresholds and when both stimuli are raised equally above their threshold on this field, then the leading and trailing edge discrepancies are of the order of 0–3 ms and 3–5 ms, respectively.

◆ **Adaptation of central colour channels**

R J Lee, J Mollon ¶, Q Zaidi §, H Smithson (Department of Psychology, University of Durham, Durham, UK; ¶ University of Cambridge, Cambridge, UK; § College of Optometry, SUNY, New York, USA; e-mail: robert.lee@durham.ac.uk)

The opponent stages of early colour processing are thought to combine to feed multiple cortical channels, each maximally responsive to a different chromaticity. We investigated the perceptual adaptation of these central colour channels. A stimulus that is modulated in time around a circular locus in the isoluminant plane of colour space provides sinusoidal modulation to each of the cone classes, and to each of the colour-opponent mechanisms. The amplitudes of these signals are the same for clockwise and counterclockwise modulations. However, owing to latency differences between the opponent mechanisms, the amplitude of the combined signal that reaches the cortex at each stimulus phase will be different for the two modulations (Stromeyer et al, 1991 *Vision Research* 31 787–803). Chromatic discrimination thresholds were measured along eight chromatic directions, before and after adaptation to hue circle stimuli. The pattern of threshold increases was different following adaptation to clockwise or counterclockwise modulation. These differences have allowed us to infer the adaptation characteristics of central colour channels.

[Supported by Durham University Doctoral Fellowship.]

◆ **Colour preference and personality**

Y Ling, N Johnson, A Hurlbert (Newcastle University, Newcastle upon Tyne, UK; e-mail: yazhu.ling@ncl.ac.uk)

Previously [Ling and Hurlbert, 2006 *Journal of Vision* 6 250 (abstract)] we reported that individuals' colour preferences may be described as the weighted sum of three universal components: the achromatic lightness channel (L + M + S contrast), and the 2 cone-contrast channels [S - (L + M) and L - M contrast]. Individual colour preferences are thereby reduced to a set of 3 weights, representing preferences for lightness, blue-yellow, and red-green dimensions. We also found robust differences between sex, culture, and age (2004 *Perception* 33 Supplement, 45), represented by differential weighting on these components. Here we investigate the relationship between personality traits and colour preference, for thirty-eight British subjects (twenty females), who pairwise compared 24 colours with various hue, lightness, and saturation values. Their 7 personality traits (extraversion, agreeableness, conscientiousness, emotional stability, intellect, femininity, and masculinity) were also measured. Our results show strong effects of femininity and masculinity on colour preference; lightness, red-green, and blue-yellow preference positively correlate with femininity and negatively correlate with masculinity. In addition, for females, conscientiousness positively correlates with lightness and blue-yellow preference, and, for males, emotional stability negatively correlates with lightness preference.

◆ **An ideal trichromatic colour atlas and its spherical representation**

A D Logvinenko (Department of Vision Sciences, Glasgow Caledonian University, Glasgow, Scotland, UK; e-mail: a.logvinenko@gcal.ac.uk)

Colour atlas should be complete, comprising all possible colours. Reflectance spectra, taking two values: k ($0 < k < 0.5$) or $1 - k$, with two transitions (from k to $1 - k$) across the spectrum, make a complete colour atlas. Specifically, for any broadband illuminant, every reflectance spectrum is metameric to some member of the atlas (with no metamerism within the atlas). Any member of the atlas is specified by transition wavelengths, l and m , and the number k . Reflectance spectra for which $k = 0$ are called optimal. An optimal reflectance is characterised by spectral bandwidth ($l - m$) and central wavelength $(l + m)/2$. The colour atlas can be geometrically represented as 3-D unit-ball, longitude and latitude encoding central wavelength and spectral bandwidth, respectively. Every optimal reflectance spectrum is uniquely located on the boundary sphere. A member of atlas with $k > 0$ is located on the same radius as an optimal reflectance with the same transition wavelengths, at the distance (from the centre) $0.5 + k$. [Supported by The Wellcome Trust grant GR068672MA.]

◆ **Stimulus correlates of Munsell papers**

T Lu, A D Logvinenko (Department of Vision Science, Glasgow Caledonian University, Glasgow, Scotland, UK; e-mail: klu1@gcal.ac.uk)

A new set of surface descriptors (central wavelength, spectral bandwidth, and chromatic purity) is suggested in the accompanying presentation by Logvinenko (2007 *Perception* this Supplement). We calculated the descriptors for the reflectance spectra of 1600 Munsell chips. Munsell hue was found to be in a good correspondence with central wavelength. Munsell value correlates with chromatic purity, though the relationship is not straightforward. Spectral bandwidth was found to be a stimulus correlate for whiteness and blackness. The descriptors values were used as internal coordinates to present Munsell papers on the colour sphere (see Logvinenko, 2007 *Perception* this Supplement, for further details). Specifically, for each Munsell chip a point on the colour sphere surface was determined which lies on the same radius. Munsell chips were found to be unevenly distributed over the colour sphere, gravitating toward the south pole. Surprisingly, vast areas on the colour sphere devoid of Munsell chips were found. It is not clear whether this is a particular feature of the Munsell collection or an essential property of the human colour vision.

◆ **Identification of colour thresholds in persons with damage of chiasma opticum**

R Lukauskienė, R Liutkevicienė, A Kucinovienė, V Viliunas¶ (Eye Department, Kaunas Medical University Clinic, Kaunas, Lithuania; ¶ Vilnius University, Vilnius, Lithuania; e-mail: luka.rita@yahoo.com)

Our objective was to estimate the colour-contrast-sensitivity (CCS) thresholds in persons with damage of chiasma opticum. Twenty-three persons with various sizes of pituitary adenoma (PA) and fifty age-matched controls were tested. Correlation was made between the CCS thresholds and the size of PA, which affects the chiasma opticum. The subjects were shown a computer-generated stimulus, consisting of a line surrounded by grey background. The line colour saturation was varied by increasing or decreasing its red, green, or blue phosphor luminance starting from the initial grey of the background. The subjects judged the orientation of the line and it was defined in terms of distance between colour of the line and the background in the L^*, a^*, b^* system of

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coordinates (CIE, 1976). The mean CCS in group PA with less than 1 cm was 1.8, in group PA with more than 1 cm was 3.5, and in the control group was 1.4. The difference between the means of colour thresholds in persons with PA and controls was significant ($p < 0.001$). We found strong correlation between the size of PA and CCS changes in persons with damage of chiasma opticum.

◆ **Perception space analysis: From colour vision to olfaction**

A M Mamlouk, M Haker, T Martinetz (Institute for Neuro- and Bioinformatics, University of Lübeck, Lübeck, Germany; e-mail: madany@inb.uni-luebeck.de)

On the way to understanding complex perception tasks based on psychophysical data alone, we propose a general framework combining several data analysis methods such as multidimensional scaling and self-organizing maps to derive topologically conserved maps of the perception space. Psychophysical data can be interpreted in two fundamentally different ways: the characterization of stimuli (eg green) using several verbal descriptions (eg bright)—a stimuli-as-points view—and conversely, the characterization of the given verbal descriptions by several stimuli—a descriptors-as-points view. We argue that only the latter view enables us to observe an objective mapping of the perception space. As an example, we show how to derive the three principal dimensions of colour perception, just based on non-comparative psychophysical descriptions. Furthermore, we extend the approach to odour perception and derive a quantitative map of the odour perception space, a space still fairly unknown.

[The first two authors contributed equally to this work.]

◆ **Cone-signal interactions maximizing information about coloured surfaces in natural scenes**

I Marin-Franch, D H Foster (School of Electrical and Electronic Engineering, University of Manchester, Manchester, UK; e-mail: ivan.marin-franch@postgrad.manchester.ac.uk)

The information available to the visual system about the spectral reflectance properties of coloured surfaces is necessarily constrained by the spectral sensitivities of the long-, medium-, and short-wavelength-sensitive (L, M, and S) cone receptors. Simple cone adaptation that accords with the scaling rule of von Kries incompletely compensates for the effects of changes in illuminant. Post-receptoral adaptation can be more effective, but it depends on the coefficients governing the interactions between cone signals. The aim here was to find the optimum values of these coefficients according to information-theoretic measures. Computer simulations were based on a linear interaction model (Sperling and Harwerth, 1971 *Science* **172** 180–184). The optimal values of the coefficients were found to vary little over a range of natural scenes and illuminant changes. The results obtained here are compatible with those obtained from behavioural studies (op. cit.); in particular, they confirm an asymmetry in the interactions between L and M cone signals which appears critical in maximizing information.

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◆ **Rod and L-cone colour matching in a complex image**

J J McCann (McCann Imaging, Belmont, USA; e-mail: mccanns@tiac.net)

Rod and L-cone interactions generate colour appearances. Appearances in a complex scene above and below M- and S-cone thresholds were measured. The test target was a ColourChecker viewed in tungsten light, or one wax candle. Firelight is an ideal illuminant for rod–L-cone colour. The observers' task was to adjust RGB digits in each area in an LCD computer display to match the appearance of the ColourChecker. With the tungsten illumination, above L-, M-, and S-cone thresholds, the matches filled a 3-D space. With one candle illumination, below M- and S-cone threshold, ColourChecker matches were darker and had a different set of colours. These colour appearances are not consistent with rods sharing S-channel alone, or M-channel alone. The colours are not consistent with the rods desaturating all three channels. Under these conditions, the colours are consistent with the rod spatial comparisons sharing both the M- and the S-cone channels.

◆ **Topology preserving resampling of the OSA-UCS**

G Menegaz, G Bartoli, A Le Troter ¶, J M Boi ¶, J Sequeira ¶ (Department of Information Engineering, University of Siena, Verbania, Italy; ¶ LSIS, Université d'Aix-Marseille II, Marseille, France; e-mail: gloria@ieee.org)

The peculiarity of the OSA-UCS (Uniform Color Space) is that the colour samples are arranged in a regular rhombohedral lattice in which each colour is surrounded by twelve neighboring ones which are perceptually equidistant from it. However, saturated colours are not adequately represented, which limits its exploitability for computer vision. In order to overcome such a limitation we propose to generate an Extended (E-OSA) basis by resampling the (L, g, j) space. The new 590 colours are added by extending the predefined 3-D sampling grid in the outer region of

the volume bounding the original 424 colours. The proposed model is trained on the categorisation data collected by a colour-naming experiment (experiment 1) and successively validated by assessing its performance in naming a different set of colours (experiment 2). Results are compared to those obtained in other state-of-the-art experiments and models, and the exploitability of the ideal observer for image segmentation is proved on a set of colour images of different types.

◆ **How does colour benefit the naming of objects?**

E M Mohr (Department of Psychology, Durham University, Durham, UK;
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Adding chromatic information to pictures of objects shows only a small effect in verification and categorisation tasks. However, when observers are required to name objects, colour speeds performance and enhances accuracy. The present experiment contrasts two different theories as to why colour may benefit object naming. The first is that colour simply aids the segmentation of the object from its background. For example, cherries pop out amongst the leaves of a cherry tree by their redness when presented as a coloured photograph, but not on a grey-scaled picture, where they must be segmented by differences in brightness and form. The second is that colour may help to elicit a wider range of associations with the object, thereby enhancing lexical access. To distinguish between these processes, an equal number of pictures containing high and low colour diagnostic objects were presented against either fractal noise or uniform backgrounds in a naming task. Performance for chromatic stimuli was compared with that for monochrome stimuli equated in luminance.

[Supported by Dr Robert Kentridge and Professor Charles Heywood, Psychology Department, Durham University.]

◆ **The usefulness of colour vision assessment in subjects with diseases of the eye**

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Disruption to either central or peripheral visual pathways can result in selective loss of red–green and yellow–blue chromatic sensitivity, reduced achromatic contrast acuity, diminished motion perception, and peripheral visual field loss. Such changes arise in various forms of retinopathy, damage to the optic nerve and brain lesions, and often affect selectively the processing of specific stimulus attributes. Assessment of acquired colour vision deficiency is often ambiguous in subjects with anomalous trichromacy. A large number of subjects have been investigated to assess the differences between acquired and congenital loss of colour vision and to establish the relative sensitivity of colour vision assessment in early detection of eye disease. The results reveal significant differences in the pattern of colour vision loss in congenital, acquired, and combined deficiencies. These observations make it possible to assess reliably acquired colour vision loss in anomalous trichromats. Comparison of contrast acuity, motion, and colour vision thresholds suggests that loss of chromatic sensitivity is the most sensitive measure for detection of early damage in subjects with eye disease.

[We would like to thank “Transport for London” for providing financial support.]

◆ **Exploring evidence for simple spatial filters in colour processing of authentic scenes**

Y Ouyang, J Kraft (Department of Life Sciences, University of Manchester, Manchester,
UK; e-mail: y.ouyang@postgrad.manchester.ac.uk)

The visual system probably combines information from different image statistics to determine colour appearance. Spatial filters may be involved, and they may also subserve edge localization and texture analysis. Previous studies have shown that larger surrounds usually induce greater chromatic contrast, intimating a spatial filter. To assess putative spatial-filter responses to varying sizes of surround, we chose 18 printed surfaces, such that the tristimulus values of 9 surfaces under a particular blue illuminant ($x = 0.2788$, $y = 0.2920$, $Y = 28.72 \text{ cd m}^{-2}$, CCT = 10 000 K) were the same as those of the other 9 surfaces under a particular red illuminant ($x = 0.3823$, $y = 0.3838$, $Y = 28.72 \text{ cd m}^{-2}$, CCT = 4000 K). Two observers made achromatic settings in the context of ‘Mondrian’ like posters having either 9 or 18 different coloured surfaces and various sizes of annular surround corresponding to the two illuminants. Surround borders coincided with edges of coloured elements and did not contain x -junctions consistent with an illumination boundary. Initial results showed significant individual variation, with one observer exhibiting greater chromatic contrast for larger surrounds, while the other did not.

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◆ **Modeling colour-naming space with fuzzy sets**

A Párraga, R Benavente, M Vanrell, R Baldrich (Computer Vision Center, Universitat Autònoma de Barcelona, Bellaterra, Spain; e-mail: ainhoa@cvc.uab.es)

Anthropological and linguistic approaches have produced a limited set of eleven universal colour categories (names) which are present in most evolved languages. In this work we present a mathematical formulation of fuzzy sets to model the colour-name assignment task. In our model, the CIE Lab colour space is divided into eleven basic categories with a Triple Sigmoid used as the basis of fuzzy sets. The overall position of the categories was first approximated by fitting the proposed model to previous psychophysical data by an iterative gradient method. To further adjust the parameters of the model, psychophysical stimuli were created (in the CIE Lab space) from pairs of isoluminant colours belonging to different neighbouring categories and the colours inbetween. These were presented on a calibrated CRT monitor (14-bit \times 3 precision) and observers indicated whether the colours belong to a given category or another one in a yes/no discrimination paradigm. Our results show that this modeling technique, combined with psychophysical data, can provide a working model for segmentation of the colour space into naming categories.

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◆ **Chromatic contrast-sensitivity functions**

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The chromatic contrast-sensitivity function (CCSF) describes the chromatic contrast range that can be processed by the visual system. In order to address chromatic contrast on its own in the stimuli, the luminance equilibrium of colour pairs was based on the apparent-motion paradigm. Two-colour dimensional sinusoidal gratings were displayed at photopic levels in either of two orthogonal directions. Five spatial frequencies (0.6 to 12 cycles deg^{-1}) supporting three colour pairs were tested: red–green, (colour-opponent pairs), cyan–magenta, yellow–purple (cone-opponent pairs). A nonchromatic pair (gray-level stimulus) allowed the comparison of CCSF with the classic luminous CSF. Six colour-normal observers took part in the experiment. Minimal colour contrast allowing grating detection was measured with a forced choice method (seen/not seen) and a double psychophysical staircase. Contrast threshold was then estimated from cone contrast definition and specific cone responses to achieve comparison across chromatic pairs. The results show significantly higher thresholds with the yellow–purple pair that emphasizes the specific processing performed on the S-cone signal.

◆ **Separate contributions of light intensity and chroma to perceived dissimilarity of yellow – blue surfaces under neutral light sources differing in intensity**

R Tokunaga, A Logvinenko, L Maloney¶ (Department of Vision Sciences, Glasgow Caledonian University, Glasgow, UK; ¶ New York University, New York, USA; e-mail: Rumi.Tokunaga@gcal.ac.uk)

As illumination decreases, the lightness continuum shrinks with black and white becoming less dissimilar (Logvinenko and Maloney, 2006 *Perception & Psychophysics* **68** 76–83). We report an analogous phenomenon for the yellow–blue chromatic dimension. Observers saw two arrays, each containing seven Munsell papers that fell along a yellow–blue continuum (three yellow, one neutral, three blue). Each array was illuminated independently with a light intensity of 440, 40, or 8 cd m^{-2} . Over the course of the experiment, the observer saw the two arrays under all combinations of two light intensities and rated the dissimilarity (on a 30-point scale) between each chip in one array and each chip in the other. We analyzed these data using non-metric multidimensional scaling to determine how light intensity and surface chroma contributed to dissimilarity and how they interacted. Dissimilarities were captured by a two-dimensional fan-like pattern with three concentric seven-point arcs. Distance along each arc corresponded to the contribution of yellow–blue surface chroma differences to dissimilarity while spacing between arcs represented the contribution of light intensity differences. Arc length decreased with increasing illumination.

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◆ **Afterimage colours are not affected by the intensity of the inducers**

K Sakata (Faculty of Arts, Joshibi University, Sagamihara, Japan; e-mail: sakata@joshibi.ac.jp)

In order to reveal how the chromatic channel is affected by the intensity of the stimulus light on the retinal cone mechanism, the colours of the afterimage were measured by the method of adjustment, in which the stimuli consisted of arranged circular inducers; one of these disappeared

after a very short time. The inducer stimuli used in this experiment had multiple levels of luminance of the same chromaticity, and the exposure time of the inducers was also variable. The results of the measurements were examined by means of the MacLeod–Boynton cone-excitation diagram; the afterimage colours were of the same adjustment chromaticity despite having different intensities. An improved model of primitive colour vision is proposed in which the retinal afterimage depends not only on the intensity of the output of each cone but also on their balance, ie the opponent system.

◆ **Visual perception, cognition, and language, embodied motivation of conceptual colour metaphor/metonym**

J L Sandford, S L Buck¶ (Department of Linguistics, Università degli Studi di Perugia, Perugia, Italy; ¶ University of Washington, Seattle, USA; e-mail: jsandfo@tin.it)

Visual perception and cognition of colour gives us embodied motivation for use of colour terms in language. The aim of this research was to understand the cognitive perceptive mechanism individuals use to discern subtle differences in conceptual colour metaphor. The data collected through our colour study involved four tasks that were presented with DirectRT software, and analyzed using SPSS. The data help us understand how we conceptualize and categorize opponent functions in the perception and language of colour. Our semantic frame of colour terminology use includes both light and pigment information. It is our hypothesis that this co-occurrence and the resulting ground/figure relation allow us to accommodate the positive and negative aspects of conceptual colour metaphor/metonym (CCMM) in our cognitive model. The fifty participants were asked to assign positive and negative values to 143 items. The items were divided between the visual aspect: colour and prototypical colour objects, and the linguistic aspect: colour metaphor and colour metonym. All four tasks involved the eleven universal basic colour terms.

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◆ **BOLD activations in response to changes in chromatic context—an investigation of instantaneous colour constancy mechanisms**

K M Spang, M Fahle, J Barbur¶ (Department of Human Neurobiology, University of Bremen, Bremen, Germany; ¶ City University, London, UK; e-mail: kspang@uni-bremen.de)

We measured fMRI signals in response to variations in chromatic context. The aim was to isolate instantaneous colour constancy (ICC) mechanisms, to measure their relative activation (to either illuminant or material changes) and to establish whether such mechanisms respond specifically to illuminant changes or play a more generic role in colour-generating interactions. The subjects viewed Mondrian stimuli that changed in both luminance and chromaticity to produce a range of chromatic interactions: (i) simulated ‘global’ changes of illuminant consistent with the ‘classic’ definition of ICC; (ii) ‘local’ changes of illuminant; (iii) ‘global’ changes of chromaticity as dictated by a change of illuminant with ‘local’ changes of luminance; (iv) random, reassignment of chromaticities and luminances amongst Mondrian patches. The different conditions investigated reveal similar activation of early visual areas (V1 to V4). ‘Local’ colour-generating interactions therefore play an important role in establishing the perceived colour of objects. The results suggest that, when objects are viewed in context, ‘local’ neural mechanisms contributing to ICC are permanently active as early as V1.

◆ **Colour perception following full-field adaptation: Effect of illuminants**

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Colour perception was studied when viewing Munsell samples in a specially designed adaptation chamber. The subject’s head was placed inside the chamber so that the entire visual field was composed of a uniform background which was illuminated by four computer controlled LEDs. 9 different illuminants were used: standard (A, D65, and S), and coloured (Y, G, G2, V, P, R). Complete or full adaptation time was defined as the period required for the background to appear neutral or achromatic. For all subjects this was between 90 and 420 s. In the second experiment, Munsell samples were sequentially presented and the subject’s task was to choose a sample which appeared neutral. All subjects chose similar Munsell samples under all illuminants, demonstrating that the illuminant was fully discounted. The data are compatible with our previous observations (Murray et al, 2006 *Vision Research* 46 3067–3078; Stanikunas et al, 2005 *Perception* 34 995–1002) suggesting the existence of two colour mechanisms, one based on colour contrast and the other linked to background colour.

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◆ **Hue discrimination in damage of chiasma opticum**

D Stanislovaitienė, R Liutkevicienė, R Lukauskienė, V Viliunas ¶ (Eye Clinic, Kaunas Medical University Clinic, Kaunas, Lithuania; ¶ Institute of Materials Science and Applied Research, Vilnius, Lithuania; e-mail: daiva@finera.lt)

Twenty persons (40 eyes) with various sizes of pituitary adenoma (PA) and forty (80 eyes) age-matched controls were tested. Computerized Farnsworth–Munsell (F–M) hue test program was used for colour discrimination. Visual acuity and perimetry were estimated. Patients were divided into two groups according to the diameter of PA: (i) less than 1 cm, and (ii) more than 1 cm. The mean error score of the F–M test in the first group was 131 and in second 244 when in the control group it reached 80 ($p < 0.05$). Visual acuity and visual field were statistically worse in the second group than in the first ($p < 0.001$). There was strong correlation between visual acuity, perimetry, and F–M 100 Hue test error scores. The greater was the diameter of PA, the worse were the visual functions and hue discrimination. Thus, hue discrimination can be one of the methods for early prediction of damage of chiasma in cases of pituitary adenoma.

◆ **Does the incongruent verbal label produce the inversed categorical perception of colour?**

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Previous studies (Roberson and Davidoff, 2000 *Memory and Cognition* **28** 977–986; Suegami and Michimata, 2006 paper presented at the 4th Asian Conference on Vision in Shimene) suggested that categorical perception (CP) of colour would be mediated by a verbal label. On the basis of those studies, we hypothesize that the discrimination of the within-category pair that has different verbal labels would be more accurate than the discrimination of the between-category pair that has the same verbal label (inversed CP). In the experiment, we employed a simultaneous 2AFC colour-matching task. A colour word was presented before the stimulus. If the word was incongruent with the colour stimulus, the word would produce an incongruent verbal label. The results showed that an incongruent word eliminated the CP but did not produce the inversed CP. However, the performance of the within-category discrimination was better for the incongruent condition than for the congruent condition, whereas the performance of the between-category discrimination was better for the congruent condition than for the incongruent condition. The results suggest that the discrimination of the within-category pair could be more accurate when different verbal labels are provided.

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◆ **Visual search in simulated dichromats**

S Sunaga, Y Yamashita (Department of Visual Communication Design, Kyushu University, Fukuoka, Japan; e-mail: sunaga@design.kyushu-u.ac.jp)

Some advantages of dichromats have been found in visual functions (Morgan et al, 1992 *Proceedings of the Royal Society of London B* **248** 291–295; Sharpe et al, 2006 *Journal of Vision* **6** 213–223). To evaluate the performance of dichromats, we compared the reaction times in searching a coloured target in multi-coloured environments between simulated dichromats and trichromats. The colours for simulated dichromats were simulated on a CRT according to the procedure of dichromats' colour appearance (Brettel et al, 1997 *Journal of the Optical Society of America A* **14** 2647–2655). The reaction times in searching a target from circularly arranged eleven coloured disks were measured. Two colours were assigned for ten distractors. Their hue angles were $\pm 45^\circ$ for the target colour chosen from the DKL colour space. In some colour combinations, the reaction times in the simulated dichromat's display were shorter than those in the original display. This suggests that the signal-to-noise ratio between a target and distractors in colour appearance for dichromats was important in evaluating the performance in colour search, and that further investigations in real dichromats are required.

[Supported in part by a Grant-in-Aid for the 21st Century COE Program, Kyushu University, Japan.]

◆ **Filling in the afterimage after the image**

R van Lier, M Vergeer (Nijmegen Institute for Cognition and Information [NICI], Radboud University Nijmegen, Nijmegen, The Netherlands; e-mail: r.vanlier@nici.ru.nl)

We have constructed a stimulus with a black central area surrounded by red and green patches. The stimulus can easily be conceived as a superposition of two different shapes consisting of all red patches in one shape and all green patches in the other shape. After disappearance of this stimulus we show a thin outline of one of the overlapping shapes. The colour appearance of the central area is as follows. Only the afterimage colour evoked by the shape corresponding to the thin outline is seen, filled-in throughout the central area. That is, one and the same stimulus evokes a green afterimage if the outline corresponds to the shape made up by the red patches

and vice versa. It should be noted here that these differential colour appearances occur within the same area of the stimulus. We discuss whether this effect is due to higher-level effects of shape-specific colour encodings or to a rapid spreading of local patch-based afterimages between the outlines.

◆ **Primate trichromacy is optimal for identification of colourful objects**

M Vorobyev (School of Biomedical Science, University of Queensland, Brisbane, Australia; e-mail: m.vorobyev@uq.edu.au)

Most of what primates see in their natural environment is comprised of brown and green backgrounds, among which colourful advertisements of plant fruits and flowers are displayed. Comparison is reported of the potential visual systems with differently placed receptors (i) to identify, and (ii) to discriminate spectra of fruits, and flowers and leaves. These two visual tasks impose different demands on the eye: identification requires absolute colour perception that is stable when illumination changes, while relative sensations suffice for discrimination. To estimate the potential of an eye to identify objects, object reflectance spectra were reconstructed from photoreceptor quantum catches, assuming ideal observer performance. For discrimination, this potential is given by a percentage of spectra whose colours can be discriminated. It is shown that colour vision with strongly overlapping L and M cones is optimal for identification of fruits and flowers, but visual systems with less overlapping photoreceptors are better suited for discriminating among these spectra. However, this confers little advantage over dichromacy for both discrimination and identification of leaf spectra.

◆ **The effect of shape on memory colour and colour constancy**

M Vurro, Y Ling, A Hurlbert (Newcastle University, Newcastle upon Tyne, UK; e-mail: milena.vurro@ncl.ac.uk)

Colour constancy is a phenomenon mediated by multiple mechanisms. Here we investigate whether cognitive factors such as object familiarity may also contribute to constancy. We employed a setup which preserves the natural 3-D shapes of real objects, while allowing us to adjust their apparent colours. The observers task was to report, as quickly as possible, whether particular colours were appropriate for particular familiar objects (banana, carrot, or courgette) under different illuminations. We varied the object shape: (i) 3-D real object; (ii) 2-D homogeneously filled object outline; (iii) 2-D homogeneous disk (object name provided). The number of 'yes' responses, as well as reaction times, vary significantly across experimental conditions and illuminations. In addition, the range of 'selected' colours, for each object, varies significantly with its preselected shape, although the mean 'selected' colour does not. Reaction times for "yes" responses are significantly slower for the 2-D disk than for other conditions. These results demonstrate that object shape and illumination conditions influence both colour perception and memory for familiar objects.

[Supported by the EPSRC (EP/D068738/1).]

◆ **Selective absorption of short-wavelength light in the eye and its effect on yellow – blue chromatic sensitivity**

G Walker, M Rodriguez-Carmona, J Harlow, J Barbur (Department of Optometry and Visual Science, City University, London, UK; e-mail: G.Walker-1@city.ac.uk)

Intersubject variation in yellow–blue chromatic sensitivity has often been associated with individual differences in pre-receptor spectral absorption of light. The macular pigment (MP) and the lens are the two main filters of blue light in the eye. We examined how absorption of blue light by the macular pigment and the lens can affect chromatic sensitivity at both photopic and mesopic light levels. Red–green and yellow–blue chromatic detection thresholds have been measured at the fovea and in the near periphery in both young (<22 years of age) and older subjects by the CAD test. The spatial profile of the optical density of the MP in the eye and changes in blue-light absorption by the lens have been measured with a novel implementation of the flicker-cancellation technique. The results show that intersubject differences in lens absorption and optical density of the macular pigment do not affect significantly yellow–blue sensitivity at high light levels. Yellow–blue chromatic sensitivity is, however, significantly reduced by selective absorption of blue light at lower light levels.

◆ **Colour categories, colour constancy, and lightness perception from information theory**

L Zhaoping (Department of Psychology, University College London, London, UK; e-mail: z.li@ucl.ac.uk)

I explore an understanding of colour appearance predicated on the brain's mapping sensory inputs into discrete categories conveying the maximum Shannon information about the input. Under sufficiently high (but not infinite) signal-to-noise ratio, when an input ensemble contains the usually

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large dynamic range, an information maximizing mapping from the contrast-gain-controlled photo-receptor inputs to, eg six, categories typically carves the input space into regions that correspond to the perception of white, black, red, green, blue, and yellow colour categories. This input-to-category mapping corresponds to another mapping from surface reflectance to category of colour appearance. Illumination changes that sufficiently preserve signal-to-noise can alter the input-to-category mapping but leave the reflectance-to-category mapping almost unchanged, achieving colour constancy. This hypothesis of informationally optimal colour boundaries, when applied to small input ensembles made of inputs from a single or a part of a scene, can account for various colour illusions and, under achromatic inputs, typical phenomena in lightness perception. It does not at present accommodate the spatial configuration factors that influence colour/lightness appearance.

[Supported by Gatsby Charitable Foundation.]

CORTICAL ORGANISATION

◆ **The influence of feedforward and feedback information flows on the organization of visual system**

S V Alexeenko, S N Toporova (Pavlov Institute of Physiology, Russian Academy of Sciences, St Petersburg, Russia; e-mail: sveta@VA1021.spb.edu)

The development of structural and functional organization of each level of the visual system depends on external (sensory) and internal (from memory) information that is provided by feed-forward and feedback neuronal connections. In monocularly deprived cats, unilateral strabismic cats, and in strabismic cats with eye torsion we tried to find out the changes in neuronal connections of areas 17 and 18 related to reorganization of these counter-directed information flows. Microiontophoretic horseradish peroxidase injections were delivered into the single ocular dominance columns (ODCs) and retrogradely labeled cells in different visual structures were assessed. Neuronal connections of deprived or strabismic eye ODCs were reduced or absent; long-range horizontal connections of intact eye ODCs were differently extended in three groups of animals with impaired binocular vision. These effects show the role of correlation of visual stimulation in the 2 eyes, interocular rivalry, and the influences from higher cortical areas. The direct evidence of the reorganization of feedback pathways was obtained by laminar analysis of retrogradely labeled cells in PMLS zone.

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DEPTH

◆ **Integration of ordinal and metric cues in depth processing: comparing contours defined by luminance, contrast, or neither**

M Bertamini, J Martinović¶, S Wuergler (School of Psychology, University of Liverpool, Liverpool, UK; ¶ University of Leipzig, Leipzig, Germany; e-mail: m.bertamini@liv.ac.uk)

Burge et al (2005 *Journal of Vision* 5 534–542) have reported that ordinal, configural cues of familiarity and convexity influence perceived depth. Familiar shapes increased perceived depth if they were shown in the foreground and decreased it if they were shown in the background, even when unambiguous metric information (binocular disparity) was present. There is evidence that luminance cues are necessary for shape information to influence figure–ground. In our experiments the contours could either be defined by disparity only (cyclopean contours), or by an additional monocular cue—luminance or contrast. First, we found that monocularly defined configural cues (either by luminance or by contrast) add to the perceived depth of the cyclopean contour. Second, for a sufficiently large disparity pedestal (about 2.5 min of arc), cyclopean configural cues exert some influence on perceived depth, even in the absence of monocular cues. We conclude that the integration of ordinal and metric cues is driven by general salience of the contours and not only by luminance or contrast.

◆ **Pseudo-holographic device elicits rapid depth cues despite random-dot surface masking**

G J Brelstaff, M Agus, E Gobbetti, G Zanetti (CRS4, Pula, Italy; e-mail: gjb@crs4.it)

Experiments with random-dot masking demonstrate that, in the absence of cues mundanely available to 2-D displays (object occlusion, surface shading, perspective foreshortening, and texture gradients), Holografika's large-screen multi-projector video system (COHERENT-IST-FP6-510166) elicits useful stereoscopic and motion-parallax depth cues, and does so in under 2 s. We employed a simplified version of Julesz's (c.1971) famous spiral ramp surface: a 3-layer cylindrical wedding-cake—via an OpenGL model that subjects viewed along its concentric axis. By adjusting its parameters, two sets of model-stimuli were rendered: one with a uniform large field of depth and one where the field was effectively flat. Each of eleven, pre-screened, subjects completed four experiments, each consisting of eight trials in a 2IFC design whereby they indicated in which interval

they perceived the greatest field of depth. The experiments tested one-eye static, one-eye head-swaying, two-eye static, and two-eye head-swaying observation—in that order. Scores improved also in that order.

◆ **Bayesian inference of visual depth based solely on primitive visual variables**

S Dimitriadis, F Domini (Department of Cognitive and Linguistic Sciences, Brown University, Providence, USA; e-mail: socrates@brown.edu)

Is it possible to estimate visual depth by only using primitive visual variables? How good and under what conditions can such an inference without complex depth cues be? We shed some light on these questions by modeling depth estimation with Bayesian inference. We do that by using two primitive variables only, binocular disparity and velocity of optical flow, that we extract from 200 range images (three types of scenes: interior, residential, forest). The prior here is generated by the statistics of the world while the posterior probability of depth is computed with a non-parametric kernel density estimation. The results show that in well-structured environments (interior scenes) the statistics of the world is enough to facilitate a good inference of depth based on two primitive variables only. The less structured the environment is though (residential or, moreover, forest scenes), the harder it is to make inferences without higher depth cues. The findings support the idea that depth perception may not always be the result of a complex cue integration.

◆ **Depth perception around the boundary between monocular and binocular areas with monocular depth gap**

Y Fujii, H Kaneko, H Mizushima (Imaging Science and Engineering Laboratory, Tokyo Institute of Technology, Yokohama, Japan; e-mail: y-fujii@isl.titech.ac.jp)

Disparity cue is known to affect the perceived depth of adjacent areas with no disparity cue. We suppose this effect of extrapolated depth cue in the monocular area depends on the difference between depths indicated by monocular cue and extrapolated disparity cue. In this study, we investigated depth perception around the boundary between monocular and binocular areas, manipulating the monocular depth gap between the areas. Stimulus was a random-dot stereogram with a monocular area in its center. The size of dots in the monocular area was varied to manipulate the depth gap from the surrounding binocular area. Observers responded specifying the depth and slant of the points around the boundary. The results showed that observers perceived the monocular area as a cylindrical curved surface connected to the binocular areas continuously, when the monocular depth gap was small. When the depth gap was large, however, they perceived separated planar surfaces with sharp depth edges at the boundary.

◆ **Horizontal-disparity processing in the presence of vertical misalignment: The role of monoptic depth**

K Fukuda, L M Wilcox, R S Allison, I P Howard (Centre for Vision Research, York University, Toronto, Canada; e-mail: kfukuda@yorku.ca)

Depth perception from stereopsis is thought to be resilient to vertical misalignments of up to 4° (Ogle, 1955 *Archives of Ophthalmology* 53 495 ff; Mitchell, 1970 *Vision Research* 10 145–162). We have replicated these results, and assessed the assumption that horizontal disparity is responsible for depth in such stimuli. A horizontal line, which extended the width of the display, was inserted between the vertically misaligned horizontally disparate targets. Surprisingly, this had no effect on depth-discrimination performance. We repeated the study with only one half-image (a monoptic target) and the central line. Depth discrimination was above chance for all observers, suggesting that previous results were not due to horizontal disparity, but to the retinal position of the stimuli (Kaye, 1978 *Vision Research* 18 1013–1022; Wilcox et al, 2007 *Vision Research* 47 in press). Tolerance to vertical misalignment has been used as evidence against an epipolar constraint in human stereopsis; the presence of monoptic depth cues in such stimuli suggests that the issue is unresolved. [Supported by Natural Sciences and Engineering Research Council of Canada and CIHR Training Grant in Vision Health Research.]

◆ **Shading gradients and figure–ground organization**

T Ghose, S E Palmer (Vision Science, University of California at Berkeley, Berkeley, USA; e-mail: tandra@berkeley.edu)

We report the interaction of extremal edges, gradient cuts, and surface curvature—features derived from shading gradients—in figure–ground organization. Extremal edges arise when a shading gradient's equiluminance contours are locally parallel to an adjacent edge (eg the vertical edge of a vertical cylinder), and gradient cuts when they are not (eg the vertical edge of a horizontal cylinder). We studied figure–ground organization in bipartite displays made up of cylindrical shading gradients, varying shared-edge type (extremal edges vs non-extremal edges), number of gradient cuts (0–4), number of cylinders (0–4), radius of curvature (flat, small, medium,

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large), and window size (small, medium, large). Our results indicate that, in general, the bias toward a region being perceived as figure is enhanced by the presence of extremal edges and reduced by increasing the number of gradient cuts, decreasing the radius of curvature, and decreasing window size. Significant interactions among these parameters are also present.

◆ **The use of changing disparity over time and interocular velocity differences for motion-in-depth perception**

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There are two potential binocular cues that can be used to see motion in depth: changing disparity over time (CDOT), and interocular velocity differences (IOVD). Mathematically, the information provided by the two cues is equivalent. We investigated how efficiently human observers can use these two cues. No previous work has directly compared these cues under equivalent conditions. We designed three types of random-dot stereograms which, respectively, contained only one or both of the two cues. In the first experiment, we found, using a detection task, that observers were most efficient when both cues were present, and least efficient when only IOVD cues were available. However, in the second experiment, using a direction discrimination task (towards or away), we found that observers could not perform the task at all with only the IOVD cue, and were equally efficient for the CDOT cue alone or when both cues were simultaneously present. The results suggest that for a range of conditions, IOVD provides a weaker source of information for the perception of motion in depth.

[Supported by the EPSRC.]

◆ **Perception of local rigidity due to lines in rotating random-dot textures viewed through an aperture**

A L Noyce, R S Hetley¶, J J Dobiás¶, W W Stine¶ (Department of Psychology, University of New Hampshire, Newmarket [¶ Durham], USA; e-mail: abby@isomerica.net)

When 2-D perspective projections of 3-D rigidly rotating planes are viewed through an aperture, viewers can perceive deformation rather than rigid motion in depth. Animations of a square surface composed of 8000 randomly arranged points, rotating around a horizontal axis in the frontoparallel plane from vertical to 0.3 radians of slant were presented. Stimuli had between zero and four straight lines dividing them into regions, and were viewed through a 10 cm aperture. The slant of planes with random-noise texture is difficult to judge when they are viewed through an aperture (Cornilleau-Pérès et al, 2002 *Vision Research* **42** 1403–1412; Zhong et al, 2006 *Vision Research* **46** 3494–3513), and we found that stimulus regions not near a line could appear to be moving non-rigidly. Texture elements near straight lines appeared to be rigidly rotating. When the texture was re-randomized in every frame, lines only appeared to move within the frontoparallel plane. The motion of the texture elements combines with the rigid lines to force a perception of localized rigidity in three dimensions.

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◆ **Misestimation of the perceived shape of disparity-defined surfaces is consistent with disparity-gradient rather than slant bias**

L M O’Kane, P Hibbard, R Goutcher¶ (Department of Psychology, St Andrews University, St Andrews, Scotland, UK; ¶ Sterling University, Stirling, Scotland, UK; e-mail: lmo1@st-and.ac.uk)

Observers overestimate vertical distances relative to horizontal distances. This bias has been interpreted as reflecting the probability distributions of distances found in the natural environment (Howe and Purves, 2002 *Proceedings of the National Academy of Sciences of the USA* **99** 13184–13188). We investigated such biases for stimuli in which depth information was available from binocular cues and whether this is best described in terms of properties of the environment (slant) or of retinal images (disparity gradients). By varying the aspect ratio and slant of rectangular planar surfaces defined by sparse random-dot stereograms, we measured the shape that appeared square to the observer, for each slant tested. Results were expressed in terms of effective slant across a range of viewing distances. Effective slants were significantly biased towards intermediate values of around 30°, in the same direction as the typical horizontal–vertical illusion. This value increased with increasing observation distance. We conclude that biases in the perceived shape of disparity-defined surfaces are most parsimoniously accounted for at the level of disparity-gradient processing, prior to a stage of distance scaling.

[Supported by the BBSRC.]

◆ **Depth-cue combination within and across modalities reflects the reliability of texture information but not in a statistically optimal way**

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It has been suggested that humans combine depth cues in a statistically optimal fashion, taking into account the exact reliability of the available cues to maximize the reliability of the depth estimate. We have reported that human performance on slant-from-texture discrimination depends on the texture type mapped onto the slanted planes. This allows a natural way of manipulating the reliability of the texture cue by simply changing the texture type. Using a slant-discrimination task we tested the reliability-sensitive combination within the same sensory modality using texture and motion, and between sensory modalities using texture and haptic cues. Both within and between senses we found little evidence for optimality. What we did find, in particular for texture and haptic cues, is that cue combination is influenced by the reliability of the cues involved. Quantitatively, however, the much stronger claim of optimality is not met. Taken together, our experiments suggest a depth-cue combination mechanism heuristically taking reliability into account. Optimality, on the other hand, does not hold generally.

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◆ **Preliminary evidence for size constancy illusion in baboons (*Papio papio*) induced by texture gradients**

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There are some differences between terrestrial humans and arboreal New World monkeys in their depth perception from texture gradients [Sakai and Fujita, 2006 *47th Annual Meeting of the Psychonomic Society, Houston, TX, 16–19 November* (Austin, TX: Psychonomic Society)]. We hypothesized that humans have evolved a strategy of 3-D perception appropriate for their visual environment. We investigated whether terrestrial baboons (*Papio papio*) also perceive depth from texture gradient cues. Five baboons were trained to classify red disks of different sizes (the sample) into two size categories, large and small. Then the middle-sized sample was presented on a background that depicted depth (ground or ceiling) in probe trials. Preliminary results showed that the baboons perceive size-constancy illusion from depth depicted by texture gradient cues, suggesting that Old World monkeys have 3-D scene perception and a similar size constancy system to humans. We propose that the visual systems of different species may have evolved sensitivity to various pictorial depth cues depending on their niches and accompanying changes in visual environment.

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◆ **Texture patterns of background effect on the reverspective illusion**

K Suzuki (Faculty of Human Studies, Taisei Gakuin University, Sakai, 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. The combination of perspective, texture gradient, and shadows produces a powerful effect (Papathomas and Bono, 2004 *Perception* 33 1129–1138). Anderson et al (1998 *Perception* 27 1087–1106) investigated the effects of four different texture patterns on depth perception. I investigated how the painted texture patterns of the ground plane and the ceiling plane effect the illusion. Five subjects participated in the study. One independent variable was the painted patterns of the ground and ceiling planes: compressed, convergent, grid, and solid color. A second variable was the viewing condition: monocular or binocular. Both variables were run as within-subjects variables. To assess the effect on the illusion, the critical distance at which a perceptual switch occurs was measured. Both variables were found to be significant, suggesting that the background pattern of a reverspective stimulus has a strong effect on the illusion.

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- ◆ **Perception of surface slant produced by horizontal and vertical disparities in human infants**
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It has been suggested that the mechanisms of processing horizontal and vertical disparities are functionally different, although both vertical and horizontal magnifications of a stereoscopic half-image (vertical-size and horizontal-size disparities) produce the same perception of surface slant about the vertical axis. This led us to expect that there would be a crucial difference in the developmental aspects of those mechanisms, which have not ever been investigated. In this study, we examined whether infants aged 20 to 40 weeks could detect horizontal-size and vertical-size disparities in the perception of surface slant using preferential looking procedure. We used random-dot stereograms of anaglyphs with 4% of vertical-size or horizontal-size disparity. For the stimulus with vertical-size disparity, the significant preferences to the side predicted to be closer was observed in the infants tested. For the stimulus with horizontal-size disparity, however, no significant preferences to either side of the surface was observed. These results suggest that the sensitivity to vertical disparity develops earlier than that to horizontal disparity in the periphery.

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LGN

- ◆ **Cascaded spatiotemporal contrast processing: Evidence from the interocular transfer of adaptation effects**

K Langley, P J Bex ¶ (Department of Psychology, University College London, London, UK; ¶ Schepens Eye Research Institute, Harvard Medical School, Boston, USA; e-mail: ucjtskl@hotmail.com)

The effects of spatiotemporal contrast adaptation on threshold contrast provide evidence for sustained and transient processes. We examined the functional organization of spatiotemporal mechanisms with monocular and interocular contrast-adaptation effects. Subjects adapted monocularly to four orientation-filtered $1/f_2$ noise patterns in separate quadrants of the monitor. The adapting patterns were immediately replaced by a horizontal and a vertical test pattern whose locations were identified in a 2×4 AFC task. Threshold contrast elevations (TCEs) were found to be generally saturating functions of adaptor contrast in dichoptic conditions, but increased monotonically in monoptic conditions. On further examining the spatiotemporal surface of TCEs as a function of both adaptor and test temporal frequency, we found that dichoptic TCEs were low-pass (sustained) but monoptic TCEs were primarily band-pass (transient). Our results are consistent with a cascaded model of contrast processing in which transient effects of contrast adaptation occur before binocular combination and sustained effects of adaptation occur after.

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MULTISENSORY INTEGRATION

- ◆ **Magnitude of tactile sensation can be modulated by visual-motion information**

K Arai, K Okajima (Graduate School of Information Science, Yokohama National University, Yokohama, Japan; e-mail: d07tc002@ynu.ac.jp)

We conducted several experiments to examine the effect of visual-motion information on the magnitude of tactile sensation (MTS). The experimental setup consisted of a CRT display and two mirrors to present a moving computer-generated ball, and a computer-controlled electric cylinder to hit the observer's palm. This enabled us to control visual-motion information and contact force independently. Subjects estimated the MTS in the test phase with various visual stimuli by comparing the MTS in the reference phase with a constant visual stimulus. The results show that a higher collision speed of the visual stimulus induces a lower MTS assuming that the time-lag between visual and tactile stimuli is less than 500 ms, suggesting that a gain-control mechanism in tactile information processing exists and there is a temporal tolerance in the modification effect.

- ◆ **The subjective visual vertical and the perceptual upright in males and females**

M Barnett-Cowan, C Thompson, J Sanderson, R Dyde, L Harris (York University, Psychology, Toronto, Canada; e-mail: mikebc@yorku.ca)

Previous reports suggest differences between males and females when performing spatial perception tasks, where males align a luminous line more accurately with gravity. This may be attributable to males and females weighting visual, gravity, and body orientation cues differently.

The subjective visual vertical (SVV) and the perceptual upright (PU) were assessed with different visual and body orientations. SVV was measured by using the luminous line. PU was measured with the orientated-character-recognition task (OCHART). For SVV, when upright, females were significantly more influenced by visual cues and had higher variances than males. When lying sideways males and females were equally influenced by vision and had equal variances. For PU, males and females were equally influenced by visual cues and had equal variances at both body orientations. These differences confirm that PU and SVV are determined by different mechanisms with only the SVV showing gender differences.

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◆ **Temporal adaptation influences non-adapted modality pairs**

M Di Luca, T-K Machulla, M O Ernst (Max Planck Institute for Biological Cybernetics, Tübingen, Germany, e-mail: max@tuebingen.mpg.de)

Repeated presentations of asynchronous audiovisual signals recalibrate the point of subjective simultaneity. It is not clear whether this effect is the result of an adaptation mechanism specific to the audiovisual modality pair or whether it is due to a mechanism common to all modalities. Only in the latter case would we expect repeated asynchronous audiovisual information to influence perceived simultaneity in other modality pairs (audiotactile or visuotactile). We presented a series of asynchronous audiovisual signals to the participants (SOA: 200 ms, –200 ms) and then estimated the point of subjective simultaneity for three modality pairs (audiovisual, audiotactile, visuotactile). Consistent with previous research, perceived simultaneity in the audiovisual modality pair changed for the two SOAs. Subjective simultaneity shifted also in the audiotactile modality pair. Hence, we conclude that the three tested modalities share a common adaptation mechanism. Moreover, since the visuotactile modality pair was not significantly affected by the manipulation, audiovisual adaptation is likely the result of a phenomenal shift of the auditory events in time.

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◆ **Crossmodal transfer in face recognition—from haptics to vision**

L Dopjans, C Wallraven, H Bühlhoff (Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: lisa.dopjans@tuebingen.mpg.de)

Prior studies have shown that humans can recognize faces by touch alone. We investigated haptic face recognition with two experiments using a well-defined stimulus face-space based on the morphable MPI-Face-Database. In experiment 1, we used an old/new recognition task for which different sets of three faces (out of six) were learned haptically with three subsequent haptic test-blocks and one visual test-block. We found that participants could recognize faces haptically although recognition accuracy was low (65%) and tended to decrease across blocks. Crossmodal recognition, however, was at chance level (48%). In experiment 2, haptic memory was refreshed before each test-block by repeated exposure to the three learned faces. We found that performance increased significantly to 76% and that it became more consistent across blocks. Most importantly, however, we found clear evidence for crossmodal recognition as visual performance rose above chance level (62%). Our results demonstrate that, during visual face recognition, participants have access to information learned during haptic exploration allowing them to perhaps form a visual image from haptic information.

◆ **Multisensory processing of congruent and incongruent auditory – visual movie clips of everyday actions**

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Event-related potentials (ERPs) were used to determine the role of semantic congruity in the processing of audiovisual movies of everyday actions (taking steps, opening a door, ...), presented either unimodally or bimodally, in congruent or incongruent combinations. Incongruent combinations elicited a broad frontocentral negativity. A source analysis of this effect points to a generator located in the anterior cingulate gyrus. In addition to this late N400-like effect, early components of the ERP for incongruent stimuli had higher amplitudes than the early components observed in congruent stimuli. We discuss potential origins of this early effect. In a second analysis, stimuli were classified into seven categories (office, kitchen, ..., and a none category for remaining stimuli). This analysis revealed that semantic incongruity only partially accounts for the negative effect. It seems rather that most of the N400-like effect is due to an ongoing search process called structural description matching (Ganis and Kutas, 2003 *Cognitive Brain Research* 16 123–144), which primarily depends on the typicality of the stimulus.

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◆ **Asynchrony adaptation is not specific to sound and vision**

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Adaptation to a fixed level of audiovisual asynchrony has been shown to produce rapid, marked distortions of relative perceived time showing that our perception of 'when' is highly influenced by recent experience (Fujisaki et al, 2004 *Nature Neuroscience* 7 773–778). As humans frequently encounter distant audiovisual events (causing sound to lag behind vision), it has recently been speculated that this type of sensory recalibration may be specific to the audiovisual domain (Miyazaki et al, 2006 *Nature Neuroscience* 9 875–877). Here we present a series of experiments examining how adaptations to audio-somatosensory (AS) and visuo-somatosensory (VS) asynchrony influence subsequent judgments of temporal order. Following repeated exposure to asynchronous AS or VS pairs, observers adaptively shift their point of subjective simultaneity toward the adaptation asynchrony. This occurs despite the fact that such asynchronies are not encountered in everyday experience. Our effects point toward highly flexible timing mechanisms that adaptively modulate the perceived relative timing of any sensory input.

[David Whitaker is supported by the Leverhulme Trust, UK.]

◆ **Effects of active observation on the temporal order of audiovisual stimuli**

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We examined how an observer's active control of the visual stimulus affects the perceived temporal order of audiovisual stimuli, and whether the effects of active control of the visual stimulus are restricted to visual processing. A white square moved upward or downward, and changed its shape into a rectangle. The timing of the changes was random. In the active condition, the stimulus movement was controlled by a computer mouse, while in the automatic condition the stimulus moved automatically. In each trial, at random times before or after the shape change, a rectangle was flashed next to the fixation point or an auditory flash was presented. Observers reported the perceived temporal order between the flash and shape change. The results show that active control of the visual stimulus facilitates the processing of the visual flash, while it has no effect on the processing of the auditory flash. These results suggest that the effect of the active control of the visual stimulus is restricted to the visual modality.

◆ **Where was the object when you heard that sound? Visual motion-based temporal localization of brief auditory events**

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We investigated the use of the spatial position of a moving object as a cue for the temporal localization of an auditory event. A brief sound (5 ms) was presented during the movement of a disc along a horizontal or vertical trajectory. The disc travelled at a constant speed and the sound occurred at one of five possible instants. Once the disc disappeared, subjects had to indicate (using the mouse) where the disc was when the sound was heard. Three experiments were conducted, in which the response was given by clicking (i) on a line located in the centre of the screen, (ii) on a line located where the disc travelled, or (iii) on the empty display without references. Subjects systematically displaced the sound forward in the direction of motion with respect to the moment when it had actually occurred. The displacement was greater when the sound was presented in the first half of the trajectory. These results suggest that auditory temporal localization is strongly influenced by visual motion.

◆ **The effect of tilt on the perceptual upright**

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The perceptual upright (PU), the orientation in which an object is most easily and naturally recognized, is determined by combining visual, gravity, and body cues. Recognizing a character the identity of which depends on its orientation can be used to assess PU. For example, the letter 'p' when rotated 180° becomes the letter 'd'. The transitions from p to d and d to p, when averaged, define PU. This is the orientated character recognition task (OCHART). The PU can be predicted from the weighted vector sum of the orientation of the visual background, gravity, and body. Observers completed OCHART in several body tilts in roll. The PU measured at some body tilts (eg 45°) was not accurately predicted by this simple model. One possible explanation for this is that the nervous system's assessment of the relative weights and directions of vision, gravity, and the body required to determine the PU may depend on the internal representation of the body tilt and the orientation of the eyes in the head.

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◆ **Perception of crossmodal simultaneity is not transitive**

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When signals in different modalities are physically asynchronous, observers may still perceive them as being simultaneous due to differential physical transmission and physiological conduction delays. If sensory signals in different modalities are processed independently of each other as assumed by independent-channels models, the relative timings that lead to perceived simultaneity should be transitive across several modality pairs. For example, if modality A has to be presented 20 ms before modality B to seem simultaneous with it and modality B 10 ms before modality C, then A should be presented 30 ms before C to seem simultaneous with it. Using temporal-order judgments, we measured the point of subjective simultaneity (PSS) in three different modality pairs (visual–auditory, tactile–auditory, visual–tactile). Our results indicate that PSSs are not transitive. Thus, we infer that signals are not processed independently. Perceived signal timing in one modality depends on which other modality it is paired with. Therefore, independent-channels models cannot account for processes underlying decisions about simultaneity of signals in different modalities.

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◆ **The effect of viewing one’s own hand as abnormally large or small on the perception of body size**

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Converging evidence from studies on multisensory integration suggests that vision dominates both touch and proprioception in the perception of body posture. We investigated whether vision has a dominant role also in the perception of body size, by measuring the effects of distorted vision on the kinematics of grasping. Eight right-handed participants were asked to grasp a cylinder with a right-hand precision grip while they were alternately exposed to a real-size, enlarged, or shrunken vision of their grasping hand. We found that the maximum grip aperture (ie the maximum distance between the index finger and the thumb) significantly decreased during the enlarged-hand viewing condition, as compared to the real-size condition. Surprisingly, this effect persisted when, following the enlarged-hand viewing condition, subjects grasped without vision (aftereffect). In contrast, the shrunken-hand viewing condition failed to produce any effect on grasping. These findings suggest that vision can play a role in body-size perception that may be so profound as to alter the kinematics of grasping in a long-lasting fashion.

◆ **Effect of visual information and body tilt on the perception of gravitational vertical**

I Negishi, H Kaneko, H Mizushima (Imaging Science and Engineering Laboratory, Tokyo Institute of Technology, Yokohama, Japan; e-mail: negishi@isl.titech.ac.jp)

Our perceptual system integrates the multiple sources of information for the perception of gravitational vertical. We investigated properties of the integration process, especially whether each source of information affects the output (perceived vertical) independently or not. To manipulate vestibular and somatosensory information of gravitational vertical relative to the body, we tilted the subject’s body using a seat which could rotate about the roll axis of the body. To manipulate visual information of the vertical, we presented a tilted square on a display placed in front of the subject. By hand, the subject adjusted the direction of a rod to the perceived direction of gravitational vertical for many combinations of body and visual stimulus tilts. The results showed that visual information affected the perceived direction of gravitational vertical only when the visual vertical was close to the perceived vertical. This result suggests that our perceptual system utilizes or discards visual information depending on its salience.

◆ **Crossmodal interactions between visual and haptic information in 3-D object learning and top–down processing: An fMRI study**

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Multimodal experiences may often influence the interpretation and recognition of 3-D objects. We used fMRI to examine the brain areas involved in crossmodal interactions in 3-D object learning and top–down processing. We generated visual 3-D objects using computer graphics. Haptic objects were produced as plaster objects with a 3-D printer. The subjects learned the objects’ shape by using either visual or haptic information and then used the other modality to judge their 3-D shape. When the subjects used haptic memory to visually judge the objects’ shape, the extrastriate visual cortex, together with the superior and inferior parietal lobules, and the precuneus were

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activated. However, when the subjects used visual memory in the haptic judgment of the objects' shape, the fusiform gyrus, together with the superior and inferior parietal lobules, the precuneus, and the somatosensory area were activated. The results suggest that networks between the visual areas in the temporal lobe and the haptic areas in the parietal lobe play a crucial role in the crossmodal 3-D object recognition.

◆ **Unimodal sequential grouping versus crossmodal simultaneous grouping of auditory and visual stimuli**

G B Remijn, H Ito (Department of Visual Communication Design, Kyushu University, Fukuoka, Japan; e-mail: gbremijn@yahoo.co.jp)

Temporal-order judgments (TOJs) were obtained on a target sound–flash pair either presented alone or with an additional sound and flash that flanked the target pair in time. The additional sound and flash were, respectively, presented 250 ms before and after the target pair, or vice versa. Theoretically, the target sound and flash thus could either group together (simultaneous crossmodal grouping), or the target sound and flash could group, respectively, with the flanking sound and the flanking flash (sequential unimodal grouping). Presented in isolation, the mean just noticeable difference (JND) between the members of the target pair was 68 ms. In conditions with an additional sound and flash, however, the mean JNDs were significantly smaller (42 ms and 38 ms). The results seem to indicate that unimodal sequential grouping constrained crossmodal simultaneous grouping, and that TOJ between two unimodal sources (one auditory and one visual source) is easier than TOJ between an auditory and visual target that emanate from a single source.

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◆ **Can visual imagery modulate haptic perception?**

L G Scocchia, J Loomis¶, N Stucchi (Department of Psychology, University of Milano-Bicocca, Milan, Italy; ¶ University of California at Santa Barbara, Santa Barbara, USA; e-mail: lisa.scocchia@unimib.it)

It has been hypothesized that sighted people adopt a visual translation process when attempting to identify 2-D raised images by touch—they employ a visual image as a mediator between the haptic sensory information and the object representation. If this hypothesis is correct, it might be expected that performance in identifying pictures by touch (with eyes closed) ought to be better when the head is facing the picture than when facing in a very different direction. Twenty-four blindfolded participants were asked to identify raised pictures of common objects with their head facing either in the same direction as the raised picture or in an orthogonal direction. Identification performance was measured in terms of accuracy and response times. Overall, participants were more accurate and faster when their heads faced in the same direction as the picture. This result supports the hypothesis that visual imagery is used to mediate haptic recognition of pictures in sighted people.

◆ **Physical self-motion facilitates object recognition, but does not enable view-independence**

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It is well known that people have difficulties recognizing an object from novel views as compared to learned views, resulting in increased response times and errors. Simons et al (2002 *Perception & Psychophysics* 64 521–530) reported, however, the elimination of this viewpoint dependence when novel views resulted from viewer movement instead of object movement. They suggest the contribution of extra-retinal information to object recognition. The aim of the present study was to clarify the underlying mechanism of this phenomenon and to investigate larger turning angles (45°–180°, in 45° steps). Observers performed sequential-matching tasks with 5 original versus mirror-reversed objects (experiment 1) and with 10 different objects (experiment 2). Test views of the objects were manipulated either by viewer or object movement. Both experiments showed a significant overall advantage for viewer movements. Note, however, that performance was still viewpoint-dependent. Object recognition performance was also highly correlated with general mental spatial abilities assessed by a paper-and-pencil test. These results suggest an involvement of advantageous and cost-effective transformation mechanisms, but not a complete automatic spatial-updating mechanism, when observers move.

◆ **The formation of crossmodal object categories in the adult human brain**

M van der Linden, M van Turenout (Learning & Plasticity, F.C. Donders Centre, Nijmegen, The Netherlands; e-mail: m.vanderlinden@fcdonders.ru.nl)

The objects around us are perceived through multiple senses. The pathways for visual and auditory perception are anatomically distinct and need to be integrated to form crossmodal representations. We investigated the formation of crossmodal object categories in the brain. The stimulus set consisted of six highly similar bird shapes and sounds that were morphed to create different exemplars of each category. Subjects learned novel crossmodal categories using a 1-back task. After training, subjects were scanned (3 T, TR = 2170 ms, TE = 30 ms, 3 mm³ voxels, 32 slices) while passively viewing and listening to the birds. Stimulus blocks consisted of bird sounds only, bird pictures only, matching pictures and sounds (crossmodal congruent), and mismatched pictures and sounds (crossmodal incongruent). fMRI data showed visual object-category learning in the right fusiform gyrus, and auditory learning in the middle temporal gyrus. Interestingly, congruency effects were observed for trained bird shapes and sounds in a network of temporal and frontal regions, providing evidence for experience-induced formation of crossmodal object categories. [Supported by NWO grant 400-03-338.]

◆ **Visual interference modulation on haptic parallelity matching**

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When incongruent information is provided via two modalities and responses based on one modality only are required, a biasing effect of the conflicting modality can be expected. We investigated the influence of visual information on haptic space perception using a haptic parallelity-matching task. The task consists of haptically orienting a bar parallel to a reference bar. Systematic deviations of on average 50° are usually observed. A pure haptic condition served as baseline, two gazing-direction conditions probed into non-informative vision, and five visual interference conditions (ranging from -40° to 40° compared to the haptic orientation) were used to study the modulation of visual interference. Non-informative vision improved performance and visual interference biased the systematic deviations in a predictable manner. The weight of the haptic information was predominant, thus showing only a partial visual capture. Deviations increased/decreased on average by maximally 13% in the direction of the visual interference. Moreover, the interplay of visual and haptic modalities was found to be gender-dependent.

◆ **Acquiring a new visual constancy**

M Wexler (Laboratoire Psychologie de la Perception, CNRS–Université Paris Descartes, Paris, France; e-mail: mark.wexler@gmail.com)

The usual view of the origin of perceptual constancies is that they arise from the extraction of invariants from the flow of sensory data. An alternate view holds that constancies arise from sensorimotor anticipation of motor actions. The usual way of studying the origin of constancies is to study infants, but results have been controversial, with claims of constancies present at birth contrasting with evidence for gradual development. I suggest a different approach: studying the acquisition of unrealized but theoretically possible constancies in adult subjects. As an example, I present data on a type of lightness constancy that does not seem to exist in adult subjects. Subjects can acquire this constancy after several hours of manipulating a virtual light source; they can also acquire it by watching the visual consequences of such manipulation, but in this case learning is slower and generalization poorer than in the active manipulation condition. The difference in performance between the two conditions supports the sensorimotor view of the origin of constancies.

NEURAL CODING

◆ **Temporal dynamics reveal topographic neural spreading of contrast suppression**

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We measured the temporal dynamics of the contrast–contrast illusion using the method of constant stimuli. A circular sinusoidal (2 cycles deg⁻¹) patch (c 50%) was surrounded by an annulus. Annulus contrast (50%–90%) varied sinusoidally with 0.5–16 Hz temporal frequency. The induced contrast modulation was low-pass, decreasing steeply above 1–2 Hz. In the control condition, the contrast of the test-patch was modulated and the perceived contrast modulation was found to be relatively independent of the temporal frequency up to 8 Hz. Similar results for experiments on color and brightness (induction limit at 2.5 Hz—De Valois et al, 1986 *Vision Research* 26 887–897) have been interpreted as evidence for topographical filling-in. In addition,

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we found interaction between the stimulus size (c/s 0.75/1.75 deg, 1.5/3.5 deg, 3/7 deg) and the temporal frequency. Larger stimulus resulted in lower cut-off frequencies for induced modulation. These results are consistent with neural spreading of contrast suppression.
[Supported by Academy of Finland 210676.]

◆ **Stimulus-induced decorrelation of neuronal activity in the visual system**

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The reliability of neuronal encoding of sensory inputs depends on the correlation structure and basic response statistics of the activity of the neurons. We examined the response statistics, including the correlation structures of responses to visual stimuli in the anterior superior temporal sulcus and inferotemporal cortex of the macaque monkey. We find that stimulus-elicited activity starts with a brief period showing reduced response variability and decorrelation of neuronal activity in both time and space. After -50 ms of decorrelated activity, the levels of correlation between and within neuronal responses during periods of stimulus-elicited activity resemble the levels observed in the resting state. The decorrelation and reduction in response variability occurs in both active and inactive neurons, suggesting a network-wide effect. These results suggest that the feedforward components of the network convey signals that are independent of each other. The re-emergence of the correlated activity may reflect signals useful for learning as well as representing the impact of prior expectations about upcoming stimuli.

◆ **Flicker – clicker: Matching the frequency and phase of visual and auditory stimuli**

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Cross-modality matching between visual flicker and auditory 'clicker' can be used to investigate the nature of stimulus encoding at central sites where visual and auditory signals interact. At frequencies below ca 2 Hz, flicker and clicker can be reliably matched in phase and in frequency. Between ca 2 to 3.5 Hz, reliable phase matches cannot be made, but residual phase-dependent changes in perceived synchrony suggest that some phase information is retained. Between ca 3.5 and 12 Hz (depending on the visual pathway) the stimuli can be accurately matched in frequency, but not in phase. Above ca 12 Hz, frequency matching fails and the visual flicker rate is consistently underestimated. Veridical cross-modality phase matching suggests that visual flicker at low frequencies is encoded by a moment-by-moment variation of the neural signal that propagates to central sites. However, at frequencies above 3.5 Hz, only rate information survives, and above 12 Hz, even this information is unavailable. Loss of information about temporal frequency and phase imposes limits on the processing of visual stimuli that can be accomplished centrally.
[Supported by The Wellcome Trust.]

◆ **A neural model of lightness and brightness scaling**

T Seim, A Valberg, B B Lee¶ (Department of Physics and Biophysics, Norwegian University of Science and Technology, Trondheim, Norway; ¶ Max Planck Institute for Biophysical Chemistry, Göttingen, Germany; e-mail: thorstein.seim@c2i.net)

Cone opponent cells are found at several levels of the primate visual system. Of the six main opponent cell types in the retina and lateral geniculate nucleus (LGN), two PC-cell types (the increment and decrement cells; also called ON and OFF cells) are devoted to the L–M dimension of cone space while other I-cells and D-cells deal with the M–L dimension. We have earlier demonstrated how subtracting responses to achromatic stimuli separates out a chromatic component that allows for the scaling of chromatic colour differences (Valberg et al, 1986 *Journal of the Optical Society of America A* 3 1726–1734). Here, we present a model of how the combined activity of I-cells neutralizes the differential response of each cell type to chromatic stimuli while it at the same time augments the response to achromatic stimuli. The model response resulting from convergence of I-cell and D-cell output correlates well with lightness and blackness perception, respectively.

[Supported by the International Neuroinformatics Coordinating Facility.]

RETINA

◆ **Dark adaptation of the human visual system**

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Our goal was to measure the psychophysical dark adaptation of individual subjects whose ERG b-wave dark adaptation was investigated. We developed a Matlab GUI program to control a commercial desktop Ganzfeld, so as to measure thresholds by an automated staircase procedure.

The subject viewed blue flashes through a mask that provided a test field of 5, 10, 15, or 20 deg diameter, centred at 12 deg in the nasal field. Bleaches were delivered in a separate Ganzfeld. Prior to each bleaching run, the subject was dark-adapted, and recovery was followed until the threshold returned to the dark-adapted level. Recovery was examined for bleaches ranging from about 2% to near-total, and in each case an S2 component was observed (Lamb, 1981 *Vision Research* **21** 1773–1782), with a slope of $\sim 0.24 \log_{10}$ units min^{-1} , as reported for the data of Pugh (1975 *Journal of Physiology* **248** 413–431). The effect of stimulus size is reported, and comparison is made with ERG b-wave recoveries.

THEORY AND MODELS

◆ Application of a vision model in nocturnal fog by video-photometric image analysis

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90% of a road user's driving task is accomplished through information obtained by visual perception of the environment. Fog alters this information and renders the driving situation unsafe. In fact, the decrease and the evening out of luminance levels reduces contrasts and delays the detection of targets. In order to quantify these deteriorations, experiments were carried out in a fog chamber, enabling the assessment of target visibility illuminated by car headlights in nocturnal fog. Photometric measurements led to the calculation of visibility thresholds which were then compared to theoretic visibility thresholds provided by Adrian's model. Visibility indexes obtained from these comparisons enable an adaptation of the model in fog to be envisaged. The synchronization required by the operating mode of these measurements was considerably facilitated by photometric imaging. This technology [luminance-calibrated CCD cameras with a spectral sensitivity close to $V(\lambda)$] enables instantaneous coverage of a field of view and an analysis of the set of luminances of this angular field.

◆ Centre-symmetric process anisotropy of form creation within the process of human visual perception

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Theoretical and experimental investigations based on the principles of transcendental psychology revealed that the form creation process taking place during gaze fixation may be characterized by centre-symmetric process anisotropy [Artemenkov, 2005 *Journal of Vision* **5**(8) abstract 727]. This internal characteristic property has been studied by size matching two simultaneously briefly presented symmetrically off-centre objects (eg contoured polygons) of constant size (A) and size varying (B): either dilating or contracting at high speed ($30\text{--}40 \text{ deg s}^{-1}$) reaching a final size of 90%–110% of A. Between the trials, A and B were changing their places and B was reversing its movement in a random way. Visual appearance of the B size was checked in its final position and the objective was to determine whether the perceived sizes of A and B were equal or different. The results confirm the predicted tendency of perceiving contracting B as smaller in size than A objects, while the size of dilating B is seen as approximately equal to that of A.

◆ Using a theoretical straylight model to predict glare disability in real-world perception

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Glare disability comprises visual impairment that occurs during exposure to a strong light source. It results from intraocular straylight, which surrounds the source in the visual field and effectively lightens the background. This can make stimuli difficult to distinguish, sometimes even when they are visually distant from the source. A succession of expressions has evolved to predict the geometry of glare effects. We combined the 2003 Vos straylight function with a piecewise visual response model of Ferwerda to predict glare disruption in real-world conditions. Our model accepts multiple input variables to characterize the source (illuminance, range, divergence, spectral composition), the viewer (age, ocular pigmentation), the viewing conditions (background luminance), and the target stimulus (contrast and size). Its output comprises indices of threshold elevation, which may be expressed either as equivalent background luminance or as field-of-view-obscured. The model is now being tested for application in vehicle-control environments and refined to operate in specialized conditions including coherent monochromatic sources and murky atmospherics.

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◆ **Elegance, phenomenal importance, and personality, as conditions of visual amodal completion of meaningful object images**

V Biasi, P Bonaiuto ¶ (Department of Educational Sciences, Third University of Rome, Rome, Italy; ¶ First University of Rome, Rome, Italy; e-mail: valeria.biasi@romascuola.net)

Incomplete images trigger amodal completion [Michotte et al, 1967, in *Studia Psychologica* (Louvain: Publications Universitaires)]. This process appears to be related to a need for completion, self-assessable on an 11-point scale and affected by different factors, including object importance (higher with important objects). Another factor is incongruity intolerance: intolerant people appearing more inclined to effect completion. Expert judges selected nine coloured car images, classified as luxury, intermediate but elegant, or modest. Each car involved five random individual presentations, ranging from very incomplete to complete. Besides the need for completion, each participant evaluated physiognomic aspects of the cars, on 7-point bipolar scales. Adults of both genders were examined, with double-blind conditions and other precautions. The luxury cars elicited significantly higher completion needs, followed by the intermediates and then the modest models. The roles of phenomenal importance and elegance were confirmed with the semantic profiles measured with the scales. Repetition of the experiment with different cars and subjects and evaluation of the individual incongruity intolerance index confirmed previous results and the influence of personality.

[Supported by the Department of Educational Sciences, University of 'Roma Tre' and Faculty of Psychology 2, First University of Rome.]

◆ **Semantic components and personality influences in visual organization of illusory contours, surfaces, and volumes**

P Bonaiuto, V Biasi ¶, A Giannini (Department of Psychology, First University of Rome 'La Sapienza', Rome, Italy; ¶ Third University of Rome, Rome, Italy; e-mail: paolo.bonaiuto@uniroma1.it)

Different conditions favour illusory patterns [Petry and Meyer (Eds), 1987 *The Perception of Illusory Contours* (New York: Springer)], like shadow depictions, amodal completion, cause-effect illustrations, etc. Among relevant variables, we evaluated semantic components: the expressions attributing importance to persons and objects. We also studied the role of incongruity intolerance. We present the criteria, depictions, and results of many experiments with illustrations of men and women with elegant vs shabby appearance, or new or used objects. Illusory clarity was evaluated on an 11-point scale. Importance levels and other physiognomic features required 7-point bipolar scales. Graphic density was equalised with Adobe Photoshop CS program. Participants were adults of both genders, individually examined with appropriate precautions, including double blindness. The Building Inclination Test described in 1990 by Bonaiuto et al was used for assessing incongruity intolerance levels. Visual clarity of illusory patterns was significantly higher with elegant figures or those whose phenomenal importance was high on the scales. Interaction with incongruity intolerance levels was significant, showing that these phenomena aim to reduce or avoid bothersome incongruities.

[Supported by Faculty of Psychology 2, First University of Rome, and Department of Educational Sciences, Third University of Rome.]

◆ **Spatio-temporal motion estimation using the Wigner – Ville distribution and the Hough transform**

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There is a lot of evidence that biological visual systems devote considerable resources to the processing of motion. In the mammalian visual system, motion analysis constitutes a key element for the perception of objects in our environment. Thus, computational approaches to motion estimation can be inspired by our knowledge of biological systems, providing potential and efficient models to be used in many applications. Many neurophysiological studies have shown that the well-organized cells in V1 exhibit spatial-frequency selectivity for moving and still sinusoidal gratings. Visual stimuli are processed in parallel by exploring data via spatial spatial-frequency channels. Thus, we present a new framework for optic flow estimation based on a spatiotemporal/feature detection approach. The method relies on the computation of the Wigner – Ville distribution of the sequences followed by a Hough transform for detecting the motion (eg Kawakami and Okamoto, 1996 *Vision Research* 36 117–147). Experimental results have been shown to be accurate for detecting motion at edges and robust to noise degradations. A comparison with variational techniques is presented.

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◆ **Generalized Rényi entropy as new image quality metric**

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Entropy as a measure of information and uncertainty can be calculated on a local basis by using a spatial spatial-frequency distribution as an approximation to a probability-density function. Normalized windowed pseudo-Wigner distribution (PWD) and generalized Rényi entropy have been selected for this purpose. As a consequence, a pixel-by-pixel entropy value can be calculated and therefore entropy histograms can be generated. Variance of such entropy distribution has been derived to define a new image-quality measure. The main purpose of this paper is to show how such metric, that could be associated with image anisotropy, can be used to assess both the fidelity and quality of images. Experimental results show that such an index presents some desirable features that resemble those of an ideal image quality function, constituting a suitable quality index for natural images. Thus, in-focus noise-free natural images have been shown to present a steady distinct maximum for this metric, compared to other degraded blurred or noisy versions.

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◆ **Model of motion field diffusion controlled by form cues**

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We present a model of motion integration and segmentation inspired by the primate visual system via coupled partial differential equations. These two key elements are combined in order to solve classical aperture problem and also to estimate velocity maps on complex scenes such as transparent motion or motion occlusion. Local motion estimation is solved through a recurrent V1–MT process (Bayerl and Neumann, 2007 *International Journal of Computer Vision* **72** 27–45). However, feedback diffusion is controlled via a second recurrent network (V1–V2 like) that estimates local form information on a different spatial scale. We investigate how this architecture can reveal some integrative centre–surround MT cell properties (Huang et al, 2007 *Neuron* **53** 761–770). We evaluate our model on several synthetic and real sequences against both neuronal and psychophysical data on the dynamics of motion integration.

[Supported in part by the EC IP project FP6-015879, FACETS.]

◆ **From variational to spiking network image-segmentation techniques**

L Gérard, P Kornprobst, T Viéville (INRIA, Sophia, France; e-mail: Leonard.Gerard@sophia.inria.fr)

Many traditional image-segmentation techniques are based on variational approaches seen as Mumford Shah's approach variants. Furthermore, it has been argued (Sarti et al, 2003 *Journal of Physiology – Paris* **97** 379–385) that such a mechanism could provide an abstract view of brain's segmentation. Following this track, we 'implement' segmentation, using a retinotopical neuron network. In our approach, the first step is to consider a discrete approximation of the Mumford Shah functional (Chambolle, 1999 *Mathematical Modelling and Numerical Analysis* **33** 261–288), yielding a dynamical system grid. We then explore different possibilities to link it to a grid of neurons, the processed value being directly the phase, the membrane voltage, or a more complex neuron state evaluation, all this depending on the considered neuron model (from integrate and fire to Hodgkin–Huxley) and encoding (with its phase, membrane voltage, or spiking rate). Using this theoretical study and the related numerical experiment, we are able to compare these alternatives, while an original biologically inspired segmentation network emerges from our study. [Work conducted within the scope of the European project FACETS (FP6-IST-FETPI-2004-15879).]

◆ **Population coding of pattern and component motion**

S Lehmann, J Braun (Institute for Biology, Otto von Guericke University, Magdeburg, Germany; e-mail: stephanie.lehmann@nat.uni-magdeburg.de)

We are interested in the representation of pattern and component motion in the extrastriate visual cortex. Lacking precise information about extrastriate areas, we derived theoretical limits on the basis of motion-selective neurons in area V1, which are quantitatively well characterized (Geisler and Albrecht, 1997 *Visual Neuroscience* **14** 897–919). Given a quantitative model of population coding for individual motion components in area V1, we predict Fisher information about speed and direction of a coherently moving pattern with N components. We used numerical maximum-likelihood estimation to verify semi-analytical calculations of Fisher information. The results show that different components contribute in different extents to information about pattern speed and direction, depending on the relative angle of component and pattern motion. Thus we would expect a characteristic pattern of speed and direction thresholds for different kinds of moving plaids. Behavioural experiments to test these predictions are under way.

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◆ **Crucial role of surrounding modulation for border-ownership determination**

H Nishimura, S Watanabe, Y Tsuji, K Sakai (Department of Computer Science, University of Tsukuba, Ibaraki, Japan; e-mail: haruka@cvs.cs.tsukuba.ac.jp)

Determination of border ownership (BO), which indicates the side of the figure with respect to a border, is fundamental for the assignment of figure/ground (Zhou et al, 2000 *Journal of Neuroscience* **20** 6594–6611). We propose a computational model for BO determination based on the surrounding modulation (Sakai and Nishimura, 2006 *Journal of Cognitive Neuroscience* **18** 562–579), which comprises hundreds of model cells with their surrounding regions assigned randomly to mimic the physiological characteristics. We carried out simulations of the model with pseudo-random stimuli that approximate all possible shapes. Many model cells determined consistently BO for most of the stimuli. Simulation results with natural images showed that the computed figure sides exhibit tendencies corresponding to Gestalt factors, even though the model does not include any mechanisms for detecting these factors. We also show that the reaction time of human subjects for BO determination is proportional to the difficulty presented by the model. These results suggest a crucial role of surrounding modulation for the determination of BO. [HN is supported by KAKENHI for JSPS fellows, 17.7216.]

◆ **Multilingual website (freeware) for teaching psychophysical methods**

H Ono, A P Mapp, K Sakurai¶, D Harnanansingh (Department of Psychology and Centre for Vision Research, York University, Toronto, Canada; ¶ Tohoku Gakuin University, Sendai, Japan; e-mail: hono@yorku.ca)

Our website (<http://www.yorku.ca/psycho/en/>) called “Precision and Accuracy with Three Psychophysical Methods” is an interactive tool designed to teach psychophysical methods in different languages (English, French, Japanese, and simplified Chinese). This freeware is accessible from any computer with an internet connection. The website teaches the conceptual differences between precision (JND) and accuracy (constant error). Students measure precision and accuracy in three different online experiments, each one by a different psychophysical method. Then they perform two other online experiments, Weber’s law and Müller-Lyer illusion, to clarify the difference between precision and accuracy. The layout consists of a main menu and its submenus, a dictionary, formula panel, and a content area at the center of each webpage. The dictionary and formulas remain visible by way of a help window that pops up and can be moved out of the way of the main content. With this layout, students know which part of the website they are working on and can navigate to any other part.

[Supported by ATR, IIPC Tohoku Gakuin University, NEC, NSERC Grant A0296, York Contract Faculty Teaching Development Grant.]

◆ **Functional adaptive sequential testing (FAST)**

E Vul, D I A MacLeod¶ (Department of Brain and Cognitive Sciences, MIT, Cambridge, USA; ¶ University of California at San Diego, La Jolla, USA; e-mail: evul@mit.edu)

Adaptive testing methods make uni-dimensional threshold estimation faster and more efficient. However, psychophysicists often measure thresholds as a function of another variable (eg contrast threshold as a function of spatial frequency). While efficient adaptive methods are available for uni-dimensional threshold estimation, two-dimensional threshold estimation is still inefficient. We present functional adaptive sequential testing (FAST), a method for estimating thresholds as a function of another variable. This method allows efficient estimation of parameters relating another variable (eg spatial frequency) to the measured threshold (eg contrast). FAST is Bayesian (specifies priors and estimates posteriors), general (works for any unique 2-D function and any psychometric function), efficient (converges faster than traditional methods), and easy to use (implemented in a Matlab toolbox). Furthermore, because FAST acknowledges the underlying function being estimated, it renders tractable some hitherto impossible experiments. We describe the formalism and implementation of FAST, present simulations, and show data from experiments which are only possible when explicitly estimating functions.

[Supported by NIH EY01711 to DM.]

◆ **Nonparametric fitting of psychometric functions: How to choose the bandwidth?**

K Żychaluk, D H Foster (School of Electrical and Electronic Engineering, University of Manchester, Manchester, UK; e-mail: kamila.zychaluk@manchester.ac.uk)

Many psychophysical experiments require the estimation of a psychometric function relating stimulus level to probability of response. One common approach is to choose a class of parametric models, eg the Gaussian, logistic, Weibull, or Gumbel distributions, and then adjust the parameters for best fit to the data. But it is not always obvious what model should be used. A poorly motivated choice may give a biased fit and consequently misleading inferences about statistics such as a threshold derived from the fitted curve. An alternative approach is to use a local

nonparametric method in which fitting is performed over neighbourhoods defined along the stimulus range. The results are much less dependent on the chosen model, but they do require an estimate of the optimal size of neighbourhood, ie the bandwidth. Results are presented here comparing the effectiveness of three methods of bandwidth estimator: the plug-in, bootstrap, and cross-validation. All three methods generally gave good fits to a range of psychophysical test data, although they sometimes differed with particular samples.

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VISUAL CORTEX: EXTRASTRIATE, DORSAL

◆ Age related changes of motion-onset VEPs in children

Z Kubová, J Langrová, J Kremláček, M Kuba (Department of Pathophysiology, Faculty of Medicine, Charles University, Hradec Králové, Czech Republic; e-mail: kubova@lfhk.cuni.cz)

The motion-onset visual evoked potentials (M-VEPs) exhibit not only latency changes during life (Langrová et al, 2006 *Vision Research* **46** 536–544) but also changes of their shape—in young children the M-VEPs are dominated by positive peak instead of dominant-motion-specific N2 peak in adults. To elucidate the role of stimulus parameters in the shape of M-VEPs, we tested in children M-VEPs to two types of motion stimuli: transitional motion of vertical gratings or isolated checks and radial motion of concentric pattern. We manipulated spatial frequency (0.2–1 cycle deg⁻¹), contrast level (0.1 and 0.95), contrast modulation (sinusoidal versus rectangular), and velocity of motion (5–25 deg s⁻¹). The M-VEPs were more comparable to the typical adult VEPs when translational movement of a pattern with high spatial frequency and contrast was used. This is another evidence of immaturity of the magnocellular/dorsal system in children, which must be taken into account in their electrophysiological examination, eg in testing of dyslexia. [Supported by Ministry of Education of the Czech Republic (VZ 0021620820).]

VISUAL CORTEX: EXTRASTRIATE, VENTRAL

◆ Network dynamics of inferotemporal cortex during categorical processing of continuously morphed natural images

A Akrami, Y Liu ¶, A Treves, B Jagadeesh ¶ (Department of Cognitive Neuroscience, International School for Advanced Studies [SISSA], Trieste, Italy; ¶ University of Washington, Seattle, USA; e-mail: akrami@sissa.it)

Neural codes for familiar visual stimuli may reflect distinct attractor states, possibly implemented in the dynamics of inferior temporal (IT) cortical networks, thought to be the long-term memory store for visual representations. Attractor networks have the ability to converge towards pre-established representations. To determine whether the IT single units of a behaving monkey exhibit such convergence we recorded their responses during a classification task on visual stimuli prepared by gradually morphing between pairs of familiar images, one of which was chosen to elicit a particularly strong response (effective image vs ineffective). The initial response reflects the distance along the morphing dimension; later the responses elicited by the effective image and its neighbours converge and it is only the natural category that determines the firing level, for effective morphs. Such evolution of the response could reflect internal IT network dynamics, underlying classification performance, induced either by attractor states or firing-rate adaptation or both—two mechanisms the relevance of which we assess by simulating an autoassociative neural network.

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◆ Spontaneous local variations in ongoing neural activity bias perceptual decisions

G Hesselmann, C Kell ¶, E Eger, A Kleinschmidt (CEA/SAC/DSV/DRM/NeuroSpin, INSERM U562, Gif-sur-Yvette, France; ¶ University of Frankfurt, Frankfurt am Main, Germany; e-mail: g.hesselmann@gmail.com)

The role of spontaneous cortical activity in perception remains elusive [Dehaene and Changeux, 2005 *PLoS Biology* **3**(5) e141]. Here, we demonstrate that spontaneous fluctuations in ongoing activity of specialized brain areas bias perceptual decisions (Smith and Ratcliff, 2004 *Trends in Neurosciences* **27** 161–168). Using fMRI we recorded brain activity while briefly showing subjects ($N = 10$) Rubin's ambiguous vase–face stimulus, at unpredictable intervals. Pre-stimulus activity in the fusiform face area (FFA), a cortical region preferentially responding to faces, was higher when subjects perceived faces instead of a vase. The effect was absent in a set of ventral control regions, including the lateral occipital complex (LOC) and parahippocampal cortex, as well as in selected parietal and frontal regions linked to attentional processes. Furthermore, the effect of ongoing on evoked activity in our data is not merely additive, but appears to be modulated by the perceptual interpretation of the stimulus. Together, our findings establish that common models of perceptual decisions remain incomplete without considering the biasing history of ongoing brain activity.

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◆ **The impact of contrast and phase on the compound-adaptation effect**

D P McGovern, J Peirce (School of Psychology, University of Nottingham, Nottingham, UK; e-mail: lpxdm@psychology.nottingham.ac.uk)

Neural mechanisms selective to particular combinations of Fourier energies, namely plaids, have previously been shown through a compound-adaptation procedure (Peirce and Taylor, 2006 *Neuroscience* **141** 15–18). Using a similar method we investigated the importance of both probe contrast and phase to the compound-adaptation effect. In our first experiment a target was compared to a reference probe that took one of five Michelson contrasts ranging from 0.15 to 0.6. The compound-adaptation effect was strongest for contrasts between 0.2 and 0.3. This is roughly ten times the optimal contrast that was reported for selective spatial frequency adaptation (Snowden and Hammett, 1996 *Vision Research* **36** 1797–1809). In the second experiment, the reference probe took one of five phase values with a constant contrast of 0.25. The relative phase had no impact on the adaptation effect, consistent with a model whereby plaid-selective mechanisms are derived from the outputs of V1 complex, rather than simple cells.

[Supported by BBSRC grant BB/C50289X/1.]

◆ **Priming and single neurons in monkey inferotemporal cortex**

D B T McMahon, C R Olson ¶ (McGovern Institute, Massachusetts Institute of Technology, Cambridge, MA, USA; ¶ Carnegie Mellon University, Pittsburgh, USA; e-mail: dbtm@mit.edu)

Repetition priming is believed to be mediated by decreases in the activity of neurons in inferotemporal (IT) cortex. These activity decreases, known as repetition suppression, are hypothesized to reflect a sharpening of the stimulus selectivity of IT neurons, which could in turn contribute to faster behavioural responses. To test this hypothesis, we recorded from single neurons in IT cortex in monkeys trained to perform a symmetry decision task. The monkeys exhibited behavioural priming, responding more rapidly when an image was repeated. This speeding of behavioural reaction time was accompanied by repetition suppression in IT neurons. However, repetition suppression did not result in sharpened stimulus selectivity. Instead, neuronal responses were scaled down by a decrease in firing rate proportional to the strength of the initial visual response. Moreover, the magnitude of behavioural priming and neuronal suppression were uncorrelated across paired stimulus presentations. We conclude that, although priming and repetition suppression occur under the same circumstances, they are unlikely to be causally related.

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◆ **Shape similarity is an organizing principle in human object-selective cortex**

H P Op de Beeck, K Torfs, J Wagemans (Laboratory of Experimental Psychology, University of Leuven, Leuven, Belgium; e-mail: hans.opdebeeck@psy.kuleuven.be)

Functional magnetic resonance imaging (fMRI) has revealed that object-selective regions in human cortex are organized in terms of the category objects belong to. However, exemplars from familiar object categories differ in many respects, including shape, meaning, and the type of processes that are evoked during visual processing. We performed an fMRI study ($N = 9$) that was designed to directly show that the organization of the object vision pathway is related to shape similarity. We designed a stimulus set with 9 novel object categories that varied greatly in shape properties. In a separate behavioral experiment, subjects rated the perceived shape similarity among these objects. The fMRI study showed that objects that were rated as having a similar shape were associated with a very similar pattern of response in object-selective cortex, whereas objects that were rated as being very different in object shape were associated with a more-different pattern of response. These findings demonstrate that shape similarity by itself is an organizing principle in human object-selective cortex.

◆ **Reading out the perceptual boundary between human and monkey face categories from the inferior temporal cortex of the macaque monkey**

G R S Alanis, N Logothetis, G Rainer (Department of Physiology of Cognitive Processes, Max Planck Institute for Biological Cybernetics, Tübingen, Germany; e-mail: rodrigo.sigala@tuebingen.mpg.de)

We demonstrated that, when human subjects have to classify human/monkey morphed faces that change along a continuum, they draw the category boundary closer to their own species (at approximately 60% human/40% monkey). Considering that neurons in the infero-temporal (IT) cortex encode face information, we recorded the single-unit activity (SUA) of 118 neurons and the local field potential (LFP) at 58 sites of the IT cortex of one macaque monkey during fixation of morphed faces. Out of 118 single units, 85% were visually responsive and 23% were face cells according to standard criteria. We used a two-class (human–monkey) classifier (k -NearestNeighbor) to analyze the population activity of visually responsive units and all LFPs.

Symmetric to the findings in humans, the classifier drew the category boundary closer to the monkey category (at approximately 40% human/60% monkey) for both kinds of neural signals. These results suggest an 'own-species' advantage in the encoding of face stimuli. Our findings also indicate that a large fraction of IT neurons participate in the encoding of face categories. [Supported by the Max Planck Society.]

- ◆ **Animate and inanimate objects in human visual cortex: Effects of stimulus size and task**
A Wiggett, I Pritchard, P Downing (School of Psychology, University of Wales, Bangor, Wales, UK; e-mail: a.wiggett@bangor.ac.uk)

Evidence from neuropsychology suggests that the distinction between animate and inanimate kinds is fundamental to human cognition. Previous neuroimaging studies have reported that viewing animate objects activates ventrolateral visual brain regions, whereas viewing inanimate objects activates ventromedial regions. We tested whether this lateral/medial bias is consistent across different tasks (categorisation at the superordinate, basic, or subordinate level). Furthermore, in order to compare the medial/lateral bias for inanimate/animate objects with a similar bias for full-field and peri-foveal stimulation, all stimuli were tested at two stimulus sizes (small or large). Stimuli were presented sequentially in pairs, and same/different category judgments were made at different levels in different scans. As predicted, the fMRI data showed ventrolateral activation for animate and ventromedial activation for inanimate objects. Further analyses within these regions revealed a main effect of size, no main effect of task, and no interactions between task, size, and animacy. These results suggest a lateral/medial bias for animate/inanimate that is insensitive to task and is above and beyond retinotopic biases.

[Supported by the BBSRC.]

VISUAL CORTEX: PRIMARY

- ◆ **A pharmacological dissection of cholinergic effects in V1 of the macaque monkey**
A Disney, M Hawken (Center for Neural Science, New York University, New York, USA; e-mail: anita@nyu.edu)

Acetylcholine (ACh) is a ubiquitous neuromodulator in the central nervous system of mammals that has been implicated in processes underlying arousal and attention. We have shown previously that nicotinic ACh receptors (AChRs) are found presynaptically at thalamocortical synapses arriving in layer 4c of macaque V1 and that nicotine acts in this layer to enhance the gain of responses to visual stimuli. We have also shown that, amongst V1 neurons, parvalbumin-immunoreactive inhibitory neurons most strongly express muscarinic AChRs. By combining *in vivo* iontophoresis of a cholinergic agonist (carbachol) with extracellular recording techniques in V1 of the anaesthetised macaque, we now show that enhanced visual responses in layer 4c similar to those seen with nicotine are observed with a broad cholinergic agonist. We also find that carbachol strongly suppresses visual responses in layers 2 and 3 of V1 and that this suppression can, in many cases, be blocked with a GABA_A receptor antagonist.

[Supported by NIH grants EY8300 and EY15549 to MJH and core grant P30-EY13079.]

- ◆ **Visual performance fields are task-dependent**
A Lingnau, J Schwarzbach (Centre for Mind/Brain Sciences, Trento University, Rovereto, Italy; e-mail: angelika.lingnau@form.unitn.it)

Performance advantages in the lower as compared to the upper visual field (He et al, 1996 *Nature* **383** 334–337) have been suggested to stem from sensory rather than attentional factors (Talgar and Carrasco, 2002 *Psychonomic Bulletin & Review* **9** 714–722; Liu et al, 2006 *Journal of Vision* **6** 1294–1306). Here, we asked whether visual-field asymmetries are task-dependent, a finding that would clearly contradict a purely sensory basis. Participants judged the presence or absence of (a) an offset in a Vernier stimulus, (b) a vowel within a letter-triplet, (c) a face embedded in noise. Stimuli were presented randomly in 49 different positions. We observed clear task-dependence of individual visual-performance fields. On the group level, there was a clear preference for the vertical meridian in the letter-discrimination task and a preference for the horizontal meridian in the other tasks. These effects cannot be explained by anatomical asymmetries alone. Instead, they are likely to be brought about by feedback modulations from higher visual areas.

- ◆ **The influence of neuronal recruitment on the visual evoked potential**
V L Marcar, L Jancke (Department of Neuropsychology, University of Zurich, Zurich, Switzerland; e-mail: v.marcar@psychologie.unizh.ch)

The relationship between brain activity and the evoked potential is still unclear. We investigated the influence of neuronal activity and neuronal recruitment on the visual evoked potential (VEP) by performing EEG measurements on twenty-four healthy, adult volunteers. We presented a series of dartboard stimuli and their root-mean-squared (RMS) counterpart. In the dartboard

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series, the stimulus area subjected to a contrast reversal was varied between 50% and 12.5%. As a consequence of the retinotopic organisation of the visual areas, the sum of the stimulus area experiencing a contrast reversal translates into numbers of neurons responding to the reversal in contrast. The dartboard series therefore enabled us to examine the influence of neuronal recruitment on the VEP. The dartboard images were either embedded in a black or a white background. By comparing the VEPs to these two series we were able to examine the influence of mean luminance on the VEP. The amplitude of the early VEP components varied linearly with the total stimulus area experiencing a contrast reversal. The amplitudes of the early VEP components were consistently lower to the RMS dartboard than to the regular dartboard series and were unaffected by the background in which the images were embedded. Our study demonstrated that neuronal recruitment is a measure of brain activity. The visual evoked potential reflects neuronal recruitment not mean stimulus luminance.

◆ **Detection threshold and cortical activity for the temporal envelope of amplitude-modulated flicker**

Y Okamoto, S Nakagawa, K Fujii, T Yano ¶, Y Ando ¶ (HSBE, AIST, Ikeda, Japan; ¶ Graduate School of Science and Technology, Kumamoto University, Kumamoto, Japan; e-mail: yos-okamoto@aist.go.jp)

Detection thresholds for envelopes of flickering lights which were amplitude-modulated (AM) sinusoidally were estimated by changing carrier and modulation frequencies and modulation depth. We also measured cortical activities for AM flickering lights using magnetoencephalography (MEG) and analyzed cortical activities at frequencies corresponding to the envelopes of AM flickering lights. Lower detection thresholds were obtained for stimuli with lower carrier frequencies than those with higher carrier frequencies, and the strength of cortical activities varied according to the detectability. The detection thresholds and cortical activities were independent of the modulation frequencies, whereas cortical activities for sinusoidal flickering lights with temporal frequencies identical to the modulation frequencies of AM flickering lights depended on the stimulus frequencies. These results imply that the envelope information of AM flickering lights is extracted after the high-pass filter in the retina.

[Supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for JSPS fellows.]

VISUOMOTOR CONTROL

◆ **Asymmetries in attention toward the dominant hand: Input or output?**

G Buckingham, D Carey (Department of Psychology, University of Aberdeen, Aberdeen, Scotland, UK; e-mail: g.buckingham@abdn.ac.uk)

Previous studies have suggested a bias in attention toward the dominant hand (Honda, 1982 *Quarterly Journal of Experimental Psychology A* **34** 499–513; Peters, 1981 *Quarterly Journal of Experimental Psychology A* **33** 95–103). However, in light of research demonstrating a possible asymmetry in motor attention (Bestelmeyer and Carey, 2004 *Neuropsychologia* **42** 1162–1167) the nature of attentional biases remain unclear (ie motoric or visuo-spatial). The current study builds on work indicating an attentional bias toward the right hand of right handers during bimanual reaching (Buckingham and Carey, *Brain and Cognition* submitted) by the addition of a novel Posner style valid/invalid direct pre-cueing technique to orient attention toward the left or right hand. It was predicted that the dominant hand will be less susceptible to invalid pre-cueing than the non-dominant hand, owing to possible advantages in the sequencing and inhibition of movements. Results are discussed in relation to input versus output biases and the generalisability of the attentional model to different tasks.

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◆ **Linguistic and spatial information for action**

Y Coello, A Bartolo, A Weisbecker (Department of Psychology, University of Lille, Villeneuve d'Ascq, France; e-mail: yann.coello@univ-lille3.fr)

Motor action can be triggered according to semantic or spatial object attributes, which are thought to predominantly involve the ventral and dorsal streams of the visual system, but with different time constraints. To evaluate the independence of semantic and spatial processing, we tested the effect of presenting congruent or incongruent information when performing a reaching arm movement in response to a linguistic or spatial stimulus. Results showed that the time to respond to a linguistic stimulus was greater than that to react to a spatial stimulus. Furthermore, we found a strong interference of the spatial target on both the reaction time and the response accuracy when responding to the linguistic stimulus, but predominantly for responses with a short reaction time. Complementary studies confirmed that the interference depends mainly on

the time required for semantic processing. Thus motor decision can be influenced by irrelevant visual information, suggesting that information processed within the ventral and the dorsal visual streams may compete in specifying the relevant visual signal for action.

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◆ **Threat mode in the human brain: Primed for action, not perception**

A Csatho, G Davis¶ (Institute of Behavioural Science, University of Pécs, Pécs, Hungary;

¶University of Cambridge, Cambridge, UK; e-mail: arpad.csatho@aok.pte.hu)

Optimising the efficiency with which we perceive, assess, and respond to stimuli in the environment is never more important than when faced with physical threat. In the laboratory, effects of threat perception on attention, memory, and cognition have been widely studied. However, perhaps the most crucial influences of threat perception, on the visual guidance of motor programming and execution, has received relatively little attention. Here, we assess the effects of perceived threat upon human targeting performance. We find that, following presentation of threatening stimuli, targeting performance improved for peripheral targets relative to central targets. Further experiments suggested that these effects were not mediated by influences of perceived threat on other aspects of perception, attention, and cognition. Rather, these details of our findings are most readily explained in terms of activation of superior colliculi, which subserves orienting to targets in the mammalian brain, and is activated following presentation of threat stimuli.

◆ **Shifted visual feedback about the distance of the hand does not change reachability**

D D J de Grave, E Brenner, J B J Smeets (Faculty of Human Movement Sciences,

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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 also be increased by providing visual feedback about the hand that indicated a larger egocentric distance. A virtual target cube was presented at various distances and subjects had to judge whether they could reach it. They did so 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 nearby virtual cubes that represented the answer possibilities (yes or no). The simulated cube was at the same position as the real cube in a first block of trials and was shifted 10 cm in depth away from the subject in a second block. We found no differences in reachability judgments between the two blocks. We conclude that visual feedback about the position of the hand close to the body does not influence judged reachability.

◆ **Visual guidance in car-following tasks**

M Fiorani, M Mariani¶ (Department of Psychology, University of Turin, Turin, Italy;

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We investigated visual control of braking when decelerating behind a lead vehicle under normal driving conditions, without asking the subjects to make soft collisions with encountered obstacles. According to our research hypothesis extending Fajen's (Fajen, 2005 *Journal of Experimental Psychology: Human Perception and Performance* **31** 1107–1123) model for braking, preferred headway and ideal deceleration are both controlled during car-following. When moving obstacles are encountered, final headway from vehicle ahead at the end of deceleration is controlled, but when static obstacles are encountered, headway information is discarded, as it does not provide salient information for future collision avoidance. Subjects performed a simulated driving task in which the absolute speed of the subject vehicle, lead vehicle size, and the relative speed between the subject and lead vehicles were independently manipulated. Analysis focused on ideal deceleration at the onset of braking, and headway at the end of braking. A first account of optic variables used to specify headway is presented, including distance, optical angle, expansion rate, and global optic flow rate.

[We would like to thank HMI group at University of Modena and Reggio Emilia.]

◆ **Spatial integration of contrast-grating drift for quick manual and ocular responses**

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Japan; e-mail: gomi@idea.brl.ntt.co.jp)

Surrounding visual motion induces ultrashort latency manual (MFR) and ocular (OFR) responses in the direction of visual motion (Gomi et al, 2006 *Journal of Neuroscience* **26** 5301–5308; Miles et al, 1986 *Journal of Neurophysiology* **56** 1381–1396). To investigate the spatial integration mechanisms of visual motion for generating such short latency visuomotor responses, we characterized the stimulus-size tuning (visual angle: 10–50 deg) of MFR and OFR for different spatial-frequency contrast-grating motions (0.02–0.8 cycles deg⁻¹, 10 Hz, 50% contrast). For the large

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stimuli (40 deg, 50 deg), the MFR amplitudes were greatest at $0.05 \text{ cycle deg}^{-1}$ among four spatial-frequency stimuli, whereas the OFR amplitudes were greatest at $0.2 \text{ cycle deg}^{-1}$. For the small stimuli (10 deg, 20 deg), both the MFR and OFR reached a maximum at $0.2 \text{ cycle deg}^{-1}$. Additionally, the MFR and OFR amplitudes continuously increased with stimulus size for 0.02 and $0.05 \text{ cycle deg}^{-1}$ but not for 0.2 and $0.8 \text{ cycle deg}^{-1}$. These data indicate that neuronal sub-population of visual motion analysis for MFR is at least partly different from that for OFR. [Supported by JST-ERATO Shimojo Project.]

◆ **Closed-loop and open-loop hand movements under rotated visual feedback**

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Technical devices frequently provide actors with artificial visual feedback, including translations or rotations of the movement space. Mental remapping between movement and visual maps are thought to be necessary to perform under such conditions. In earlier experiments under open-loop conditions, rotations of the visual field caused systematic spatial errors of pointing movements towards the pictorial target point. However, it could be argued that such errors are only made under open-loop conditions, when movement planning has to be completed before movement execution. In this new experiment, participants ($N = 40$) performed tracking movements under closed-loop conditions. Visual feedback was experimentally varied by rotations of the visual space by means of a video system. The deviation of the performed movements from the given path was measured. Each given path had a turning point which required the participants to change movement direction. The type of movement error at this point was also analysed, dependent on the rotation of the visual field. The movement deviations were similar to those found under open-loop conditions.

◆ **Colour and spatial cue for action: Subliminal colour cue effects on motor behaviour**

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We addressed two important implications one could draw from Millner and Goodale's theory on dissociation of vision for perception and for action: (i) colour processing in the ventral stream is not integrated in the visual guidance of body movements, and (ii) the access of colour information to motor systems is obligatory, based on visual awareness. To address the first notion we exploited redundant-target paradigm in which subjects reacted to spatial, colour, or combination of both (redundant) targets. Further, our subjects reacted to isoluminant coloured targets preceded by subliminal incongruent ones. Second condition without subliminal priming target was presented and compared with the first one. The reaction time gain that we observed can be the result of combined sensory information in reaching some decision criterion on the basis of which responses were initiated. We showed that stimuli blocked from awareness (subliminal cues) were able to retard the fast motor responses. Overall, these results are inconsistent with the theory of two parallel and independent visual streams, and provide behavioural evidence for interaction between perception and action signals.

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◆ **No evidence for autonomic induced changes in accommodation due to cognitive demand**

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The aim of the present study was to confirm accommodation as possible indicator of changes in autonomic balance caused by cognitive demand. Besides cardiovascular indicators (pulse transit time and heart period), performance (errors and reaction time) and pupil size were measured to establish increasing task demand and physiological changes. Cognitive demand was varied by presenting numbers monocularly (at 5 D) which had to be read, added, or multiplied. Accommodation was measured for twenty subjects with the PowerRef II (PlusoptiX). Cardiovascular parameters indicated an increase in sympathetic activity due to a switch from reading or adding to multiplying numbers; performance as well as pupil dilation indicated an increase in cognitive demand. Accommodation, however, remained stable after the correctness of task processing was taken into account; this observation questions a common autonomic source of variation due to cognitive demand. Previous reports of the cognitive-induced-shift in accommodation may be confounded by incorrect task performance or gaze shifts (which were measured as well, and lead to erroneous accommodative measures).

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◆ **Cue recruitment in active control of a moving line**

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The visual system can actively recruit new cues for perception (eg Haijiang et al, 2006 *Proceedings of the National Academy of Sciences of the USA* **103** 483–488). To explore whether this cue recruitment occurs in visuomotor control, we examined observers' performance as they used a joystick to keep a horizontal line centered while its vertical position was randomly perturbed, either under velocity or acceleration controller dynamics. Observers needed position feedback for velocity control, and velocity feedback for acceleration control. An additional colour cue was introduced by making the line appear redder the more it deviated from the display center (position–colour cue) or the faster it moved (motion–colour cue). For velocity control, the overall rms position error was smaller in the position–colour condition than in the no-colour or motion–colour conditions ($13.7 \pm 8.4\%$ and $8.9 \pm 4.1\%$ smaller, mean \pm SE, $N = 4$); for acceleration control, the rms error was smaller in the motion–colour than in the no-colour or position–colour conditions ($26.8 \pm 15.1\%$ and $9.8 \pm 7.1\%$ smaller). The visuomotor system can selectively recruit novel cues to enhance existing perceptual information for purposes of control.

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◆ **Simultaneous processing of visual information and planning of hand movements in a visuo-manual search task**

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When searching for a target with eye movements, saccades are planned and initiated while the visual information is still being processed. If hand movements are needed to perform a search task, can they too be planned while visual information from the current position is still being processed? To find out we studied a visual-search task in which participants had to move their hand to shift a window through which they could see the items. The task was to find an O in a circle of Cs. The size of the window and the sizes of the gaps in the Cs were varied. Participants made fast, smooth arm movements between items and adjusted their movements, when on the items, to the window size. On many trials the window passed the target and returned, indicating that the next movement had been planned before identifying the item that was in view.

◆ **Visually timed actions benefit from audiovisual targets**

J Lopez-Moliner, E Tubau (Department of Psychology, Universitat de Barcelona, Barcelona, Spain; e-mail: j.lopezmoliner@ub.edu)

When we synchronise a motor action with a visual stimulus (eg hitting a ball) we often hear a sound as a sensory consequence that informs us of the success of our action. If this auditory feedback exerts some influence over the timing with visual stimuli then we should be able to find benefits when we have to synchronise our action with audiovisual stimuli compared to when our actions are timed with visual stimuli only. In two conditions subjects hit four consecutive visual targets (circles of radius of 1.2 cm) by quickly moving a pen across a digitising tablet. The time intervals between targets were in the range of 0.36 s and 0.44 s and were located along the diagonal (bottom-left to top-right) of the tablet. In the audiovisual condition a beep was sounded in synchrony with each visual target. Not only did subjects hit audiovisual targets much more often (60% vs 40%) but also the kinematics of the arm movements were modified. Peak velocities were significantly higher in the audiovisual condition.

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◆ **Using vision to update a movement plan during rapid pointing**

A Ma-Wyatt (School of Psychology, University of Adelaide, Adelaide, Australia; e-mail: anna.mawyatt@adelaide.edu.au)

People make both slow and rapid goal-oriented actions to interact with their environment. During a movement, visual and proprioceptive feedback are compared to predicted sensory output and a decision must then be made about whether the discrepancy (sensorimotor error) warrants altering the movement online. Sensorimotor error from earlier trials can significantly affect online control of slow guided movements. How is visual feedback used to decide to alter a movement during rapid pointing? To answer this, a two step paradigm was used. Observers pointed rapidly to the final location. The step occurred early or late in the reach and was a large discrete direction or movement direction change. Observers corrected for a step 45° away in direction from initial target location. Endpoint precision decreased for early changes, and accuracy decreased for late changes, suggesting new visual information is also used to make a prediction of target location

Friday

for the rest of the reach. The results are discussed with reference to how visual information contributes to the sensorimotor decision to update a movement.

◆ **A dissociation between motor and perceptual performance in the Poggendorff illusion**

D R Melmoth, M J Morgan (Department of Optometry and Visual Science, City University, London, UK; e-mail: d.melmoth@city.ac.uk)

We found a motor-performance bias for a task in which subjects maintain accurate perceptual judgments. Poggendorff illusion alignment errors were larger for motor performance than for perceptual performance because of an additional motor-specific bias that occurred in the presence of the oblique pointer alone. We tentatively characterised this motor-specific bias as an underestimation of required distance in the unknown dimension. However, since this underestimation produced an effect in the same direction as the Poggendorff illusion it was difficult to disentangle the two biases. Therefore, we performed an experiment where the second Poggendorff line (landing line) was either parallel or orthogonal to the inducing line. Under the latter condition, underestimation of the unknown distance would operate in the opposing direction to the Poggendorff illusion. Consistently, we found that under this condition the effect of the Poggendorff inducer on motor judgments was not just reduced, but actually reversed: motor judgments were biased in the opposite direction to that predicted by the Poggendorff illusion, whilst perceptual judgments remained biased in the Poggendorff illusion direction.

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◆ **Visual-task performance with walking and running observers**

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Many visual tasks are performed when we are not motionless. During locomotion, we need to discriminate velocities, estimate motion direction, or avoid obstacles. Locomotion, however, introduces complex distortions of the optic flow field, due to trunk, head (HMs), and eye movements (EMs). We have started to examine visual behavior with observers who are walking or running on a treadmill while performing visual tasks. We recorded EMs and HMs when observers were standing, walking, or running on a treadmill while observing flow fields or other stimuli for various visual tasks on a large screen. General fixation patterns, velocity discrimination thresholds, and pursuit efficiency were measured. We analyzed horizontal and vertical EMs and HMs. In most cases, performance during walking and running was comparable, and sometimes even better, than during standing. HMs were only partially offset by stabilizing EMs, leaving considerable amounts of noisy distortions of the flow fields. Hence, there exist various mechanisms, in addition to extra-retinal feedback, that can compensate for the extra noise produced by locomotion.

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