



**The 14<sup>th</sup> AVA  
Christmas Meeting**

**Bristol  
18<sup>th</sup> December, 2009**

We would like to thank the following for serving as referees:

Craig Aaen-Stockdale  
David Badcock  
Daniel Baker  
Marco Bertamini  
Aline Bompas  
Patrick Cavanagh  
Steven Dakin  
Ron Douglas  
Mark Georgeson  
John Harris  
Mike Harris  
Christina Howard  
Claire Hutchinson  
Keith Langley  
Rebecca Lawson  
Casimir Ludwig  
Keith May  
Eugene McSorley  
Tim Meese  
Marko Nardini  
Gillian Porter  
Neil Roach  
Alexa Ruppertsberg  
Mark Scase  
Andrew Schofield  
Dietrich Schwartzkopf  
Joshua Solomon  
Petroc Sumner  
Peter Thompson  
Tom Troscianko  
Andrew Welchman

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Cambridge Research Systems  
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**PROGRAMME**  
**14<sup>th</sup> AVA Christmas meeting 2009**

*Priory Road Complex*  
*University of Bristol, UK*  
*Lecture Theatre 2D3 (talks)*  
*Lecture Theatre 2D2 (posters)*  
*Atrium (registration, lunch and evening reception)*

**10.00 Registration and Coffee/tea**

**10.50 Welcome**

*Tim Meese and Tom Troscianko*

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**SESSION 1:** *Chair: Tom Freeman*

**11.00 Invited talk**

**Towards a new theory of figure-ground organization**

*Zygmunt Pizlo, S Sebastian, J Catrambone, T Sawada*

**11.30 Are interactions between static- and motion-defined global form revealed by cross-adaptation?**

*David Badcock, J Edwin Dickinson, Limin Han, Jason Bell*

**11.45 Children exploit multiple visual cues for speed, not accuracy**

*Marko Nardini, Rachael Bedford, Meera Desai, Denis Mareschal*

**12.00 Part-report for successive visual inputs**

*Wayne Smith, John Mollon, Hannah Smithson*

**12.15 Changes in direction of motion attract attention**

*Christina Howard, Alex Holcombe*

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**12.30 Posters and Lunch**

**SESSION 2:** *Chair: Tom Troscianko*

- 1.30 CRS Guest lecture**  
**Phantom limbs and synaesthesia: inter-sensory interactions as a key to understanding the brain (DVD presentation)**  
*Vilayanur Ramachandran*
- 2.00 More GABA, less distraction: A neurochemical correlate of variability in human eye movement control**  
*Petroc Sumner, Richard Edden, Aline Bompas, Krish Singh*
- 2.15 Perceptual biases reveal characteristics of neural coding mechanisms for multisensory timing**  
*Neil Roach, James Heron, David Whitaker, Paul McGraw*
- 2.30 Neural activity in higher dorsal visual areas relates to the discrimination of disparity-defined depth position**  
*Andrew Welchman, Matthew Patten*
- 2.45 A necessary role for the lateral occipital cortex and the occipital face area in the rotational invariance of shape processing**  
*Dietrich Schwarzkopf, Juha Silvanto, Sharon Gilaie-Dotan, Geraint Rees*
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**3.00 Tea/Coffee and posters**

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**SESSION 3:** *Chair: Joshua Solomon*

- 3.30 Invited Talk**  
**A couple of challenges for visual perception under uncertainty**  
*Pascal Mamassian*
- 4.00 Learning reconfigures the decoding of sensory signals for fine discriminations**  
*Ben Webb, Neil Roach, Gaelle Coullon*
- 4.15 Axis cueing effects under noise masking imply that symmetry discrimination is an active two-stage process**  
*Christopher Tyler*
- 4.30 Influence of contrast gain changes on the apparent duration of a visual stimulus**  
*Aurelio Bruno, Alan Johnston*
- 4.45 Perceptual grouping of ambiguous motion**  
*Stuart Anstis*
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**5.00 Wine, curry and posters (until late)**

## POSTERS

in (fairly) arbitrary order

1. **What is happening behind my neighbour's fence? -Investigating our ability to use unmatched regions in a binocular scene**  
*Katharina Zeiner, Julie Harris*
2. **Implementing curve detectors for contour integration**  
*Keith May, Robert Hess*
3. **Non-linear global summation in the perception of non-circular contours**  
*Gunnar Schmidtman, Graeme Kennedy, Harry Orbach, Gunter Loffler*
4. **Weber's Law for circle diameters; not areas**  
*Joshua Solomon, Charles Chubb*
5. **Object-position binding in visual short-term memory for serially presented unfamiliar stimuli**  
*Raju Sapkota, Shahina Pardhan, Ian van der Linde*
6. **Filter transformations for shift-insensitive feature detection**  
*Miles Hansard, Radu Horaud*
7. **Temporal precision of a contour-selective mechanism**  
*Sarah Hancock, David McGovern, Jonathan Peirce*
8. **Mach bands: multi-scale spatial filtering and co-operative coding of edges and bars**  
*Stuart Wallis, Mark Georgeson*
9. **Misestimation of light source elevation alters lightness judgments**  
*Yoana Dimitrova, Peter McOwan, Alan Johnston*
10. **Interactions between light-from-above and convexity priors in visual development**  
*Rhiannon Laura Thomas, Marko Nardini, Denis Mareschal*
11. **Task-specific perceptual learning of texture detection and identification**  
*Zahra Hussain, Allison Sekuler, Patrick Bennett*
12. **Area summation of contrast is scale invariant and occurs over at least 8 carrier cycles**  
*Daniel Baker, Tim Meese*
13. **Isotropic masking reveals losses in spatial frequency specificity at high temporal frequencies: An isotropic third temporal channel?**  
*John Hobday, Keith Langley*
14. **Direct tilt after-effect increases with test duration when testing at high temporal frequencies**  
*Veronique Lefebvre, Keith Langley*

15. **The Riesz transform and linear summation across orientation tuned filters for phase dependent, phase independent and second-order spatial orientation computations**  
*Keith Langley, Veronique Lefebvre, Stephen Anderson*
16. **Peeling plaids apart: Context counteracts cross-orientation contrast masking**  
*Elliot Freeman, Preet Verghese*
17. **Perceived orientation: The tilt illusion dominates parafoveal vision, but the periphery is dominated by crowding**  
*Isabelle Mareschal, Joshua Solomon*
18. **Do lower visual cues provide online control for reaching and grasping while standing?**  
*Valentina Graci, Marina Bloj, John Buckley*
19. **Post-saccadic memory of the location and identity of previously viewed objects**  
*I-Fan Lin, Andrei Gorea*
20. **What determines the direction of microsaccades?**  
*Frouke Hermens, Robin Walker*
21. **Beta suppression in human extra-striate cortex reflects eye position during pursuit eye movements**  
*Ben Dunkley, Tom Freeman, Suresh Muthukumaraswamy, Krish Singh*
22. **Supplementary motor area activations in unconscious inhibition of voluntary action**  
*Frederic Boy, Petroc Sumner, Krish Singh*
23. **The neural correlates of visuospatial oculomotor and perceptual extrapolation**  
*Marc Tibber, Ayse Saygin, Simon Grant, Dean Melmoth, Geraint Rees, Michael Morgan*
24. **A critical test for decision models using MEG**  
*Aline Bompas, Iain Gilchrist, Suresh Muthukumaraswamy, Krish Singh, Petroc Sumner*
25. **Electrophysiological correlates of perceptual suppression during dynamic ocular accommodation**  
*Sven Mucke, Velitchko Manahilov, Niall Strang, Dirk Seidel*
26. **Variation of chromatic discrimination thresholds with luminance and state of chromatic adaptation**  
*Ben Jennings*
27. **Depth perception of the chromatic Mach card (CMC): Influence of colour gradients and outline**  
*Glen Harding, Marina Bloj, Julie Harris*
28. **Characterising negative phototaxis in brown planaria**  
*Claire Hutchinson, Colin Davidson, Darrel Barnes, Rachel Sherlock, Claire Gibson, Andrew Young*

29. **Quantitative evaluation of Ishihara and Rabkin colour deficiency tests using multispectral colour analysis**  
*Maris Ozolinsh, Sergejs Fomins, Michèle Colomb*
30. **A surprising influence of retinal size on distance judgments**  
*Arthur Lugtigheid, Andrew Welchman*
31. **Amodal memorial completion: Masking novel pictorial shapes reveals a role for visual short-term memory in the completion of partially occluded objects**  
*Simon Davies, Peter Walker*
32. **The role of presentation order effects in adaptation based duration compression**  
*Inci Ayhan, Aurelio Bruno, Alan Johnston*
33. **Perceived motion from illusory brightening and spatial gradients**  
*Peter Scarfe, Alan Johnston*
34. **Form information in the perception of biological motion heading**  
*M Thirkettle, N Scott-Samuel, C Benton*
35. **Octopaminergic modulation of velocity coding in a blowfly optic flow-processing interneuron**  
*Kit Longden, Holger Krapp*
36. **Optimisation of speed perception in virtual environments by manipulation of the geometric field of view**  
*Cyriel Diels, Andrew M Parkes*
37. **The train window illusion - people cannot locate the projection of an object on the surface of a mirror**  
*Rebecca Lawson*
38. **Global motion processing is impaired in patients with Alzheimer's disease**  
*Gillian Porter, John Wattam-Bell, Antony Bayer, Judy Haworth, Andrea Tales*
39. **Visual gaze behaviour of adults and older adults at a pedestrian crossing**  
*Christopher Egan, Alexandra Willis*
40. **Location, location, location: Examining spatial vision and spatial working memory in schizophrenia**  
*Shahrazad Mazhari, Johanna Badcock, Flavie Waters, Milan Dragovic, David Badcock, Assen Jablensky*
41. **Affordance processing in Parkinson's disease**  
*Dorothy Cowie, Patricia Limousin, Amy Peters, Brian Day*

## ABSTRACTS

### **Towards a new theory of figure-ground organization**

*Zygmunt Pizlo, S Sebastian, J Catrambone, T Sawada*

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Determining which regions and contours in the image represent individual objects "out there" is referred to as figure-ground organization. Despite its fundamental importance in vision, understanding perceptual mechanisms underlying this perceptual capability did not go much beyond a number of observations and theoretical speculations. One factor that might have been responsible for the slow progress was the absence of a theory explaining how the output of figure-ground organization is actually used in visual perception. Our recent theory of 3D shape recovery provided a clear specification of what must be computed in the preceding stage. With this information at hand, we started formulating a new computational model of figure-ground organization. The first application is visual navigation of humans and robots in 3D scenes. Our new model has two basic processes: one establishes similarity of regions and the other finds meaningful contours in the image. Both processes rely on spatially global operations that take precedence over local detectors. Spatially global operations in figure-ground are necessary once the ultimate goal is the recovery of 3D shape, which itself is spatially global. The result of the model's figure-ground organization is the occluding contour of each object plus the internal contours that allow the detection of 3D symmetry of a 3D shape and its subsequent recovery. The new model will be illustrated with synthetic and real images.

### **Are interactions between static- and motion-defined global form revealed by cross-adaptation?**

*David Badcock, J Edwin Dickinson, Limin Han, Jason Bell*

The University of Western Australia; email: [david@psy.uwa.edu.au](mailto:david@psy.uwa.edu.au)

In order to characterise the shape of objects it is necessary for the visual system to combine local estimates of stimulus properties into a global description. Recent work has argued that this global form process is either conducted in both the motion and form pathways or, at least, conducted separately using local motion and local pattern inputs. The experiments to be described examine global form processing using radial frequency patterns defined by relative motion or contour location in order to determine whether the two types of stimulus information drive separate processes or, instead a single process. Initially we demonstrate that shape adaptation is both extremely rapid and capable of producing strong shape after-effects. Shape adaptation is then used to examine the influence of motion-defined shape on pattern-defined shape and vice versa, in a nulling paradigm. The results indicate that there is interaction across pattern types in both directions, although the motion influence on form is weaker. We also show that the evidence for motion-defined global form in radial frequency patterns is unconvincing and can be attributed to the motion-position illusion which leads to the conclusion that both types of radial frequency pattern drive the same spatial global shape detection process.

## **Children exploit multiple visual cues for speed, not accuracy**

*Marko Nardini*<sup>1</sup>, *Rachael Bedford*<sup>2</sup>, *Meera Desai*<sup>3</sup>, *Denis Mareschal*<sup>4</sup>

<sup>1</sup>Institute of Ophthalmology, UCL; email: m.nardini@ucl.ac.uk

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Human adults integrate cues to reduce sensory uncertainty. In recent studies children did not integrate cues across modalities to improve spatial localization or shape discrimination until 8 years or later (Nardini et al. 2008, *Curr Biol*, 18 689-693; Gori et al. 2008, *Curr Biol*, 18 694-698). However when orienting speed is measured rather than precision, even infants less than one year old benefit from multiple cues. To investigate the development of cue integration further, we studied integration within vision, a single modality, measuring both accuracy and speed gains for multiple cues. Six- to 12-year-olds and adults judged which of two surfaces was more slanted, given texture and/or binocular cues. Uncertainty reduction by cue integration did not emerge until 12 years even within the single modality of vision. However, 6-year-olds' ability to keep stereo and texture cues separate enabled them to outperform adults when discriminating stimuli in which these cues conflict. Further, 6-year-olds showed speed gains consistent with following the fastest-available single cue. Thus, while adults exploited multiple cues for accuracy, young children exploited them for speed. These results suggest that developing and mature visual systems are optimized for different goals. Keeping estimates separate allows detection of sensory conflicts, an error signal needed to recalibrate the senses as the body changes (e.g., as interocular distance increases) during childhood. Further, it allows speed gains relative to single cues, which may improve the abilities of children, whose information processing is relatively slow, to keep up with the pace of events in the world.

## **Part-report for successive visual inputs**

*Wayne Smith*<sup>1</sup>, *John Mollon*<sup>2</sup>, *Hannah Smithson*<sup>3</sup>

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The part-report advantage has been used to identify short-lived forms of visual storage (Sperling, 1960, *Psychological Monographs: General and Applied*, 74(11), 1-29). A cue that directs the observer to report a spatial subset of an alphanumeric array is sufficient to support a part-report advantage. We ask whether a cue that directs the observer to report one of two successive arrays can also support a part-report advantage. In each trial of our experiments, eight digits were presented, arranged in two successive arrays, each of four digits. The two arrays were spatially coincident, and each was followed by a random pattern-mask. In the part-report conditions, an auditory cue that was presented at the end of the visual sequence indicated whether the observer should report either the first or second array. The results consistently showed a part-report advantage, ranging in size from 16% to 37%. Delaying the cue by 500 ms abolished this advantage, in that performance was then similar to that in whole-report conditions. An analysis of performance per array showed that the earlier cue improved retrospective report from the first array. Subsequent experiments confirmed that the advantage was not achieved by (i) extracting information from a single snapshot containing an integrated representation of the targets and masks; (ii) transferring a subset of material to a phonological store; or (iii) making eye-movements that spatially displace the second array relative to the first. We propose instead that

observers have access to a limited, rapidly-decaying representation of successive visual inputs stored in temporal sequence.

### **Changes in direction of motion attract attention**

*Christina Howard*<sup>1</sup>, *Alex Holcombe*<sup>2</sup>

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Predicting objects' future locations requires keeping up to date with their current motion direction. Whether a change in the direction of a moving object attracts attention is still unexplored. We investigate this using a task in which observers attend to the changing orientation of two grating patches, among four gratings on the screen. All four grating patches changed smoothly and semi-randomly in their positions and orientations. The stimuli disappeared at an unpredictable time, one of the two target gratings was queried, and observers were to report the orientation it had at the time of its disappearance. Hence direction of the gratings' motion across the screen was an irrelevant feature. Nevertheless, if this queried grating had changed direction of motion near the end of the trial, report accuracy was better than when it had not. In contrast, a recent direction change in the other attended grating (that was not queried) caused a decrement in performance. In a separate experiment, the motion-limiting boundaries were drawn on the screen though all other parameters were kept identical. Now, with the reason for most of the direction changes obvious, no effects of direction changes were seen either in the queried or non-queried grating. This suggests that violation of expectations about motion attracts attention. This tendency for unexpected motion changes to attract attention is likely to provide important benefits for our everyday monitoring of objects in our environments.

### **Phantom limbs and synaesthesia: inter-sensory interactions as a key to understanding the brain**

*Vilayanur Ramachandran*

UCSD; email: [vramacha@ucsd.edu](mailto:vramacha@ucsd.edu)

Abstract not available

## **More GABA, less distraction: A neurochemical correlate of variability in human eye movement control**

*Petroc Sumner, Richard Edden, Aline Bompas, Krish Singh*

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Every researcher of human behaviour knows that people perform differently, and this remains true even in the most basic situations involving the fundamentals of simple actions. Yet, although stimulating growing interest, the reasons for such differences are generally unknown. Here we show that differences in basic performance can correlate tightly with subtle neurochemical differences in relevant brain regions. We investigate the ability to inhibit an irrelevant distractor when making eye movements, and find that it is well predicted by the concentration of GABA – the main inhibitory neurotransmitter – measured by magnetic resonance spectroscopy in a region including human frontal eye field (FEF), but not in a control region. Moreover, by employing a model that distinguishes three types of motor inhibition, we can specifically associate GABA variation in the FEF region with just one of them – top-down reactive inhibition.

## **Perceptual biases reveal characteristics of neural coding mechanisms for multisensory timing**

*Neil Roach<sup>1</sup>, James Heron<sup>2</sup>, David Whitaker<sup>2</sup>, Paul McGraw<sup>1</sup>*

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We typically perceive external events as coherent multisensory entities – if a balloon pops in front of us for example, we see and hear it happen simultaneously. That this occurs is not trivial, given that considerable differences exist between both the speed of light and sound through air, and the rate at which each is transduced into neural signals by our senses. Recent studies demonstrating that an observer's point of subjective simultaneity (PSS) can be biased by a short period of exposure to a consistent multisensory asynchrony suggest that the brain might correct for pervasive delays by constantly recalibrating timing perception. However, the principles governing the coding of multisensory timing information in the brain remain poorly understood. Here we measured the effect of asynchrony adaptation on the perception of a wide range of sub-second temporal relationships. Observers were required to estimate the magnitude of the stimulus onset asynchrony (SOA) between pairs of brief auditory and visual stimuli with and without prior adaptation (i.e. passive exposure) to a fixed asynchrony ( $\pm 100$ ms SOA). Results revealed a distinctive, non-uniform profile of induced biases, which could be well accounted for by a model in which: (i) relative audio-visual timing is represented by the distributed activity across a relative small population of neurons tuned to different delays; (ii) the algorithm for reading-out this population code is efficient, but subject to small sample bias; and (iii) adaptation acts primarily to reduce response gain, as is commonly reported for neurons tuned to unisensory features (e.g. orientation, direction).

## **Neural activity in higher dorsal visual areas relates to the discrimination of disparity-defined depth position**

*Andrew Welchman, Matthew Patten*

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Neural responses to binocular disparity have been observed throughout the visual cortex. To investigate the relationship between this activity and the perception of disparity-defined depth, we measured fMRI responses while observers viewed random dot stereograms depicting planes with crossed (near) or uncrossed (far) disparity. On each trial, observers judged the depth position (near or far) and we manipulated performance by parametrically changing the correlation of dots presented to the two eyes. When 100% of the dots were correlated (e.g. white dots in one eye match white dots in the other) the task was trivial; however, when 100% of the dots were anticorrelated (white dots in one eye match black dots in the other), discrimination performance dropped to chance. We measured concurrent event-related fMRI responses and used multivariate analysis methods (SVM: support vector machine) to determine cortical regions that contained information about the disparity-defined depth (cf. Preston et al, 2008, *J Neurosci*, 28, 11315-27). In particular, we trained an SVM to discriminate near/far depth for 100% correlated stereograms and then tested the SVM with fMRI responses evoked at lower coherence levels, thereby obtaining 'fMR-metric' functions. Comparing fMR-metric and psychometric functions indicated a close association between psychophysical judgments of depth and activity in higher dorsal areas V7 and VIPs. In conjunction with other recent findings, these results suggest an important role for higher dorsal areas in the perception of depth.

## **A necessary role for the lateral occipital cortex and the occipital face area in the rotational invariance of shape processing**

*Dietrich Schwarzkopf, Juha Silvanto, Sharon Gilaie-Dotan, Geraint Rees*

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Shapes and objects can be recognised in spite of large angles of rotation. Here we investigated the roles of the lateral occipital cortex (LO) and the occipital face area (OFA) in the rotational invariance of shape processing using transcranial magnetic stimulation (TMS). Rather than using a conventional 'virtual lesion' approach, we capitalised on the state-dependency of TMS effects (Silvanto et al., 2008, *Trends Cogn Sci*, 12(12), 447-54). Participants were primed by a novel two-dimensional shape defined by aligned Gabors. They subsequently judged the direction of rotation of a probe shape embedded in a noisy background and rotated 20° or 70° from vertical. TMS was applied before probe onset over LO, OFA (localised by functional magnetic resonance imaging) or not at all. Without TMS, participants performed more accurately when the probe was the same shape as the prime. TMS over LO abolished this priming benefit for shapes with small rotations, while TMS over OFA abolished priming with larger rotations only. Thus, our findings demonstrate that both LO and OFA play roles in rotation invariant shape recognition. This challenges the modular view of object recognition according to which each functionally defined area is involved only in the detection of targets of its preferred category (Spiridon & Kanwisher, 2002, *Neuron*, 35, 1157–1165). Our results suggest that invariance is achieved in stages, such that smaller degrees of rotational invariance are associated with neuronal populations in LO, while larger degrees of rotational invariance are associated with neurons in OFA.

## **A couple of challenges for visual perception under uncertainty**

*Pascal Mamassian*

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Visual perception is often seen as an inference problem where uncertainty comes from ambiguities in the world (e.g. the two 3D interpretations of the Necker cube), noise in the world (e.g. identifying a scene behind falling snowflakes), or noise in the visual system (e.g. synaptic noise). To deal with ambiguities, the visual system relies on prior knowledge such as the assumption that light comes from above our head. We have measured the characteristics of this assumption and found a systematic bias to the left for the illumination direction preference. In addition, using fMRI coupled with a model of behavioural performance, we found evidence that the above-left assumption for the light source position was encoded early in the visual system and processed in a bottom-up way. To deal with noise, the visual system relies on the integration of information in space and time. Usually such an integration over a well-chosen region helps increase the signal-to-noise ratio. However, there are situations where integration can be highly detrimental. We report conditions where stereo-acuity drops by two orders of magnitude when the elements over which depth is compared belong to a single object. These results can be well accounted for by a model where object uncertainty propagates to all its parts. In summary, uncertainty is an unavoidable aspect of visual perception and the search for the solutions found by the visual system to cope with it is a fundamental part of the investigation of visual perception.

## **Learning reconfigures the decoding of sensory signals for fine discriminations**

*Ben Webb, Neil Roach, Gaëlle Coullon*

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When using sensory information to guide behaviour, the brain has to decode the noisy responses of population of neurons. Mounting evidence demonstrates that brain systems have developed optimal, unbiased decoding solutions. When making fine discriminations for example, observers optimize performance by exploiting information-rich signals from neurons tuned away from the discrimination boundary. Yet perturbing the responses of these neurons via short-term adaptation produces a cost for discriminative accuracy, suggesting that the brain persists with the same decoding strategy even though it is no longer optimal. Here we ask whether the weighting of sensory information for fine discriminations is rigid or can be flexibly reconfigured over longer time scales. Observers judged whether the axis of dot motion was clockwise or counter clockwise of vertical. We measured the elevation in direction discrimination thresholds caused by adapting to motion either in an upwards direction ( $0^\circ$ ) or two directions offset symmetrically from  $0^\circ$  ( $\pm 10$  to  $\pm 50^\circ$ ). The most effective adapter directions for raising discrimination thresholds were  $\pm 20^\circ$ , consistent with the notion that observers rely heavily on the most informative neurons. Repeated practice of the task whilst in this adapted state dramatically improved discrimination performance to a level that ultimately surpassed that obtained without adaptation. However, this remarkable improvement came at a price: adapter directions that previously had little effect now induced a significant increase in discrimination thresholds. Our results suggest that the weighting of sensory information for fine discriminations can be flexibly reconfigured in response to changes in the state of the system.

## **Axis cueing effects under noise masking imply that symmetry discrimination is an active two-stage process**

*Christopher Tyler*

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Symmetry detection is an interesting probe of pattern processing because it requires the matching of novel patterns without the benefit of prior recognition. We investigated how the prior information about the symmetry axis affects symmetry detection under noise-masking conditions. The target stimuli were random-dot displays structured to be symmetric about vertical, horizontal, or diagonal axes and viewed through eight apertures ( $1.2^\circ$  diameter) evenly distributed around a  $6^\circ$  diameter circle. Information about axis orientation was manipulated by (1) cueing of axis orientation before the trial and (2) varying axis visibility by including or excluding the axis region within the visible pattern. The percentage of correct detection of the symmetry was measured at for a range of both target and masking noise densities. The threshold vs. noise density function was flat at low noise density and increased with a slope of  $\sim 0.75$  beyond a critical density. Cueing of the axis orientation and position reduced the target threshold by a up to a factor of four at all noise densities while axis visibility had an effect only at high noise density. Modeling the results showed that they are inconsistent with an ideal observer or signal-to-noise account of symmetry detection. However, the data can be explained by a two-stage, multiple-channel model in which the response in each symmetry-processing channel is given by the ratio between the nonlinear transform of the responses of sets of early symmetry detectors degraded by both external and intrinsic sources of noise.

## **Influence of contrast gain changes on the apparent duration of a visual stimulus**

*Aurelio Bruno, Alan Johnston*

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To test the hypothesis that adaptation-induced time compression (Johnston, Arnold & Nishida, 2006, *Current Biology*, 16(5):472-9) and temporal impulse response shortening in M cells (Kaplan & Benardete, 2001, *Prog Brain Res*, 134:17-34) are related, we investigated the effect of the contrast context of a stimulus on its apparent duration. We observed that the apparent duration of an interval containing a 50% luminance contrast grating drifting at 20Hz is compressed when preceded by a 90% contrast interval as compared to when preceded by a 10% contrast interval. Conversely, a 10% or 90% contrast static inducer had no significant effect on the apparent duration of a drifting test. In order to dissociate the effect of contrast context from other non specific variables, we also measured the apparent temporal frequency and contrast of an interval preceded by a 10% or 90% contrast inducer. We observed no significant difference in apparent temporal frequency for 20Hz drift, which induces duration compression, as compared to 5Hz drift, which does not. We also found a reduction in apparent contrast followed the 90% contrast interval, but not the 10% contrast inducer for both 20Hz and 5Hz drift. No difference in apparent duration between 5 and 20Hz was observed when we asked subjects to directly compare a 10% contrast and a 90% contrast interval. Our results show that contrast gain, but not contrast per se, has an effect on duration. This effect is limited to moving stimuli implicating the magnocellular pathway and can be dissociated from changes in perceived temporal frequency or perceived contrast.

## **Perceptual grouping of ambiguous motion**

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Introduction. What are the rules of common fate? How are spots that move in different directions grouped perceptually? Method. A pair of spots, separated by  $2^\circ$ , rotate about their common centre at 1 rps. Four such pairs spin in synchrony at the corners of an imaginary square of side  $8^\circ$ . Results. On first viewing, observers report four spinning pairs (Local motion), but after 5-20s the percept suddenly changes to two overlapping  $8^\circ$  squares circling around (Global motion). Thereafter, global motion tends to predominate. Factors that increase local motion include: Gazing straight at a spinner. Proximity - putting the two spots in a spinner closer together. Orientation - replacing the spots within a spinner by two radial or tangential dashes (as if painted on an invisible disk). Luminance - making each spot-pair a different grey. Increasing the number of spots in each spinner from 2 up to 3 or 4. Factors that increase global motion include: Viewing spinners in peripheral vision. Moving the two spots in a spinner further apart. Orientation - replacing the spots with two floating lines that remain horizontal (or vertical) as they spin. Luminance polarity - on a grey surround, four spots defining an  $8^\circ$  square (one spot from each pair) are black, the remaining spots are white. Increasing the number of spinners from 4 to 8. Conclusions. It is a more parsimonious perceptual hypothesis to group the data from the motion array into only two objects (squares) moving globally, rather than into four objects (spinners) moving locally.

## **What is happening behind my neighbour's fence? -Investigating our ability to use unmatched regions in a binocular scene**

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Because we have two horizontally offset eyes there is significant overlap between the two retinal images. To obtain binocular disparity, points in the two eyes' views are matched. Traditional models of binocular disparity extraction have assumed that unmatched points are treated as noise by the visual system and thus ignored (e.g. Marr & Poggio, 1979, Proc. P. Soc. Lond. B. 204, 301-328) However, these unmatched points and regions can be visible in our binocular representation of the scene (e.g. Ono et al., 2003, Journal of Exp. Psych: Gen. 132(2), 253-265). It is unclear whether we are as sensitive to information in these unmatched regions as we are to information that is presented binocularly. In order to investigate this, a relative numerosity task was utilised. Participants were asked to indicate, in a 2AFC task, which one of 2 clouds of dots was more numerous. The clouds were presented either behind a set of vertically oriented fence-like occluders (each dot could only be seen by one eye), or behind a set of horizontal occluders (each dot was binocular but only half the dots were visible). No significant difference in sensitivity was found between the vertical and horizontal occluder conditions. These results suggest that: a) unmatched points in a binocular scene are not ignored and b) we are able to integrate the two sets of unmatched regions from the left and right eyes' views as well as fully binocular regions.

## **Implementing curve detectors for contour integration**

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We recently presented a model of contour integration in which the image receives two stages of oriented filtering, separated by a nonlinearity [May & Hess 2008 *Journal of Vision* 8(13):4, 1-23]. If the 1st and 2nd stage filters have the same orientation, the model detects 'snakes', in which the elements are parallel to the contour path; if the 1st and 2nd stage filters are orthogonal, the model detects 'ladders', in which the elements are perpendicular to the path. The model correctly predicts that detection of ladders is largely unaffected by contour smoothness, but fails to predict that jagged snakes are harder to detect than smooth snakes. The advantage for smooth snakes suggests the existence of a third stage which detects fragments of snake contour with constant sign of curvature. It has been argued that contours are analysed using mechanisms that multiply the outputs of subunits along the contour [Gheorghiu & Kingdom 2009 *Journal of Vision* 9(2):23, 1-17]. We implemented multiplicative curve detectors by multiplying spatially shifted outputs from different orientation channels in our model, giving curve detector responses for different orientations and curvatures. For each orientation, we summed responses across detector curvature, to give a 3D response space, with dimensions representing orientation and the 2D retinal image. Responses were then thresholded to form 3D zero-bounded regions within the response space, tracing out the contours. The model, which is a hybrid between association field and filter-overlap models, successfully accounts for the improvement in snake detection performance with increasing contour smoothness.

## **Non-linear global summation in the perception of non-circular contours**

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The ability to discriminate minute deviations from circularity is dependent upon mechanisms integrating information along entire contours. To determine if global summation is specific to circles or a more universal feature of shape processing, contour discrimination for various contour shapes, described by radial frequency patterns, was measured. Thresholds for detecting shape deformations were determined for shapes of 3 (RF3) and 5 lobes (RF5), each with amplitudes ('sharpness' of each lobe) ranging between 0 (i.e. discrimination against a circle) and  $20 \times$  thresholds for detecting deviation from a circle (e.g. discriminating five-sided star-shapes). The ability to integrate information along contours was measured by comparing the effect of applying radial deformations to the entire contour or to only fractions (various number of lobes). Discrimination thresholds remain in the hyperacuity range for low amplitudes of up to  $2.5 \times$ , but increase for higher amplitudes. As for signal integration, discrimination, expressed as a function of the amount of contour deformed, exhibits a shallow and a steep regime: discrimination improves only marginally as more contour cycles are deformed until a critical point, after which thresholds decrease dramatically. The slope of the steeper part typically exceeds linear summation. The amount of deformed contour required to reach the critical point depends on the overall contour shape. The marked increase in performance as the patterns become complete argues in favour of highly specialized shape mechanisms. The results indicate a highly global, non-linear mechanism, which responds most strongly when it is stimulated by the entire pattern and comparatively weakly when it is stimulated only by parts of it.

## **Weber's Law for circle diameters; not areas**

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Weber (1851) found it "immaterial" whether two lines were approximately one or two inches long; the ease with which the larger could be selected depended only on the ratio of their lengths. What about circles? We wondered whether Weber's Law held for their diameters, their areas, or some non-integer power of diameter. To get the best estimate of this power, we measured psychometric functions for two (spatial) alternative, forced-choice size discriminations. The diameters of our circles were approximately 1.5 and 3.0 degrees of visual angle. Probabilities for reporting circle A larger than circle B were best fit by a cumulative Gaussian distribution over the four equally spaced Weber fractions of diameter (i.e. the differences between diameter A and diameter B divided by diameter B) that were randomly interleaved with equal frequency in our experiment, when the latter were raised to the power  $1 \pm 0.04$ . This result is consistent with the visual system adding the same amount of Gaussian noise to all logarithmically transduced circle diameters.

## **Object-position binding in visual short-term memory for serially presented unfamiliar stimuli**

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The effect of spatial position on visual short-term memory (VSTM) for serially presented objects has been investigated little, despite that vision in natural environments is characterised by frequent changes in object position and gaze location. In this study, five observers performed a yes-no recognition task for a memory display comprising 1/f noise discs (i.e., possessing spectral properties akin to natural images) presented serially (each for 750 ms) at random coordinates. Following a blank interval (1000 ms), at test, a single stimulus was presented either at its original spatial position (condition 1), a new position (condition 2), a fixed central position (condition 3), or a spatial position previously occupied by alternative stimuli (condition 4). Observers indicated if the test stimulus matched (in appearance) one of the preceding memory stimuli (i.e., spatial position was task-irrelevant). In condition 1, performance (measured in  $d'$ ) was 24.92% higher than in condition 2. Furthermore, hit rate in condition 1 was significantly greater than condition 2 [ $F(1,4)=16.96, p=0.01$ ], 3 [ $F(1,4)=19.30, p=0.01$ ], or 4 [ $F(1,4)=15.56, p=0.02$ ], suggesting that appearance and spatial position previews confer an integrated (bound) rather than independent (unbound) contribution to VSTM. This study shows the generality of object-position binding to a serial display scenario, places the same position advantage (Hollingworth, 2007 *Journal of Experimental Psychology: Human Perception and Performance*, 33, 31-47) firmly within VSTM (suggesting that the semantic and associative components of visual long-term memory are inessential), thereby ruling out object type priming (Pollatsek et al., 1990 *Journal of Experimental Psychology: Human Perception and Performance* 16, 199-210) as the sole cause of this phenomenon, and also eliminates spatial context and extra-foveal perception as necessary/underlying factors.

## **Filter transformations for shift-insensitive feature detection**

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The representation of oriented image-structure is an important part of most biological vision models. It is possible, for example, to estimate both motion and binocular disparity from the responses of oriented filters (Adelson & Bergen 1985, JOSA A 2(2), 284-299). It is particularly useful to combine the responses of different filters, in order to obtain a response to edge-like structures that is insensitive to slight shifts (in the direction perpendicular to the edge). It has been hypothesized that complex cells achieve this by separating the local energy of the signal from its phase. We describe an alternative approach, which is based on the 'local jet' representation (Koenderink & van Doorn 1987, Biol. Cyb. 55, 367-375). Each jet is computed from a set of oriented derivative filters, of order 1 to N, which are applied at a given image location. We show that these filters can be used as a basis for a new set, which contains filters of a single order, each at a slightly different location. The maximum response, over the new set, is insensitive to small image-shifts. This approach can be justified by noting that a Taylor approximation of the shifted Kth order filter can be obtained from the N-K higher-order filters in the jet. It is shown, however, that a least-squares construction is more practical. Finally, it is noted that the responses of the new filters can be obtained from a linear transformation of the original N image derivatives.

## **Temporal precision of a contour-selective mechanism**

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Temporal cues, such as temporal coincidence, can be important for visual grouping. Here, we investigated the influence of temporal characteristics on the binding of grating elements into a contour using a curvature aftereffect (CAE; Hancock & Peirce, 2008, Journal of Vision, 8, 11). On one side of the visual field (contour side), observers adapted to two sinusoidal gratings oriented at  $\pm 20$  degrees from horizontal, presented together to form a chevron-like contour that alternated with a blank field. On the other side (component side), the same two component gratings alternated with each other. Under these conditions, a straight probe stimulus shows a greater aftereffect on the contour- than the component-side, indicating an aftereffect to the contour stimulus over and above the tilt aftereffects generated by its parts. Here, we examined the dependence of this effect on the temporal coincidence of the components. As the components comprising the contour were made increasingly asynchronous, to the point where they were perfectly out of phase with each other, we observe a gradual decrease in the amplitude of the effect rather than a rapid, nonlinear reduction. Furthermore, keeping the components perfectly out of phase, but increasing the rate of alternation between them to 4Hz or greater results again in selective adaptation effects. It seems that the mechanism underlying the CAE has rather poor temporal precision, integrating any components presented within 250ms of each other.

## **Mach bands: multi-scale spatial filtering and co-operative coding of edges and bars**

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Perception of Mach bands may be explained by spatial filtering ('lateral inhibition') that can be approximated by 2nd derivative computation, and several alternative models have been proposed. To distinguish between them, we used a novel set of 'generalised Gaussian' images, in which the sharp ramp-plateau junction of the Mach ramp was replaced by smoother transitions. The images ranged from a slightly blurred Mach ramp to a Gaussian edge and beyond, and also included a sine-wave edge. The probability of seeing Mach Bands increased with the (relative) sharpness of the junction, but was largely independent of absolute spatial scale. These data did not fit the predictions of MIRAGE, nor 2nd derivative computation at a single fine scale. In experiment 2, observers used a cursor to mark features on the same set of images. Data on perceived position of Mach bands did not support the local energy model. Perceived width of Mach bands was poorly explained by a single-scale edge detection model, despite its previous success with Mach edges (Wallis & Georgeson, 2009, *Vision Research*, 49, 1886-1893). A more successful model used separate (odd and even) scale-space filtering for edges and bars, local peak detection to find candidate features, and the MAX operator to compare odd- and even-filter response maps (Georgeson, VSS 2006, *Journal of Vision* 6(6), 191a). Mach bands are seen when there is a local peak in the even-filter (bar) response map, AND that peak value exceeds corresponding responses in the odd-filter (edge) maps.

## **Misestimation of light source elevation alters lightness judgments**

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The problem of recovering reflectance from a single image is under-constrained. Therefore, the visual system must use heuristics or biases to be able to recover lighting, geometry and reflectance. We investigated lightness perception in a 3D context. Participants adjusted the reflectance of the central face of a static dodecahedron to match the reflectance of the remaining five sides. Reflectance was systematically overestimated for vertically eccentric illuminant angles and underestimated for illuminant angles close to the horizontal plane. Additional information from distant contextual objects and kinetic depth cues did not enhance accuracy. Removing local features (y-junctions and edges) did not decrease accuracy. However, varying the proportion of ambient to directional light altered apparent reflectance. Modelling of the data pointed to three possible causes of the reflectance misestimation: a light direction bias, a bias in the proportion of ambient to directional light or a simple brightness averaging over the image. To investigate perceived illuminant direction, we asked participants to adjust the illumination direction for a sphere until it matched the lighting direction for a dodecahedron rendered using a range of illuminant elevations. The pattern of light direction adjustments was consistent with a bias of perceived illuminant elevation that is both shifted away from vertically eccentric angles and away from the horizontal plane. This finding supports the view that the systematic errors in reflectance settings are caused by a bias in the assumed direction of illumination.

## **Interactions between light-from-above and convexity priors in visual development**

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Having an assumption about where light originates from can disambiguate perceptual scenarios. Previous studies have reported a ‘light-from-above prior’ as well as a convexity prior, which allow observers to constrain perception of shape-from-shading. One interpretation of such priors is that they reflect information acquired about the visual world, where objects tend to be convex and light tends to come from above. In the current study 4-12 year olds and adults made convex/concave judgements for two sets of shaded images. When observers judged shaded circles (Ramachandran, *Nature* 1988, 331, 163-165) as bumps or dents, all groups showed a similar assumption that on average the light came from above ( $\pm 20$  degrees from the vertical). However, the mean variance of assumed light directions declined with age, showing that observers became increasingly consistent in their judgements. Participants’ responses to a more complex ‘polo-mint’ stimulus (Gerardin et al., *J of Vis* 2007, 7(11), 1-11) suggest that the light prior and the convexity prior interact. Overall, observers preferred to interpret the stimulus as lit from above-left rather than below-right, and as mostly convex rather than mostly concave. However, given stimuli in which both these assumptions could not be true at the same time, younger children were more likely to assume convexity, whereas older groups were more likely to assume light from above. It seems that with age observers are increasingly influenced by an ‘above’ or ‘above-left’ rather than a convexity prior.

## **Task-specific perceptual learning of texture detection and identification**

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Previous studies have shown that practice lowers identification thresholds for textures embedded in noise, and that such perceptual learning is stimulus-specific and long lasting. Here we ask whether better detection of the relevant signal is sufficient to improve identification, or whether experience in distinguishing the textures is necessary. In other words, is perceptual learning of texture identification task specific, or does it simply reflect improved stimulus detectability? Separate groups of subjects practiced texture detection and identification on Day 1; on Day 2 they performed either the same task as on Day 1, or transferred to the untrained task. Stimuli were 10 briefly (200 ms) presented band-limited noise textures embedded in static noise. Detection performance was measured with a Yes/No task, and identification performance was measured with a 10-AFC task. Texture contrast was varied across 7 levels using the method of constant stimuli; feedback was provided on each trial. We calculated  $d'$  at each contrast level to compare psychometric functions across tasks and days. On Day 1, psychometric functions spanned the full performance range for both tasks. On Day 2, after practice with the same task, texture identification improved substantially at all contrasts whereas texture detection improved only slightly. There was no transfer of learning from detection to identification, and some evidence for transfer in the opposite direction. Therefore, better detection of the stimulus is not sufficient to improve identification of noisy patterns. Learning requires telling the patterns apart - perceptual learning of texture identification is task-specific as well as stimulus-specific.

## **Area summation of contrast is scale invariant and occurs over at least 8 carrier cycles**

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Classical studies of area summation – in which detection thresholds are measured as a function of target diameter – confound summation of signal with summation of internal noise, and are compromised by retinal inhomogeneity. A “swiss cheese” stimulus recently introduced by Meese & Summers (2007; Proc Biol Sci, 274, 2891-2900) was designed to avoid these problems by keeping target diameter constant and modulating the contrast of interdigitated ‘check’ regions. This approach has revealed substantial area summation at and above detection threshold. Here, we investigate the spatial limits of this integration process over a range of carrier frequencies (1 – 16c/deg) and modulator frequencies (0.25 – 32cycles/check). We used two experimental designs: a simple method in which component ‘check’ thresholds were compared with those for their linear sum, and a normalization method in which the strength of each component in the compound stimulus depended on its detectability. The second design was of particular benefit for large check sizes (low spatial frequency modulators). Plotting results as functions of carrier cycles per check revealed contrast summation to be scale invariant for both designs. Summation remained strong (~6dB) up to at least 4cycles/check, implying linear physiological summation over 8 carrier cycles or more, and declined monotonically for larger check sizes. We consider area summation models involving spatial filtering, nonlinear transduction, linear summation over a fixed region, and Minkowski summation over multiple regions. These analyses support our conclusion that physiological summation of contrast occurs over a minimum of 8 carrier cycles after the initial stage of linear spatial filtering.

## **Isotropic masking reveals losses in spatial frequency specificity at high temporal frequencies: An isotropic third temporal channel?**

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When both masking and testing with 1-D image signals, the consensus of psychophysical research points to the existence of two temporal channels: one sustained, the other transient. Unequivocal evidence for a third temporal channel has remained elusive. Here we demonstrate the possibility for a broadly tuned isotropic spatial channel that serves at high temporal frequencies. We do so by masking with high spatial frequency signals but employing a test probe across the full spatial frequency range. Using a 2AFC paradigm, subjects were required to detect a test signal superimposed upon a spatial (isotropic) and temporal frequency bandlimited mask. The peak spatial frequency tuning of the mask was fixed at 8.0 cycles per degree but its peak temporal frequency tuning was varied across sessions. The root mean square contrast of the mask was fixed at 0.15 while the contrast of the test was varied. When the temporal frequency of both test and mask was low, threshold contrast elevations (defined as the ratio of contrast thresholds in the masked to unmasked conditions) were bandpass functions with the peak of the masking function coinciding with the peak spatial frequency of the test. However, when masking with temporal signals around 30Hz we found that threshold contrast elevations became spatially lowpass rather than bandpass. Our results suggest the existence of a broadband spatial channel tuned to high temporal frequencies. However we cannot rule out other explanations, for example, local adaptations in which visual information is lost at the lower spatial frequencies through masking induced adaptations.

## **Direct tilt after-effect increases with test duration when testing at high temporal frequencies**

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The perceived orientation of a 1-d test pattern can be distorted following adaptation to a tilted 1-d signal. We examine the magnitude of these Tilt After-effects (TAEs) as a function of the temporal frequency (TF) and duration of the test signal, and luminance of the display. The test and adapting signals were 2.0 cycles/deg sinusoidal gratings. The adaptor was always 60% contrast, 2.5s long, oriented at 15° counter-clockwise (CC) from vertical, while its TF was 0.4, 18 or 25 Hz. Test TF ranged between 0 and 50 Hz and its duration between 0.05s and 0.6s. Test contrast was fixed at 30% while the monitor luminance was also varied (1-400 cd/m<sup>2</sup>). Subjects reported whether the test grating was oriented either clockwise or CC from vertical. As test duration was increased the magnitude of the direct TAE generally decreased for low test TFs, but could increase for high test TFs (38 - 50 Hz). The increase of direct TAE for longer test durations is found to be more pronounced at lower luminance, where it could be observed for lower test TFs (19Hz).

Control experiments showed that the TAE magnitude, and its reliance on test TF and duration, cannot be wholly accounted for by variations in perceived contrast. We suggest that the test triggers a fast, adaptive mechanism that recovers too quickly to have an effect at low TFs. Such mechanisms may be responsible for boosting adapted signals, thus accounting for the saturation of adaptation effects as a function of adapting signal strength.

## **The Riesz transform and linear summation across orientation tuned filters for phase dependent, phase independent and second-order spatial orientation computations**

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The Riesz Transform (Felsberg and Sommer, IEEE Trans. on Signal Processing, 49, 3136-3144, 2001) is an extension of the 1-D analytic signal to higher dimensional signal spaces where the number of Riesz transformed filters is equal to the signal's dimensions. For spatial images there exist two Riesz Transformed signals and one original signal from which an image signal's spatial orientation, spatial phase and energy may be represented as a vector in a 3-D signal space. We show that the steered derivatives of Riesz Transformed image signals may be represented by a singular value decomposition (SVD) of a Riesz matrix from which phase independent and dependent estimates of spatial orientation may be estimated from the left and right eigenvector matrices, respectively. Energy is defined by the central matrix of singular values. From the left eigenvector matrix one may estimate multiple local orientation vectors which is an advantage given the general instability of phase independent orientation estimators for a single spatial orientation to image signals composed of several local orientations. We show that the expected responses of even and odd symmetric filters derived from the Riesz transform may be represented by a single signal autocorrelation function leading to a balancing of signal-to-noise ratios that are independent of an image signal's spatial phase. The balancing is critical when considering Bayesian computations for the estimation of spatial orientation. We demonstrate that the linear properties of Riesz transformed image signals allow one to weight linearly across orientation tuned filters thus accounting for some phase distortions observed in 2-D image

signals, notably one's perception of edges for plaid patterns whose orthogonal component gratings are either equal or unequal in contrast. Finally, we demonstrate the utility of the Riesz Transform in estimating second-order image signal properties as a two-stage process through its precise definition of an image signal's local energy as a scalar quantity.

### **Peeling plaids apart: Context counteracts cross-orientation contrast masking**

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Contrast discrimination for an image is usually harder if another image is superimposed on top. We asked whether such contrast masking may be enhanced or relieved depending on cues promoting integration of both images as a single pattern, versus segmentation into two independent components. Contrast discrimination thresholds for a foveal test grating were sharply elevated in the presence of a perfectly overlapping orthogonally-oriented mask grating. However thresholds returned to the unmasked baseline when a surround grating was added, having the same orientation and phase of either the test or mask grating. Both such masking and 'unmasking' effects were much stronger for moving than static stimuli. Our results suggest that common-fate motion reinforces the perception of a single coherent plaid pattern, while the surround helps to identify each component independently, thus peeling the plaid apart again. These results challenge current models of early vision, suggesting that higher-level surface organization influences contrast encoding, determining whether the contrast of a grating may be recovered independently from that of its mask.

### **Perceived orientation: The tilt illusion dominates parafoveal vision, but the periphery is dominated by crowding**

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Outside central vision, small differences between target and flank orientations can go unnoticed (as in crowding), while larger differences are exaggerated (as in the tilt illusion). New data using same sized stimuli demonstrate that the switch from crowding to the tilt illusion depends on stimulus visibility. With all of the flank angles ( $\pm 5$ ,  $\pm 10$  and  $\pm 22.5$  deg) and viewing eccentricities (0, 4 and 10 deg) we tested, the addition of luminance noise to target and flank caused a slight shift in the perceived orientation of the target toward that of the flanks. More surprising was our finding that the size of the tilt illusion varies non-monotonically with viewing eccentricity. Consistent with previous studies, ours confirms that the tilt illusion is greater at 4 deg eccentricity than it is in central vision; but at 10 deg it was much smaller. We propose that crowding and the tilt illusion are manifestations of opponent influences on orientation perception. The strengths of these influences depend on viewing eccentricity and/or cortical distance between target and flank. The aforementioned non-monotonicity can be ascribed to different monotonic relationships between viewing eccentricity and the strength of each influence.

## **Do lower visual cues provide online control for reaching and grasping while standing?**

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Previous literature on reaching and grasping presents equivocal findings about the role of peripheral visual cues. In some studies, peripheral cues were found to be involved mainly in the planning of arm movements (Prablanc et al 1979, *Biol Cyber*, 35, 183-7) while in other studies peripheral cues were found to control both reaching and grasping online, but under monocular visual condition (Gonzalez-Alvarez et al, 2007, *Ophthal Physl Opt*, 27, 265-74). The aim of the present study was to determine if peripheral visual cues (i.e. dynamic spatial position between body/arm and target) provided by the lower visual field controlled online reaching and grasping. While standing, eighteen subjects reached and grasped either a semi-empty or a full glass. Standing position allowed us to analyse postural adjustments made prior to movements (APAs), representing the feedforward control of posture for the execution of arm movements, and during movements (CPAs) corresponding to the online control of posture for the execution of arm movements. Two binocular visual conditions were investigated: normal vision and lower occlusion. Outcome measures were determined using 3D motion capture techniques. Results showed that lower visual occlusion increased CPAs and influenced both reaching and grasping particularly in the final stage of movement (e.g. longer time between maximum handgrip and contact, higher maximum handgrip and lower grip closure velocity) but had no effect on APAs. Taken together, we interpret these findings as evidence that lower visual cues are mainly used online to update the dynamic position of the hand relative to the target location.

## **Post-saccadic memory of the location and identity of previously viewed objects**

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Efficient search in dynamic scenes requires visited items be tagged by identity and location and the tags be stored. While such object identity and spatiotopic location storage may sustain the cross-saccadic stability of the world, retinotopic location storage may hamper it. We address this issue by assessing localization and recognition performances ( $d'$ ) of both the last (N) and penultimate (N-1) saccade-target in a series of 2 to 6 saccades. Nine letter-pairs were displayed within a  $20^\circ \times 20^\circ$  gray rectangular frame on a virtual  $3^\circ$  radius circle around a fixation dot with a target letter-pair signaled by its different contrast polarity. Subjects were instructed to saccade to the target with the nine items presented for 100 ms and renewed once the eye landed at the target position, now displaying a fixation dot. A color change of the fixation dot signaled the end of the trial and prompted subjects to report the identity and/or location (dual/single-task) of the target. The location response was to be given with respect to subjects' present fixation (retinotopic), or to the gray rectangle frame (spatiotopic). Identical conditions were run with the eyes maintaining fixation throughout the trial but with the gray rectangle frame moving so as to mimic its retinal displacement when the eyes moved. Spatiotopic location was better stored (by  $\sim 0.33 d'$  units) and reported faster (by  $\sim 140$  ms) in the saccade compared to the maintained fixation condition. Instead, saccades degraded retinotopic location memory (by  $\sim 0.29 d'$  units) and delayed response time (by  $\sim 68$  ms). The better and faster spatiotopic location storage and retrieval during eye-movements is compatible with the notion that spatiotopic representation takes over retinotopic representation during eye movements thereby contributing to the stability of the visual world as its projection jumps on our retina from saccade to saccade.

## **What determines the direction of microsaccades?**

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During visual fixation, our eyes are not entirely still. Instead, small eye movements, such as microsaccades, can be observed. We here study what determines the direction of these microsaccades. The relative contribution of three possible factors was examined. These were: (1) the direction of covert attention, (2) the possible locations at which targets could appear (in the horizontal or in the vertical direction), and (3) whether monocular or binocular microsaccades are considered. Our results suggest that all three factors play a role, but that whether the microsaccades are monocular or binocular is the most important determinant of their direction. The relevance of these findings to other studies will be discussed.

## **Beta suppression in human extra-striate cortex reflects eye position during pursuit eye movements**

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Research suggests eye movement signals from non-retinal sources are fed to visual areas to guide smooth pursuit eye movements (SPEM). We aimed to explore changes in oscillatory power (specifically, neuronal desynchronisation) associated with SPEM. Given previous findings, we hypothesised that visual areas will exhibit oscillatory power changes, a correlate of cortical activation, and that this dynamic cortical coherence acts as a mechanism in the maintenance of SPEM. Therefore, we predicted that when controlling for perceptual processing by eliminating retinal slip of background objects during pursuit (by using customised cross-polarised filter goggles), we would observe beta desynchronisation in visual areas during eye movements in the absence of retinal motion. Eleven participants took part. Electrooculography (EOG) and 275-channel MEG data was collected under 3 conditions; (1) pursuit of low-contrast dot in the dark, (2) pursuit over a stationary background and (3) retinal motion from a translating dot field during fixation. Each run comprised of 30 x 20s epochs (10s passive/10s active period). Beta desynchronisation was observed over bilateral extrastriate areas during all conditions. Additionally, beta power changes in extra-striate cortex observed during pursuit in the dark would appear to correlate with eye position in the contralateral hemifield, because beta suppression was greatest when the eye was at maximum eccentricity. This beta decrease suggests these regions may be involved in maintaining SPEM as a result of receiving extraretinal input from the pursuit system to help make veridical estimates of parameters such as object motion.

## **Supplementary motor area activations in unconscious inhibition of voluntary action**

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There are now repeated evidences that regions within the dorsal medial frontal cortex such as the supplementary eye field (SEF), Supplementary motor area (SMA), and pre-SMA are involved in the control of voluntary action, especially during motor sequences, eye movements or tasks involving rapid choices between competing response plans. For instance, Sumner et al (2007, *Neuron*, 54(5), 697-771) showed that two patients with rare microlesions of the SEF and SMA demonstrated strong deficits in unconscious and involuntary motor control, as evoked by masked-prime stimuli. The aim of the present BOLD functional MRI study was to use similar masked stimuli to test in healthy volunteers whether activity in the medial frontal cortex was detected when generating unconscious motor inhibition. For each participant, we defined two regions of interest (ROIs), one in SMA, and the other in pre-SMA. Analysis of reaction time data revealed that automatic inhibition was indeed present in every participant and fMRI results showed that BOLD signal was higher in the SMA when unconscious control was needed. Conversely, the control ROI in the pre-SMA didn't reveal this specific pattern. These findings demonstrate in healthy participant that part of the medial frontal cortex (SMA) is involved in mediating rapid, unconscious and involuntary visuomotor control.

## **The neural correlates of visuospatial oculomotor and perceptual extrapolation**

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The human visual system must perform complex visuospatial extrapolations across space and time in order to extract shape and form from the optical projection of a complex visual environment characterized by occluded surfaces and moving objects. Even if this problem is collapsed to just 2 spatial dimensions, e.g. a judgement of stimulus collinearity, the mechanisms of spatial extrapolation remain opaque. In order to identify the neural correlates of this phenomenon, we used a factorial design functional magnetic resonance imaging study to scan 16 observers whilst they saccaded to, or judged the relative position of, a target defined by the extrapolated 'trajectory' of a pointer. As control tasks, observers made similar judgements and eye movements to explicit (dot) targets. Analyses focused on predefined regions of interest, defined using well documented functional localizers, including the lateral occipital cortex (LOC), which has been implicated in perceptual completion, as well cortical regions associated with the control of visuospatial attention: the frontal, parietal and supplementary eye fields (FEFs, PEFs, SEFs). Activation levels were greater during extrapolation in the LOC and FEFs only, which emerged as a main effect of target type (extrapolated > explicit); however, none of the regions examined exhibited an interaction between target type (extrapolated / explicit) and response type (oculomotor / perceptual), findings that were corroborated using whole-brain analyses. These data are consistent with a unitary mechanism of extrapolation for perceptual and motor responses, as well as premotor theories of attention, which emphasize the close association between covert and overt shifts of attention.

## **A critical test for decision models using MEG**

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In all current models of saccadic decision, alternative motor plans compete for action, with the activity favouring each of them accumulating until one eventually reaches some initiation threshold: speed is therefore what determines choice. Even before the target occurs, choice is thought to be modulated by variations in baseline activity: a higher baseline for left than right response should make the left wins more often. Crucially, according to all bottom-up decision models, whatever favours left responses in a choice should also speed them up. We used magnetoencephalography (MEG) to search for neural signature of speed and choice. Participants made saccades to onset targets (left or right), and on one third of the trials had to choose freely between two simultaneous targets (left and right). We split these bilateral trials according to the choice made (left versus right) and compared the MEG activity during the 200 ms before the stimulus onset. Similarly in single target trials, we compared the baseline MEG activity preceding fast and slow saccades. Although both choice and speed revealed significant signatures, these were very different. Importantly, the speed comparison showed bilateral, non-lateralised, occipital differences (similar for left and right saccades), suggesting that speed is modulated by an overall baseline unspecific to target location. The choice comparison revealed left frontal differences, suggesting that choice bias is modulated by a different baseline.

## **Electrophysiological correlates of perceptual suppression during dynamic ocular accommodation**

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Recently, we showed that fast ocular accommodation responses reduce contrast sensitivity to high spatial frequency information (Mucke, et al., 2008, *Current Biology* 18, R555-R556). Here, we recorded visual evoked potentials (VEPs) to gratings of low and high spatial frequencies to test the hypothesis that the perceptual suppression during dynamic ocular accommodation is associated with a reduction of activity in primary visual cortex. Three young subjects (aged 19-34 years) were presented with briefly appearing sinusoidal gratings of low (0.5c/deg) and high (9c/deg) spatial frequencies on a monitor at 1m distance. The experimental procedure compared VEP amplitudes recorded over primary visual cortex during dynamic and steady-state accommodation (1m – 33cm). VEP amplitudes for the high spatial frequency stimulus during dynamic accommodation responses were significantly (paired t-test,  $P < 0.001$ ) reduced by  $77 \pm 5\%$  around the time of peak accommodation velocity as compared to steady-state accommodation. VEP amplitudes elicited by the low spatial frequency grating were not significantly different between static and dynamic conditions. These results are in agreement with psychophysical data for accommodative suppression, and provide objective confirmation of its existence. Accommodative suppression, together with saccadic suppression, may be used to attenuate visual disturbances during oculomotor responses, and provide the observer with a clear and stable visual environment.

## **Variation of chromatic discrimination thresholds with luminance and state of chromatic adaptation**

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Colour discrimination is affected by both luminance level and the spectral composition of the adapting background. In this investigation we measured colour detection thresholds under conditions that isolate the use of colour signals (Barbur, 2003: Prog Brain Res, 144, 243-259). We examined specifically how the luminance level of the adapting background field and the state of chromatic adaptation of the eye affect both red/green and yellow/blue chromatic sensitivity. Thresholds were measured for seven background luminance levels (range: 0.3 to 31 cd/m<sup>2</sup>) and twelve different chromatic backgrounds. For each background luminance and state of chromatic adaptation we measured the chromatic discrimination threshold ellipses of four subjects, then computed the corresponding cone photoreceptor excitations. The results show that the cone excitations in the red, green, yellow and blue colour directions relate linearly to corresponding cone excitations produced by the background, over most of the range. A model was produced that predicts colour detection thresholds based on the spectral radiance of the adapting background and assumed spectral responsivities for cone photoreceptors in the eye. The discrimination ellipse parameters can be predicted from knowledge of background cone excitations levels and measured experimental data. The model predicts well the parameters of the measured ellipses with typical errors of less than 7% (over most of the range of light levels investigated). In conclusion, the colour discrimination model developed in this study can be used to predict colour discrimination threshold ellipses from a knowledge of the spectral radiance of the adapting background field.

## **Depth perception of the chromatic Mach card (CMC): Influence of colour gradients and outline**

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Relatively little is known about the effects of colour and the inter-reflections (mutual illumination) between surfaces in complex 3D scenes. It has been previously shown that object shape / depth perception can significantly influence colour perception through mutual illumination cues (Bloj, Kersten & Hurlbert, 1999, Nature 402(6764): 877-879). From this result a related question arises: can colour gradients due to surface shape and mutual illuminations affect three-dimensional shape and depth perception? In order to answer this we created similar CMC stimuli to those used by Bloj et. al. (1999) using the RADIANCE rendering system and displayed them in 42-bit colour. A wide range of card angles were produced resulting in a range of direct and mutual illumination colour gradients on the card surfaces. Observers viewed stimuli monocularly, through a small circular aperture to exclude other cues to depth, and were asked to estimate the angle of the card stimuli by adjusting the angle between two lines in a 'view-from-above' configuration, displayed on another monitor. Observers also performed matches to wire frame stimuli ('outline-cue-only' condition), and large Mach card stimuli that extended beyond the field of view ('gradient-cue-only' condition). Results indicate that the information in the colour shading of the CMC is a poor depth cue in isolation, and also ambiguous. However, the addition of the colour shading to the 'outline-cue-only' case increased the perception of depth and improved the accuracy of card angle estimates.

## **Characterising negative phototaxis in brown planaria**

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The planarian flatworm is one of the most primitive animals to have developed two forward-facing eyecups enabling it to register the presence and direction of light. Planaria instinctively avoid light exposure, often by swimming away from it (negative phototaxis). This behaviour has been used to study their ability to acquire and retain conditioned responses. Their visual responses have also been used as a behavioural correlate of successful CNS regeneration after head amputation. However, studies have typically used a very bright light stimulus, with the result that little is known about whether and how their phototactic behaviour is dependent on luminance intensity. Here we report preliminary data quantifying the limits of phototaxis in 25 brown planaria. We used the distance travelled at 2 and 4 minutes after the introduction of a light source as an index of phototactic behaviour over a range of luminance intensities (0.001-128 cd/m<sup>2</sup>). We found that planaria became negatively phototactic at luminances greater than around 0.002 cd/m<sup>2</sup>. Negative phototaxis increased as luminance intensity increased, with little change in responsivity above around 10 cd/m<sup>2</sup>, levels well below those typically employed to elicit photonegative behaviour. The luminance intensity-dependence of planarian negative phototaxis presented here has quantified the behavioural limits of planarian photonegativity. Additionally, it will provide a baseline against which to measure how planarian visual regeneration affects the precise nature and time-course of absolute sensitivity in planaria.

## **Quantitative evaluation of Ishihara and Rabkin colour deficiency tests using multispectral colour analysis**

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We have applied a multispectral colour analysis spectrally scanning Ishihara and Rabkin colour deficiency test book images by use of tuneable liquid crystal LC filters (Nuance II, CRI) for quantitative characterization of printed tests. Comparing to reflectance spectroscopy with excellent spectral resolution (Lee&Honson 2003, *Color Research and Application* 28, 267-276) multispectral analysis keeps information regarding spatial content of the tests. Images were taken in the range of 420 to 720nm with a 10nm step under halogen incandescent lamp illumination. 10nm steps allow to obtain at least 10 independent spectral inputs within the spectrum range of each of L, M and S cone colour sensitivity range. For both tests we obtain satisfactory alignment of colour pigments along the protan and deutan confusion lines in CIE xyz colour gamut. Spatially detailed inputs of L, M and S cone systems were estimated and processed according to colour opponency models using cone functions. Cross-correlation was performed between the test image M (protan), L (deutan) and (L - coeff M) inputs and the reference image containing only the pseudoisochromatic plate high contrast latent object. Thus the signal-to-noise value – a ratio of the cross-correlation peak value (at position when the latent object in reference image spatially coincides with the related object in the cone input chart) to the mean valley value (at position when objects on both images are distant each from other) characterizes the subject ability to recognise the corresponding latent object in the test plate. As example for an annulus in the 17th test plate (Rabkin) the ratio of signal/noise equals to 2.2 for L-cone input (deutans) and

1.3 for M-cone input (protans). Thus these values can be assigned to the pseudoisochromatic plates of different colour deficiency tests.

### **A surprising influence of retinal size on distance judgments**

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From simple geometry, the retinal projection of an object in the environment depends on both its physical size and its distance from the observer. Thus, given a sensed retinal size, the brain should know nothing about the distance of the object: the retinal measurement is compatible with an infinite number of combinations of physical sizes and distances. Here we report the seemingly surprising result that size influences observers' judgements of disparity-defined distance. Our stimuli consisted of large and small discs surrounded by a peripheral reference volume of textured cubes that provided a continuous reference frame to support reliable disparity estimates. Observers judged which of two, sequentially-presented stimuli was closer to them. Disparity-defined depth was varied parametrically to measure psychometric functions. Our results showed a mean shift in the PSE of approximately 5 cm, so that the large object was seen as closer than small objects when disparity-defined distance was the same. In contrast, there was no bias when presenting two objects of equal size. Varying the ratio of object sizes, and testing objects placed at different distances reveals that bias increases as (i) the viewing distance increases; and (ii) the ratio of the object sizes increases. We propose that the retinal size of an object is probabilistically related to its distance in the environment (i.e. objects with a small retinal size are generally farther away), and this appears to have an influence on distance estimations even when disparity information is available.

### **Amodal memorial completion: Masking novel pictorial shapes reveals a role for visual short-term memory in the completion of partially occluded objects**

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Amodal completion of partially occluded shapes is typically associated with early level perceptual processes or with reference to stored representations in longer-term visual memory. Two experiments are reported that isolate pictorial shape completion mechanisms to visual short-term memory. A same/different matching task required participants to say whether one of three memory shapes was the same as a single test shape after a 1 sec ISI. Memory shapes could either be partly hidden behind a square occluder, or else the same shapes were presented in a truncated format separated from the occluder by a small gap. Test shapes could also be complete or truncated, in the absence of an occluder. It was predicted that partially occluded shapes would facilitate completion, providing a better match for a complete rather than truncated test shape. The first experiment used a large stimulus set of novel shapes to preclude completion being undertaken with reference to longer-term representations. Completion was evident, supporting the view that longer-term access is not required for completion to take place. The second experiment masked the same memory displays at 90 ms, which has been shown to arrest perceptual completion in a visual search task (Rauschenberger, R., & Yantis, S., 2001, *Nature*, 410, 369 – 372). Despite this possibility, completion benefits were observed, presumably due to

brief maintenance in visual short-term memory. Together, these experiments identify a role for visual short-term memory in the completion of partially occluded pictorial shape, independent of early perceptual processes or longer-term visual representations.

### **The role of presentation order effects in adaptation based duration compression**

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The apparent duration of a subsecond 10Hz drifting grating is compressed following high temporal frequency adaptation (Johnston, Arnold and Nishida, 2006 *Current Biology*, 16(5)472-479) specifically at the location of the adaptor (Ayhan, Bruno, Nishida and Johnston, 2009 *Journal of Vision*, 9(11) 1-12). However, recently, Burr, Tozzi & Morrone (2007 *Nature Neuroscience*, 10(4) 423-425) reported spatially selective duration effects occur in a spatiotopic frame of reference and ascribed the retinotopic compression to a misrepresentation of speed, suggesting a high-level adaptation site. We first eliminated the influence of temporal frequency adaptation on speed judgements by temporally interleaving adaptors that were higher (20Hz) and lower (5Hz) than the test frequency (10Hz) and then investigated the effects of spatiotopic and retinotopic adaptation on duration judgements. Burr et al. always presented the first of the two test stimuli in the adapted region. It is known that the second of a pair of durations appears to be longer than the first (Jamieson and Petrusic, 1975 *Perception and Psychophysics*, 17, 197-202). In different conditions, we changed the presentation order of the two test stimuli presented in the adapted and unadapted positions. We found robust retinotopic compression. We found spatiotopic compression relative to the standard duration only when the first test stimulus was in the adapted region but this effect disappeared when adaptation conditions were compared to no-adaptation control conditions. The reason for this appears to be that for the controls the first interval also appears to be slightly but non-significantly compressed relative to the second interval.

### **Perceived motion from illusory brightening and spatial gradients**

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Previous research has shown that apparent motion is seen when local temporal ramp after-effects are viewed slightly out of register against a static display of light or dark regions (Anstis, 1990, *Perception*, 19, 301-306). Here we quantify the apparent motion produced by after-effects such as these. Observers adapted to a radial pattern of ramping lightening or darkening regions, which were replaced by static luminance gradients. Observers perceived clear rotational motion produced by the combination of a temporally ramping luminance after-effect and a static luminance gradient. We measured the perceived speed of illusory rotation by comparison against real rotation within a two alternative binary choice task. We found that the perceived speed of the rotation was very regularly related to the magnitude of the static luminance gradient. Shallower gradients resulted in faster rates of rotation. The rate of ramping during adaptation had no effect on the speed of perceived rotation. Our results point to a very precise integration of a perceptual brightening and a physical spatial luminance ramp in the computation of image motion.

## **Form information in the perception of biological motion heading**

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Encoding the direction that a person, predator or prey is facing and moving – their heading – might reasonably be assumed to be a capability of the specialised mechanisms proposed for the visual perception of biological motion (BM). Previous work has shown BM stimuli to be encoded by viewpoint dependent mechanisms; with judgements of stimulus heading susceptible to adaptation aftereffects. We compared the strength of the aftereffects produced by prolonged exposure to either static or moving, full-body, BM stimuli. This allowed us to assess the role of static form information in encoding the heading of BM stimuli independent from motion information. The perception of the heading of a moving BM stimulus was no more affected by adaptation to moving displays than adaptation to static displays. However, the perceived heading of static BM stimuli was significantly more affected by adaptation to static presentations than moving presentations. The difference in patterns of aftereffects between dynamic and static test stimuli suggests that static and dynamic information do not contribute equally to heading encoding. Static form appears to contribute to the encoding of heading of both dynamic and static BM stimuli to an extent not found for dynamic information. This supports the notion of the primacy of form in BM processing, at least in the encoding of heading direction. Interestingly, the aftereffect magnitude with the static test stimulus was found to be independent of the postural relationship between test and adaptor, leading us to propose that the mechanisms encoding static form generalise over the gait cycle.

## **Octopaminergic modulation of velocity coding in a blowfly optic flow-processing interneuron**

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Flight generates much higher optic flow velocities than walking in blowflies, and uses a tremendous amount of energy. We were interested to know how the visual encoding of velocity changes with the locomotor state of the animal when energy is in short supply. The biogenic amine octopamine (OA) is released during flight, affecting the metabolism and sensory processing. We investigated the effects of an OA agonist, chlordimeform, on the velocity coding of an optic flow-processing spiking neuron, the H2 cell. This cell is involved in gaze-stabilization responses to yaw rotations. Chlordimeform increased the velocity information of the cell's response to a white noise velocity stimulus by ~35%. We identified three factors that contributed to the increase in velocity information: i) the spontaneous activity was increased, increasing the negative signalling range of the cell ii) the initial, transient responses to stimuli increased and iii) the motion adaptation of responses was decreased. In contrast, the information per spike decreased by ~20%. These findings suggest that OA adapts the visual system to the higher stimulus bandwidth experienced during flight, but these changes require more energy because they use a larger number of spikes. The additional energy appears to be well-invested as impaired sensory coding would result in less efficient locomotor control and thus, overall, in a much greater waste of energy in the power-hungry flight motor.

## **Optimisation of speed perception in virtual environments by manipulation of the geometric field of view**

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In driving simulators and other virtual reality systems, visual speed is frequently underestimated leading to speed overproduction. This, in turn, may compromise the validity of human behaviour in these environments. The aim of this study was to investigate the feasibility of improving speed perception in a driving simulator by manipulating the Geometric Field Of View (GFOV). The GFOV, or internal FOV, is the FOV which the graphics generator is using to render its images. The effect of changing the GFOV, while holding the size of the FOV constant, is to minify (wide angle view) or magnify (telephoto view) the displayed image; with a  $GFOV > FOV$  the visible scene is larger than in the real world. 16 experienced drivers were asked to produce four target speeds (20, 30, 50, and 70mph) with the speedometer covered. Each target speed was produced under four GFOV/FOV ratios (.83:1, 1:1, 1.17:1, 1.33:1) twice whereby a GFOV/FOV ratio of 1:1 refers to the standard simulator configuration displaying geometrically correct optic flow. Results showed that in the standard configuration, visual speed was consistently underestimated resulting in speed overproduction of 10% on average. The smaller GFOV/FOV ratio of .83:1 led to even greater overproduction, whereas the larger GFOV/FOV ratios reduced the error in speed production. Based on a linear regression, the optimum GFOV/FOV ratio was determined at 1.22:1. It was concluded that manipulation of the GFOV provides a subtle technique to improve the perception and production of speed within simulated and virtual environments.

## **The train window illusion - people cannot locate the projection of an object on the surface of a mirror**

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Although flat mirrors are familiar in our everyday environment people make striking errors when asked about projections of objects on their glass surface. Many people incorrectly think that they could see their own reflection when standing to the side of a mirror, they overestimate the projected size of objects on mirrors and they falsely believe they could see more of themselves in a mirror if they moved away from it (Lawson, Bertamini & Liu, 2007, JEP:HPP, 943-954). These misunderstandings of mirror optics led to a new prediction: If people only perceive the virtual world through a mirror, not the reflection of objects projected onto the mirror surface then they should fail to spatially locate the projection of objects on mirrors. An observer and experimenter stood at opposite ends of a wide, rectangular, flat mirror. The observer was told to stick a face-sized card onto the mirror which would cover up the reflection of the experimenter's face from their viewpoint. Observers had to remember this location because the experimenter moved away before allowing them to respond. Cards were placed much too far from the observer, so too close to the experimenter. With repeated testing, errors reduced but were not eliminated. Children and adults were equally inaccurate, whilst females performed worse than males. However, if the experimenter stuck a card onto the mirror then removed it, observers could relocate this position. Locations on mirrors were thus remembered accurately only if they were specified physically; projections of objects were not perceived to be physically located on mirror surfaces.

## **Global motion processing is impaired in patients with Alzheimer's disease**

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Measures of coherence sensitivity are a valuable tool for probing global visual processing. They have revealed that global form and motion are processed by distinct extra-striate cortical systems, have different developmental trajectories, and show differential vulnerability in early development. In a variety of developmental disorders, motion coherence thresholds are more affected than form coherence thresholds, which has led to the concept of a 'dorsal stream vulnerability' in infancy and childhood. Here, we turn our attention to the other end of the developmental spectrum. While previous studies have found impairments in processing complex motion in later life, especially in neurodegenerative diseases, it is not yet clear whether such impairments are specific to motion or part of a general disruption of global visual processing. To address this, we have compared thresholds for identifying coherent rotational motion and coherent form in young adults (n=30, aged 18-24 years) with healthy older adults (n=32, 57-86 years) and patients with Alzheimer's disease (n=26, 58-90 years). Mean thresholds for the young group were 16.1% (form) and 18.3% (motion). Thresholds in the healthy older group were higher (form 18.1%; motion 19.4%), but not significantly so. The Alzheimer's group had the highest thresholds (form 23.4%; motion 31.9%), representing a significant elevation of motion, but not form, coherence thresholds relative to older controls'. These data indicate that there is a specific global motion processing deficit in patients with Alzheimer's disease. We conclude that dorsal stream vulnerability persists throughout the lifespan.

## **Visual gaze behaviour of adults and older adults at a pedestrian crossing**

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Adults over the age of 70 are over-represented in pedestrian injuries; in 2007 this age group accounted for over 33% of all pedestrian deaths despite making up only 11% of the population. Age-related decline in cognitive, perceptual and attentional abilities and skills are likely to contribute to the greater vulnerability of older adults. We have previously shown that children display significantly different gaze behaviours during the final three seconds before crossing a road compared with adults in a real-world road crossing task (Egan et al, 2008, *Perception*, 37, p149). Here, we examined the gaze behaviour of older adults during a similar task using a head-mounted, mobile eye-tracker. Eight young adult participants (aged  $24.1 \pm 4.5$  yrs) and ten older participants (aged  $70.7 \pm 4.1$  yrs) were asked to cross a road in a familiar location when they felt it was safe. In the final 3 s before crossing, older adults fixated significantly less on the road and vehicles (17% of total time) compared with younger adults (55%), and fixated considerably more in the central field (77%) compared with younger adults (43%). The central field was fixated when the scene camera had both the left and right of the pedestrian crossing in view. They also spent more time looking at the ground in front of them. These results suggest that older adults use a different strategy from younger adults when deciding to cross the road. Focussing more of their attention to the central field and to the ground may reflect older adults' increased concerns about tripping and falling, but may also place them at greater risk of pedestrian accidents.

## **Location, location, location: Examining spatial vision and spatial working memory in schizophrenia**

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Spatial working memory (SWM) dysfunction is a central finding in schizophrenia. In contrast the encoding of spatial locations appears to be intact (when speed of processing confounds are removed). These findings point to specific deficits in the maintenance of spatial information in schizophrenia, which may interfere with daily functioning. The present study examined the encoding and maintenance of spatial coordinates over three unfilled delays (0, 2, and 4 sec), and the influence of a vertical reference axis in maintaining spatial precision in 58 patients with schizophrenia and 50 healthy controls using the Visuo-Spatial Working Memory (VSWM) Test. Performance was significantly less accurate for both distance and direction responses at 2- and 4-sec delays in schizophrenia, but was not significantly different from controls at the 0 sec delay, i.e. immediately after target offset. Patients showed a particularly marked loss of accuracy between the 0- and 2 sec delays, indicating very rapid loss of spatial precision. Furthermore, schizophrenia participants exhibited significantly greater variability of responses to targets presented on the vertical axis of symmetry (compared to other target angles) than controls at the 2- and 4-sec delays, but not at the 0 sec delay. These data clearly show both impaired maintenance of spatial coordinates over time and difficulty using a vertical frame of reference in schizophrenia. The latter findings are discussed with reference to Dynamic Field Theory.

## **Affordance processing in Parkinson's disease**

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Situations in which visual information must be incorporated into an action plan often provoke dramatic changes to walking in Parkinson's disease (PD): viewing a line can increase step size, but stepping through a doorway can cause the patient to come to an involuntary standstill (Azulay, 2006, *J Neurol Sci*, 248: 192-5). We used doorways to test whether walking changes in PD result from an impairment in visual affordance processing. Explicit perception of the door's affordance did not differ between PD and healthy control (HC) groups, when they were asked to judge the critical width of door they could fit through without turning shoulders. A second task measured walking parameters as PD and HC participants passed through a doorway of variable width. Although a doorway affords passing through, it also affords some alteration of movement in order to avoid collision with the frame. We found that both PD and HC groups responded to this affordance by decreasing walking speed as doors became narrower. However, these changes were amplified in the PD group, where walking speed dramatically decreased while approaching the doorway. Speed reductions were not predicted by motor disability. These results suggest that PD causes exaggerated responses to the visual affordance information provided by the doors. This hypothesis offers a new explanation for gait disturbances in PD, and suggests a distinction between our explicit judgements of affordances and the motor responses they control.