INTERNATIONAL CONFERENCE ON LEVELS OF PERCEPTION

Centre for Vision Research
York University

June 19-23, 2001

PROGRAMME
AND
ABSTRACTS

The conference is sponsored by the Centre for Vision Research, Departments of Psychology and Computer Science, York University and the Human Performance Laboratory of the Centre for Research in Earth and Space Technology.

York International Conference on Levels of Perception

Centre for Vision Research
June 19-23, 2001

Tuesday, June 19

1:00–5:00	CRESTech HPAE Theme Workshop – Everyone Welcome – CLH 'L"
6:00-10:00	Buffet and Registration – Faculty Club, 166 South, Ross Building

Wednesday June 20 – CLH "L"

Perception of brightness symposium

9:00	Levels of brightness perception	F. Kingdom
9:45	Lightness perception and lightness illusions	T. Adelson
10:30	Coffee break and Posters	
11:45	Perception of surface lightness: The pattern of errors strongly constrains a model	A. Gilchrist
12:30	LUNCH	
1:45	Levels of perceptual delusion: The problem of post-attentive vision	J. Wolfe
2:30	Neural correlates of multistable perception	N. Logothetis
3:15	Coffee and laboratory tours	

Thursday June 21

9:00	How do bumblebees look at patterns?	T. Collett
9:45	Binocular rivalry: A fresh look	R. Blake
10:30	Coffee and Posters	
12:00	LUNCH	

Levels of perception symposium

1:00	Population coding for commands for smooth pursuit in area MT	S. Lisberger
1:45	Levels of motion perception	S. Anstis
2:30	Coffee break	
3:00	Theme presentation: levels of perception	I.P. Howard
6:00	**BANQUET – Pioneer Village**	

Friday June 22

Visual directions symposium

9:00	The laws of visual direction require a slight Y2K upgrade	H. Ono
9:45	Heading in the right direction?	B. Rogers
10:30	Coffee and Posters	
11:15	Knowledge of eye position: Tendon organs play an important role	M. Steinbach
12:00	LUNCH	

Vestibular symposium

1:00	Human visual orientation and spatial memory in weightlessness	C. Oman
1:45	Neural processing of ambiguous gravito-inertial cues	D. Merfeld
2:30	Coffee break	
3:00	Neural encoding of passive versus self-generated motion	K. Cullen
3:45	Visual-vestibular interactions in 3D	L. Harris
5:30	**SOCIAL EVENING – Ian Howard's House**	

Saturday June 23

Eye movements symposium

9:00	Population coding of vergence eye movements in cortical area MST	F. Miles
9:45	Plasticity of synergistic motor interactions that coordinate eye alignment	C. Schor
10:30	Coffee break	
11:00	The cerebellum and adaptive control of eye movements	D. Zee
11:45	Vergence and versional eye movements during translation	D. Angelaki
12:30	LUNCH	

LEVELS OF PERCEPTION
SPEAKERS ABSTRACTS

Lightness Perception and Lightness Illusions.
E. Adelson, Massachusetts Institute of Technology
Lightness illusions tend to be strongest when they effectively engage the mechanisms of lightness constancy. By studying the illusions, we can reveal the mechanisms. The well-known simultaneous contrast illusion is often explained with low-level filtering models, but it is now clear that such models are inadequate. Mid-level mechanisms, such as those involving contours, grouping, surfaces, transparency, etc., have profound influences on lightness perception. There is some evidence for high-level mechanisms as well. A full understanding of the illusions, and of normal lightness perception, will involve contributions from multiple levels of perception.

Vergence and Versional Eye Movements during Translation.
D. Angelaki, School of Medicine, Washington University, St. Louis
Linear disturbances of the head along directions close to current gaze result in distortions of the visual field that can be described as a radial expansion of the retinal image. Since the pattern of image distortion across the retina depends on both the direction of motion and current gaze direction, it can not be counteracted globally by a single eye movement. However, because visual acuity degrades from the fovea towards the retinal periphery, a useful strategy of minimizing image slip would be to care about maximal stability on the fovea at the expense of stability in the retinal periphery. Primates and humans have evolved highly specialized vestibular (otolith) mechanisms that are capable of eliciting short-latency (<10 ms) robust eye movements (Translational Vestibulo-Ocular Reflexes) that operate in concert with short-latency low-level visual mechanisms to optimize binocular gaze stability.
During translation, otolith afferents simply encode the direction of head movement, without a priori relation to gaze parameters. Thus, depending on the functional requirements, the oculomotor system could take advantage of these signals to stabilize any particular part of the visual field by generating the appropriate eye movement. It is often assumed that the transformation of vestibular otolith signals into oculomotor commands during such movements is based on the functional need to stabilize images on the fovea, often at the expense of peripheral vision. We tested this hypothesis in trained rhesus monkeys who were asked to maintain fixation on isovergence targets during movement along different heading directions. The movements of both eyes were compatible with the geometrical constraints of the foveal-stabilization hypothesis, although response gains were generally small (~0.5). Tuning to heading direction was most accurate for motion directions within *30* from straight-ahead, whereas for movements close to side-to-side, response tuning exhibited greater variability and directional errors. In contrast to under-compensatory version (conjugate) responses, the disjunctive part of the response (vergence) exhibited high, i.e. unity or higher than unity gains. The high gains of vergence eye movements might reflect a strategy to maintain binocular coordination despite the low gain of the version movements.

Levels of Motion Perception.
S. Anstis, University of California, San Diego
I shall present some new, or newish, illusions to show that motion signals in the early parts of the visual system are profoundly altered by stimulus luminance and contrast. I shall show that contrast affects:

1. Motion strength in Time till breakdown
2. Motion strength in Crossover motion
3. Speed in The Footsteps illusion
4. Direction in The Plaid illusion
5. Direction: Split dots

I shall then consider how it is that higher perceptual processes massage these neural motion signals into the perception of moving objects. Thus, moving line terminators help to solve the aperture problem. But these solutions are modified by stimulus contrast in the Plaid illusion and in the Peripheral-oblique illusion. In the Chopstick and Sliding Rings illusion, the motion of terminators propagates along straight lines and is blindly (and incorrectly) assigned to the motion of the central intersection. Finally, a new display of moving dots alternates perceptually between two radically different perceptual interpretations. Usually the Local percept (trees) is seen first, but the Global interpretation (forest) gradually takes over in the course of time.

Temporal Structure as a Binding Agent in Visual Grouping.

R. Blake, Vanderbilt University

Visual features are registered at multiple spatial scales by patterns of activity among neurons comprising distinct pathways and visual areas. How are these distributed neural representations conjoined over space and time to promote perception of coherent objects and events? Over the years a great deal of work has focused on spatial cues that promote grouping, dating back to the classic work of the Gestalt school and extending up to contemporary work on visual search and "pop-out." Not so much is known, however, about the role of temporal factors in grouping, although it has long been recognized that "common fate" -- a form of temporal structure -- effectively promotes grouping. For the last few years, my colleagues and I have sought to learn the extent to which features changing together over time tend to group together over space. Using a novel psychophysical procedure, we have discovered that correlated modulations over time in the contrast of separate components of complex images are easier to detect when those components form meaningful objects. Moreover, correlated contrast modulations can promote perceptual grouping of spatially distributed features. Finally, we have demonstrated that synchronized change among visual features can support figure/ground segmentation in the absence of any other grouping cues. These results lend credence to the notion that temporal and spatial coherence are jointly involved in visual grouping.

How do Bumblebees Look at Patterns?

T. Collett, B. Cartwright and D. Harland, University of Sussex, U.K.

Bees learn to approach sites that are defined by particular patterns. Hitherto an understanding of what bees learn about such patterns has been hampered by our lack of detailed knowledge of how they inspect patterns during learning and recognition. Using a tracking system developed by Brian Cartwright, we can now monitor on-line the 3-D position and heading direction of bumblebees as they fly towards a tiny sucrose feeder whose position is defined by computer generated patterns that can be transformed during the bee's approach. We hope to present results obtained using this system.

Signal Processing in Vestibular Nuclei:Dissociating Sensory, Motor, and Cognitive Influences.

K. Cullen, McGill University

The vestibular sensory apparatus and associated vestibular nuclei are generally thought to encode head velocity during our daily activities. Indeed, angular head-in-space velocity is detected by vestibular hair cells within the semicircular canals of the inner ear. In turn the afferent fibers of the vestibular nerve project directly to neurons in the vestibular nuclei which, in head-restrained animals, encode head velocity during passive whole-body rotation. However, in addition to direct inputs from vestibular afferents, the vestibular nuclei receive substantial projections from cortical, cerebellar, and other brainstem structures. Given this diversity of inputs the question arises: Are the responses of vestibular nuclei neuron to head velocity modified by these additional inputs during naturally occurring behaviors?

In this study, we focused on the signal processing carried out by two classes of neurons in the vestibular nuclei which receive direct input from the vestibular nerve: (1) position-vestibular-pause (PVP) neurons which mediate the vestibulo-ocular reflex (VOR), and (2) vestibular-only (VO) neurons which mediate the vestibulo-collic reflex (VCR). The eye and head movement commands generated by these vestibular reflexes can be counterproductive during certain voluntary behaviours. The VOR functions to stabilize the visual axis in space by producing a compensatory eye movement of equal and opposite amplitude to the movement of the head. Thus, the eye movement response produced by the VOR does not lead to appropriate eye movements when gaze is redirected using a combination of eye and head movements; an intact VOR would function to generate an eye movement command in the direction opposite to the intended shift in gaze. Similarly, the VCR functions to stabilize the head in space, via activation of the neck musculature, during head motion. Thus, the stabilization response produced by the VCR would be counterproductive when an animal's goal is to move its head on its body.

We found that neither the VOR nor VCR are hardwired reflexes, but rather pathways that are modulated in a behaviorally dependent manner. The head velocity signals carried by VOR interneurons (PVP neurons) are reduced when the goal is to redirect gaze in space. The head velocity signals carried by VCR interneurons (VO neurons) are reduced when the goal is to move the head relative to the body. To characterize the mechanisms that underlie this differential processing of vestibular inputs, PVP and VO neurons were tested during passive whole body rotation, passive rotation of the head-on-body, active head-on-body movements, as well as during a task in which a monkey actively 'drove' both its head and body together in space. We conclude that neither the activation of neck proprioceptive information nor the fact that a motion is self-generated produce differential processing of vestibular information. Rather the VOR and VCR pathways use efference copies of eye and neck movement commands, respectively, for the differential processing of vestibular information.

Perception of Surface Lightness: The Pattern of Errors Strongly Constrains a Model.

A. Gilchrist, Rutgers University

Visual perception of surface gray levels - called lightness - is remarkably accurate. Nevertheless, errors in lightness perception are widespread, if typically small. These errors are systematic, not random. Thus they must constitute a signature of the visual software used to compute lightness values. Lightness errors fall into two broad categories. (1) Illumination-dependent errors include traditional failures of lightness constancy. The fundamental form is that surfaces in higher illumination tend to appear too light while those in lower illumination tend to appear too dark. (2) Background-dependent errors are best represented by simultaneous lightness contrast. A gray target on a white background tends to appear too dark while that on a black background tends to appear too light. I will describe an anchoring model of lightness that was driven by the attempt to account for both classes of error. The model has been very successfully applied to the entire range of errors reported in the extensive literature on lightness perception.

Visual-Vestibular Interactions in 3D.

L. R. Harris, York University

Eye movements evoked in response to passive head movement are often treated as resulting from a closed-loop feedback system for minimizing gaze error and retinal slip. In this model, when the feedback loop is temporarily opened by darkness, the goal remains the same and learning processes (vestibulo-ocular plasticity) keep the eyes moving in such a way as to simulate the closed loop activity. I suggest that such eye movements are not minimizing retinal slip but instead tending to keep the eyes stable in space. Normally these goals require similar eye movements. Here I dissociate the goals of retinal slip maintenance and ocular stability by using vision to reduce the vestibulo-ocular reflex response around one axis in humans and cats and show that, surprisingly, ocular stability in space rather than retinal slip reduction might be the more significant goal of the vestibulo-ocular system.

Levels of Visual Processing for Stereopsis and Motion.

I. P. Howard, York University

Signals arising from stereoscopic depth and signals arising from visual motion interact for various purposes, including the control of vergence, the control of pursuit eye movements, perception of relative motion and self motion, perception of slant and inclination, and perception of 3-D shape. These interactions occur at several levels in the nervous system, even when serving the same purpose. I will review my own work and the work of others that illustrates these interactions.

Levels of Brightness Perception.

F. A. Kingdom, McGill University

From the time of Hering and Helmholtz controversy has surrounded the issue of whether brightness perception implicates low-level mechanisms that process contrast, or high-level mechanisms concerned with interpreting the pattern of illumination and reflectance in the scene. I consider the evidence for both low- and high-level determinants of brightness perception, and interpret this evidence in terms of two different types of lightness constancy mechanism.

Population Coding and Decoding of Commands for Smooth Pursuit Eye Movement in Area MT.

S. G. Lisberger, Howard Hughes Medical Institute and University of California, San Francisco

Smooth pursuit eye movements depend on visual motion inputs that arise heavily from extrastriate visual area MT. Because neurons in MT are tuned for both the direction and speed of image motion, individual neurons do not provide unambiguous guidance for pursuit: commands for eye motion must result from decoding the population response in MT. We have used apparent motion to determine the neural computation that does this decoding. As apparent motion was degraded by increasing the temporal and spatial separation between target flashes, we observed an illusion of increased target speed in both pursuit and perception. Recordings from MT neurons in awake monkeys revealed that the neural basis for the illusion was evident only in the population response. When the responses of many neurons to each stimulus were plotted as a function of the preferred speed of each neuron, apparent motion caused the peak of the population response to shift toward higher preferred speeds. Computational analysis revealed that the population response recorded in MT could be decoded to reproduce the effect of apparent motion on pursuit if we computed the weighted average of an opponent motion signal. Averaging was weighted according to each neuron's preferred speed, and was performed after subtracting the responses of neurons with opposite preferred directions.

Neural Correlates of Multistable Perception.

N.K. Logothetis, Max Planck Institute

Figures that may be seen in more than one way are invaluable tools for the study of neural basis of visual awareness. For such stimuli permit the dissociation of the neural responses that underlie what we perceive at any given time from those forming the sensory representation of a visual pattern. To study the former type of responses monkeys were subjected to binocular rivalry and the response of neurons in a number of different visual areas was studied while the animals reported their alternating percepts by pulling levers. Perception-related modulations of neural activity were found to occur to different extents in different cortical visual areas. The cells that were affected by suppression were almost exclusively binocular, and their proportion was found to increase in the higher processing stages of the visual system. The strongest correlations between neural activity and perception were observed in the visual areas of the temporal lobe. Striking was the great number of neurons in the early visual areas that remained active during the perceptual suppression of the stimulus, a finding suggesting that conscious visual perception may be mediated by only a subset of the cells exhibiting stimulus selective responses. These physiological findings together with a number of recent psychophysical studies, offer a new explanation of the phenomenon of binocular rivalry. Indeed rivalry has long been considered to be closely linked to binocular fusion and stereopsis, and the sequences of dominance and suppression have been viewed as the result of competition between the two monocular channels. The physiological data presented here are incompatible with this interpretation. Rather than reflecting interocular competition, the rivalry is most likely between the two different central neural representations generated by the dichoptically presented stimuli. The mechanisms of rivalry are probably the same with or very similar to those underlying multi-stable perception in general, and further physiological studies may reveal a great deal about the neural mechanisms of our perceptual organization.

The Influence of Rotational Cues on the Neural Processing of Tilt and Translation.

D. Merfeld, Massachusetts Eye and Ear Infirmary Harvard and Massachusetts Institute of Technology

All graviceptors, including the otolith organs, measure gravito-inertial force, which is the vector sum of inertial force due to linear acceleration and gravitational force. Therefore, all graviceptor measurements are ambiguous in that changes can indicate tilt with respect to gravity or translation due to linear acceleration. This ambiguity can only be resolved by utilizing other sensory information. For example, it has been shown that rotational cues, provided via vision and the semicircular canals, influence the neural processing of tilt. Similarly, it has been shown that rotational cues influence the neural processing of translation. The evidence for these sensory interactions can be found both in perceptual responses and eye movement recordings. The evidence, recent and not-so-recent, demonstrating the importance of rotational cues on the neural processing of tilt and translation will be reviewed and discussed.

Population Coding of Vergence Eye Movements in Cortical Area MST.

F. A. Miles, A. Takemura, K. Kawano and C. Quaia, National Institute of Health

Disparity steps applied to large textured patterns elicit vergence eye movements at ultra-short latencies (<60 ms in monkeys, <80 ms in humans). We will present data from lesions and single unit recordings in monkeys suggesting that these responses are mediated at least in part by neurons in cortical area MST. Comparatively few of these neurons had disparity tuning curves that resembled the tuning curves for vergence and, when sorted using a fuzzy clustering algorithm, the curves fell into four major groups, corresponding roughly to classes of disparity-selective neurons described at earlier stages of the visual cortex. Thus, qualitatively at least, most individual tuning curves resembled those at earlier, overtly sensory, stages. However, when these curves were simply summed together they fitted the tuning curves for the vergence responses very closely, even reproducing idiosyncratic differences between animals. Additional analyses of the spike trains elicited by disparity steps revealed considerable variation across cells in the latency, amplitude and time course of the changes in discharge rate. When all of the spike trains elicited by a given disparity step were summed together to give an average discharge profile for the whole population of cells, many were rather noisy, but others that were less so, matched the temporal profile of the motor response, vergence velocity, quite well. Based on these findings, we hypothesize that the disparity-sensitive cells in MST each encode only some aspect(s) of the sensory input, but that the population of cells as a whole encodes the complete motor output (vergence velocity).

Human Visual Orientation and Spatial Memory in Weightlessness.

C. M. Oman, Massachusetts Institute of Technology

An astronaut's sense of self-orientation is relatively labile, since the gravitational down cues provided by gravity are absent and visual cues to orientation can be ambiguous. For example, when working upside down, or viewing another crew-member working that way, astronauts frequently experience visual reorientation illusions (VRIs; Oman et al 1986, EBR 64:316) - sudden shifts in perceived self-orientation which can trigger attacks of space motion sickness and cause reaching and navigational errors. VRIs sometimes occur in daily life on earth (e.g. when emerging from a subway station), but the reorientation is normally about an axis aligned with gravity. However, using compelling visual scenes - such as provided by Ian Howard's tumbling room, or virtual reality equivalents - it is possible to create VRIs about almost any axis even in 1-g, and to study how visual cues determine spatial orientation and spatial memory. This paper reviews the decade of collaborative research conducted by our team from York and MIT, (and more recently including Dartmouth and Wright State) including animal head direction cell experiments in parabolic flight, and human perceptual experiments conducted aboard the 1998 Neurolab shuttle mission.

The Laws of Visual Direction Require a Slight Y2K Upgrade.

H. Ono, York University

Although the existing laws of visual direction have adequately explained most of the experimental stimuli considered in the past, our recent work, as well as that of other researchers, indicates that there are experimental stimulus situations for which the laws are inadequate. I will discuss the historical work as well as survey and review the recent work on visual direction and attempt to modify the existing laws so that the new findings are explainable. This modification will entail incorporating the idea that the visual system attempts to create a unified visual picture from two disparate inputs, one from each eye.

Heading in the Right Direction?

B. Rogers, Oxford University

Analyses of the optic flow field from J.J. Gibson onwards have shown that there is information to specify the *point of impact* in the visual scene if locomotion were to continue along the same path. Locomotion direction can be modified if there is a discrepancy between the actual and desired points of impact. Use of these optic flow characteristics would be highly desirable if there are forces, such as side winds or cross currents, which result in there being a difference between the observer's direction of heading (with respect to a body or vehicle axis) and their actual locomotor path. If there are no such forces, observers could use the *visual direction* of the intended target (with respect to a body or vehicle axis) to alter their locomotor direction either directly, by their changing walking or swimming direction, or more indirectly by turning a steering wheel. Studies by Rushton et al (1998) and Rogers and Dalton (1999) suggest that observers rely more on visual direction than optic flow. Providing richer optic flow information through motion parallax or the addition of road markings produces locomotor paths which are more consistent with the use of optic flow information but these results are also consistent with the greater salience of static (rather than dynamic) *alignment cues* in these situations. Thus it remains to be shown if optic flow *per se* plays any role in the control of locomotor direction.

Rushton, SK, Harris, JM, Lloyd, MR and Wann, JP (1998) "Guidance of locomotion on foot uses perceived target location rather than optic flow" *Current Biology* **8**, 1191-94.

Rogers, BJ and Dalton, C (1999) "The role of (i) perceived direction and (ii) optic flow in the control of locomotion and for estimating the point of impact" *Investigative Ophthalmology and Visual Science*, **40** S764.

Plasticity of Synergistic Motor Interactions that Coordinate Binocular Eye Alignment.

C. Schor, Berkeley School of Optometry

The oculomotor system facilitates binocular alignment of foveal images with three degrees of freedom by coupling vergence in three dimensions with distance and direction of gaze. Horizontal alignment of the foveal images is controlled by convergence that is scaled inversely by viewing distance and by a coupling with accommodation. Vertical alignment of foveal images of unequal vertical size, arising in asymmetric convergence, is controlled by vertical vergence that, depending on coordinate system, is scaled by convergence and horizontal gaze eccentricity. Torsional alignment of the monocular planes of regard is controlled by cyclovergence that is scaled by combinations of convergence and vertical eye position. The latter vergence-dependent changes in the orientation of Listing's plane have been referred to as a binocular extension of Listing's law. Cn these couplings be modified? Plasticity has been demonstrated previously for two of the three dimensions of vergence (horizontal and vertical). The current study demonstrates that convergence-dependent deviations of torsion from Listing's plane can be adapted to either exaggerate or to reverse the cyclovergence that normally aligns the monocular planes of regard with the visual plane during gaze elevation in symmetrical convergence. The adaptability of vertical vergence and cyclovergence demonstrates a neural mechanism that, in conjunction with the passive forces determined by biomechanical properties of the orbit, could play an active role in implementing Listing's extended law and provide a means for calibrating binocular eye alignment in three dimensions.

How might convergence-coupled modifications of vertical and torsional binocular alignment be implemented? Vertical vergence and cyclovergence could be adapted independently by a central process that couples the innervation of the vertical recti and obliques with specific combinations of convergence and versional-eye position. Alternatively, there could be an associated adaptation of vertical vergence and cyclovergence mediated by a central process that couples the innervation of the vertical recti and obliques with convergence, without explicit regard to versional eye position. In the latter case, orbital mechanics would constrain vertical and cyclovergence to vary with direction of gaze. Indeed, normal convergence-dependent variations of vertical vergence and cyclovergence can be simulated with a biomechanical model (Orbittm) by scaling the gain of vertical recti and obliques with convergence. This simple convergence-related gain change transforms the innervation pattern appropriate for far viewing distances into ones consistent with the extended Listing's law for torsion and also for vertical vergence in asymmetric vergence.

Knowledge of Eye Position: Tendon Organs Play an Important Role.

M. Steinbach, York University

Studies of strabismus patients tested on an open-loop pointing task, before and after surgery on their eye muscles, have led to two important conclusions: first that there can be a proprioceptive (inflow) source of eye position information and second, that musculo-tendinous proprioceptors (palisade endings) are probably playing a key role in supplying this information. I will review our behavioural and anatomical data that support these claims, and describe some of their theoretical and behavioural consequences.

Levels of Perceptual Delusion: The Problem of Post-attentive Vision.

J. M. Wolfe, Harvard University

What does it take to recognize an object? First, an object-like bundle of features needs to be segmented out of the visual scene. At this stage, a pre-attentive proto-object may have a loose collection of attributes like red, green, brown, round, vertical, and so forth. Second, attention must be directed to that bundle in order to accurately bind the features together. Binding allows the visual system to explicitly represent the fact that the red bit is also the round bit and that the green bit is smaller and more numerous. Third, the bound visual representation must be linked to a representation in memory. With this link, the bound features can be recognized as, perhaps, an apple tree. With continued exposure to a scene, the observer seems to experience a world containing several recognized objects at the same time. However, the data from visual search experiments suggest that only
one object is attended at any one time and that only the attended object is actually recognized. If the data are to be believed, an object that has been attended, bound, and linked to a representation in memory reverts to an unrecognized, unbound bundle of features when attention is redeployed to another object. This talk will attempt to reconcile these data with the useful delusion that we are perceiving a world filled with simultaneously recognized objects.

Three-Axis Approaches to Ocular Motor Control: A Role for the Cerebellum.

D. Zee, Johns Hopkins University

In animals with fovea, where the eyes are pointing determines what we will see. The precise orientation of the eyes around its line of sight, i.e., torsional eye position, is less critical for object identification, though perception of the shape, orientation and three-dimensional location of an object does depend upon eye torsion. Important are both the relative torsional alignment between the two eyes (e.g., for perception of slant) and the torsional orientation of both eyes in the head (e.g., for compensation for head rotations). Here we will review some new observations about control of eye torsion including adaptive control of torsional alignment, mechanisms that assure that the eyes rotate around the correct three-dimensional axis in response to visual and vestibular stimuli, and the role of the cerebellum in control of eye torsion.

LEVELS OF PERCEPTION
POSTER ABSTRACTS

Factors Affecting the Discrimination and Perceived Attitude of Multiple Transparent Surfaces

J. Amati and J. H. Elder, Centre for Vision Research, York University, Toronto, ON

In the natural world, each region of an image typically projects from a unique surface in the scene. This rule is broken when surfaces are transparent, as for water or glass. Surfaces with many gaps or holes, either at a fine scale (sheer cloth) or at a course scale (a wire fence), approximate transparency in that patches of multiple surfaces may be interleaved in the image in a complex way. While the necessary conditions for perceived transparency are well studied, little is known about how the visual system extracts the 3D geometry of these surfaces. In this study, we examine visual perception of 3-D attitude from texture for multiple, overlaid transparent surfaces. In each trial, observers monocularly viewed transparent planar surfaces rendered in perspective within a circular window of diameter 45 degrees. Two surfaces were painted with different textures and rendered at identical slants but systematically different tilts. Subjects were asked to: i) indicate whether 1 or 2 different planar surfaces were perceived, and ii) use a mouse-controlled visual gauge figure to indicate the attitude of the perceived surface(s).

Data were partitioned into two groups based on whether 1 or 2 surfaces were perceived. The latter group was used to estimate statistical distributions of estimated tilt error for each textured surface in the presence of each of the other textured surfaces. Based on these data, a statistical model was constructed to predict, as a function of the surface textures and the tilt difference between the 2 surfaces, i) the incidence with which 1 vs. 2 surfaces are perceived, and ii) the mean and variance of the tilt estimates for those cases in which a single fused surface is perceived. The fusion and discrimination of multiple transparent surfaces can be understood within the framework of statistical decision theory, based on estimated uncertainties in the attitude judgement of the individual surfaces.

Afferent Delays and the Mislocalization of Perisaccadic Stimuli

L. Boucher, H. C. Hughes and J. M. Groh, Dept of Psych and Brain Sciences, Dartmouth College, Hanover, NH

Determining the precise moment a visual stimulus appears is difficult because visual response latencies vary. This temporal uncertainty could cause localization errors to brief visual targets presented before and during eye movements if the oculomotor system cannot determine the position of the eye at the time the stimulus appeared. We investigated the effect of varying neural processing time on localization accuracy for perisaccadic visual targets that differed in luminance. Although systematic errors in localization were observed, the effect of luminance was surprisingly small. We explore several hypotheses that may explain why processing delays are not more disruptive to localization performance.

By Stimulating the Superior Colliculus

A.G. Constantin, H. Wang, E. M. Klier and J. D. Crawford, Centre for Vision, York University, Toronto, ON

It is currently unclear where and how the common gaze command is allocated into separate commands for eye and head movements. Our goal was to determine if the neural mechanisms for adaptative eye-head coordination during gaze shifts take place downstream from the Superior Colliculus (SC). 3-D eye and head orientations were recorded in 2 monkeys, using search coils. Monkeys were trained to perform a gaze search pattern while looking through a 10 degrees aperture in opaque, head-fixed goggles. This training produced context-dependent alterations in eye-head coordination, including relatively large head contributions and converging eye movements (toward the aperture). The SC was then electrically stimulated (20 or 50 microA, 300 Hz, 200 ms), with and without goggles. To date, 23 electrode tracks have been made in the SC region of animal 2. Results from putative SC sites agree with previous results from animal 1 (14 SC sites), as follows: (1) final eye-in-head positions converged more toward the aperture site with the goggles, compared to control. This does not appear to be a trivial initial-position effect, because outlying positions were also drawn toward the aperture. (2) However, there was no evidence for an increase in head movement amplitude during SC stimulation with the goggles. Based on these findings, we conclude that some aspects of adaptive eye-head coordination may be implemented downstream from the Superior Colliculus and that the increased contribution of the head is probably provided by cortical commands.

Time-to-Collision in the Mongolian Gerbil

R. Dolomount and C.G. Ellard, University of Waterloo, Waterloo, ON

When Mongolian gerbils are trained to run down a dark corridor to a visual target, kinematic analyses show that their velocity profiles are influenced by the dynamic properties of the target. Increasing or decreasing target size in synchrony with the animals' movements lead to early or late braking, respectively. We have also found that there is a strong negative correlation between peak running velocity and time of braking. Such a correlation has been taken as evidence for the use of tau in the control of locomotion. In previous studies, the variable that produces the smallest coefficient of variation has been argued to be the one controlling action at that moment. We found that the coefficients of variation for tau were smaller just before the onset of braking than they were after braking had begun. This suggests that tau may exert its strongest influence on performance up to and including the onset of braking. We have also found a linear relationship between the rate at which the target expands or contracts and the magnitude of retarded or accelerated braking. These results suggest that animals use tau to control locomotion but they use it in conjunction with other variables to estimate time-to-collision.

Evidence for a role of Rapid Temporal Coherence in Segmenting Overlapping Patterns

S. Suzuki and M. Grabowecky, Department of Psychology, Northwestern University, USA

Objects overlap in the visual world, and the ability to segment these overlapping patterns into coherent objects is critical. We examined the potential role of temporal coherence in image segmentation. Using rapidly alternating displays we found that stable grouping could occur within overlapping patterns on the basis of coherent temporal phase, resulting in sustained image segmentation by depth segregation, slow orientation rivalry, and apparent shimmer on one surface. Some of these segmentation mechanisms can utilize temporal phase differences as small as 20-40 ms (beyond temporal resolution of individual frames). Our results support the idea that sustained temporal coherence of neural responses in the magno pathway plays a role in parsing overlapping patterns.

Measuring Diplopia Thresholds Using Howard's "Same Contrast Polarity" Stimuli

P. Grove, Centre for Vision Research, York University, Toronto, ON

As a tribute to Ian Howard, I explored his observation that all experiments measuring the limits of binocular fusion, "employed lines, bars, or dots... the diplopia threshold for these stimuli is therefore a threshold for diplopia between contours of opposite luminance polarity" (Howard and Rogers, 1995, p. 325). To investigate the diplopia threshold for contours of the same polarity, Howard suggests stimuli consisting of extended horizontal bars. I measured and compared diplopia thresholds for extended bars and thin vertical lines. Diplopia thresholds for the extended horizontal bars were significantly higher than for the thin vertical bars. Higher diplopia thresholds for contours of the same luminance polarity may account for the rare occurrence of diplopia outside the laboratory, since our visual world is composed of more surfaces than isolated lines, bars, or dots.

Disparity Tuning for Cyclopean Shape Discrimination is Broad Band

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Previous psychophysical studies have provided evidence that cyclopean shape discrimination for crossed and uncrossed disparities is processed independently. The present study extends this by examining adaptation effects for cyclopean shape discrimination at several crossed and uncrossed disparities to determine the disparity tuning for cyclopean shape discrimination. Random dot patterns were used to create rectangles defined exclusively by binocular disparity. After adapting to an elongated disparity-defined (DD) rectangle for 5 min, subjects were presented with one of a series of DD test rectangles for 1500 ms and asked to determine whether the rectangle was more elongated horizontally or vertically (method of single stimuli). Following each test rectangle, a 7 sec refresh stimulus was presented to maintain a state of adaptation. Convergence angle was monitored with nonius lines. Subjects were not given feedback regarding correct responses. In the first condition, subjects were asked to adapt to a rectangle at 5 min crossed disparity and tested using rectangles at a variety of crossed disparities. In the second condition, subjects adapted to a rectangle at 5 min uncrossed disparity and tested with rectangles at a variety of crossed and uncrossed disparities.

When disparity of test and adapt rectangle were equal, adaptation effects were similar to those obtained with luminance-defined rectangles. In addition, similar effects were observed when adapt and test rectangle were of the same type (i.e. crossed vs. uncrossed) but of different disparity strength. These effects were markedly attenuated when adapting to one type of disparity and testing with the other. When adapting and testing across disparity type, changes in disparity strength near zero disparity produced no effect, thus providing no evidence for a separate "zero-tuned" mechanism. Adaptation effects demonstrate consistency with broad band disparity tuning for cyclopean shape discrimination. These results provide additional evidence consistent with the hypothesized existence of a neural mechanism sensitive to the aspect ratio of cyclopean stimuli, and with the hypothesis that this mechanism consists of separate "near" and "far" pools of neurons.

The Visuomotor Transformation for Head-Free Pointing Accounts for Differences in the Centres of Eye, Head, and Arm Rotation

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When we point to remembered targets, the brain computes the line in space between the eye and the target, and then brings the fingertip into alignment with the target (e.g. Henriques et al., Exp Brain Res, 2000). However, when the head moves eccentrically from straight ahead, the line in space between the eye and target changes because the centre of rotation of the eye translates with respect to the centre of the rotation of the arm. In order to compensate, the brain must be "aware" of this geometry and take head position into account. To test this, human subjects pointed to a briefly flashed center LED, when their head, eye, or both were maintained along 9 horizontally eccentric directions (40° left to 40° right at 10° intervals) in the dark. Subjects either fixated the target while repositioning the head with a laser; repositioned both the eye and head (natural eye-head combinations, and laser-guided alignment of the eye and head), or repositioned only the eye. Closed-loop control pointing responses were also recorded. Orientation of the eye, head and arm were recorded using search coils during the experiment, while geometry between the eye, head and arm were measured prior to that. To date, we have run four subjects. These preliminary results suggest that pointing responses compensate for the translation occurring between the centers of the rotation of the eye and the arm when gaze is on target but the head is deviated. However, pointing accuracy sometimes decreased when both the head and gaze were deviated from the central target. This suggests that when gazing directly at visual targets, the system is calibrated to derive the translational position of the eye from head orientation information.

Illusory Line-Motion in Depth Dimension and Facilitation of Visual Information Processing in 3D Space

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A line that is presented shortly after a cue stimulus is perceived to be drawn from the side that is nearer to the cue. This illusory motion is called "line-motion", and is supposed to be produced by facilitation of visual information processing at the locus of attention (Hikosaka et al., 1993 Vision Research). I examined how the closeness between the cue and line in retinal image (2D dimension) and that in depth plane (3D dimension) determines the direction of the illusory line-motion. I found that there is a tendency that observers perceived the line is drawn from the nearer side to farther side, and that the 3D closeness determined the direction of the motion more frequently for the consistent condition than for inconsistent condition. These results suggest that the facilitation of visual information processing increases with the increase of the magnitude of the cue depth, and that the facilitation is larger for near space than for far space.

Judging Visual Angles With Pictures: Deviations Toward Metric Size Increase With Separation of Targets

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In a series of studies, we have used real objects as targets, and asked subjects to judge their relative visual angle, from a fixed vantage point. Subjects are relatively accurate for judgments of targets that are adjacent in direction. But major errors arise as targets separate. The error is in the direction of the relative height ratio. Here we tested with pictorial targets. Similar errors arose. This error is one key reason why drawing pictures of objects in a scene is very difficult, and artists use a third, standard object of comparison when drawing. The El Greco fallacy is not a complete finesse of the error because we view pictures from variable vantage points, and we plan to use height ratios when drawing objects.

Extraction of Binocular Disparity From Retinal, Spatial and Object Frames

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The object of this study was to investigate whether it is possible to perform binocular matching and extract binocular disparity from images presented at non-corresponding positions on retinal. Right and left images of a stereogram were briefly and successively presented with a temporal interval and a spatial offset during pursuit eye movement or fixation. The combination of the interval, offset and state of eye movement could produce situations in which the right and left images were presented at corresponding positions on one frame but at non-corresponding positions on the other frames. The results showed that extraction of binocular disparity mainly depends on retinal frame, but it might also depend on the other frames.

Eyes 'n' Ears: A System for Attentive Teleconferencing

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The multiple speaker teleconferencing systems currently available typically focus on a single speaker and provide limited, if any, automatic speaker tracking technologies. However, in a multiple-speaker setting, speakers must be localized and tracked in both the video and audio domains. Although many fast and portable video trackers capable of locating and tracking humans exist, they employ conventional cameras thereby providing a narrow field of view. In addition, audio localization systems are expensive, non-portable and computationally intensive. Furthermore, there have been very few attempts to combine both audio and visual systems. This work investigates the development of a simple, economical and compact teleconferencing system utilizing both audio and video cues. An omni-directional video sensor is used to provide a view of the entire visual hemisphere thereby providing multiple dynamic views of all participants. Using a statistical color model and simple geometrical properties, the location of each participant's face is determined and provided to the audio system as a possible direction to a sound source. Beam-forming with a small, compact microphone array allows the audio system to detect and focus on the speech of each participant. The results of experiments conducted in normal, reverberant environments indicate the effectiveness of the system.

Eye Position Dependence of Ocular dominance in a reaching/Grasping Task

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It is generally assumed that ocular dominance is a stable property of one eye (Walls, A.M.A. Arch. Opth. 1951; Porac and Coren, Psych. Bull. 1976). However, the visual system might want to switch dominance to the eye with the better field of view when looking far left or right. To test this theory, 13 head-fixed subjects looked at randomly presented targets at 10° intervals from 50° left to 50° right. Subjects were required to manually grasp a ring surrounding the target (10 repetitions each), maintain gaze on the target, and then align the ring with the viewing eye as a measure of ocular dominance. Most subjects showed a reversal of dominance when gaze was fixated in the direction of the "non-dominant" eye. On average, the crossover point (where left-right dominance was equally probable) was only 11° in the "non-dominant" direction, and was always within the binocular range. Switching was not perfectly discrete but was complete over an average range of 26°. This study suggests that ocular dominance can change as a function of eye position to optimize the monocular visual reference point, and suggests that cortical eye position signals might be useful -- in addition to spatial computations -- for the gating of monocular visual information.

Eye Tracking Evidence of Spatial Indexing in Infants: Binding Multimodal Properties by Location

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Converging evidence suggests that spatial indices are employed to track objects, link incompatible sensorimotor and cognitive codes, and organize working memory. Recent eye tracking work presented adults with auditory semantic facts that co-occurred with visual events in four locations (Richardson & Spivey, 2000). When answering a question about one of the facts, subjects made saccades to the (now empty) region of space associated with that fact. Although location was task-irrelevant, adults tagged auditory information with a spatial index. In the present study we asked whether spatial indexing is functional in infants. Six-month-olds were shown six trials with two moving objects in specific locations, one at a time, each with a unique sound. The infants then heard one of the two sounds with no object present, and their eye movements were recorded. The infants tended to make saccades back to the location previously associated with that sound ($p < .04$), providing evidence for early emergence of the spatial indexing mechanism.

Three-dimensional Eye-head Coordination is Implemented Downstream From the Superior Colliculus

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Our previous study showed that the superior colliculus (SC) encodes two-dimensional gaze commands in oculocentric coordinates (*Nature Neuroscience*, June 2001). Thus, the three-dimensional aspects of eye/head kinematics should be implemented downstream. We examined eye/head movements evoked by head-free stimulations of the SC (88 sites were stimulated with pulse trains of 200 ms.). A 3-D analysis showed that the stimulation-induced movements were nearly identical to normal, head-free movements. The head obeyed Donders' Law, while the eye-in-head obeyed Listing's Law. To accomplish the latter, the eye-in-head saccades had to produce varying amounts of torsion that anticipated and compensated for equal-but-opposite torsional violations produced by VOR slow-phases. This suggests that the eye-to-head reference frame transformation occurs downstream from the SC.

Perceptual Space Coded in Body Coordinates

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Is perceptual space coded in the reference frame of the eye, head, body or space? We moved eyes with respect to head, the head with respect to a stationary body, the body with respect to a stationary head and both the head and body with respect to space to separate the head, body and space frames. Auditory (60L-60R) targets were presented when eyes, head and body were pointing straight ahead. Subjects adjusted the interaural intensity ratio of 1kHz, 15ms sound bursts presented through headphones to indicate the remembered position of these targets relative to the head after actively moving their head, body (with head restrained) or both head and body together.

There was a significant shift in localization with head position (0.023db/deg, equivalent to approx 2.3 deg/deg head rotation in the direction of head eccentricity, $p<0.0001$). A similar effect was also observed when the head was fixed in space while body position was changed. Moving the eyes with respect to the head, and body and head together had no effect on auditory localization judgments. Perceptual localization requires head-on-body, but not body-in-space information indicating the use of a body reference frame.

Motion Transparency: Optical flow or Optical Snow?

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Perceptual studies of motion processing in humans and monkeys often make use of stimuli composed of moving dot patterns, gratings, or blurred noise. One interesting issue is how the superposition of such patterns can give rise to the perception of transparency. Here we introduce a computational model of motion transparency, which is not based on surfaces, but rather on moving points in 3D space. The stimuli we consider are similar to what an observer sees during a snowfall or when walking through a densely cluttered scene such as a forest. We show that such images give rise to a bow tie signature of power in the 3D spatio-temporal frequency domain. This result generalizes the finding of (Watson and Ahumada, JOSA 85) that translational motion of a surface gives rise to a plane in the frequency domain. Our model also suggests that the problem of determining motion in such transparent images can be decomposed into two natural sub-problems: first, determine the direction of motion, and second, determine the range of speeds of the motion. We present results from this computational model using both synthetic and natural image stimuli.

Space and Feature-based Attention Modulate Direction Tuning Curves in Areas MT/MST in the Macaque

Julio C. Martinez-Trujillo[1] and S. Treue[2], [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]German Primate Center, Goettingen, Germany.

We have previously shown that spatial attention scales direction-tuning curves of MT neurons in the macaque and that the responses of these units can also be modulated by non-spatial attention (i.e. feature based attention). Here we show that a space-based attentional scaling of responses can be combined with different magnitudes of a feature-based based attentional modulation causing changes in direction-tuning curves profile of MT/MST neurons. These results show that the two attentional effects (space- and feature-based) are independent and can be combined resulting in a powerful tool by which attention can modulate neuronal responses according to task demands.

Effects of Rim Around Rivalrous Pattern on Depth Produced by the Sieve Effect

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In the sieve effect the impression of a surface with fluctuating black and white areas seen through holes is created when an array of identical small black discs is presented to each eye and slightly smaller white discs are superimposed on the black discs in one eye (Howard, Perception, 1995, 24, 67). The effect is produced by binocular rivalry. Howard found that the sieve effect was weak when there were no rims around the rivalrous discs. This could be because (1) the rims are needed to create an impression of a porthole or (2) vergence becomes unstable when there are no matching contours in the two eyes to lock vergence. We conducted experiments to decide between these two hypotheses.

A Nonlinear Multiscale Spatial Filtering Explanation for Brightness Perception

M. E. McCourt and B. Blakeslee, Department of Psychology, North Dakota State University, Fargo, ND.

Blakeslee & McCourt (1997) demonstrated that a multiscale array of 2-D difference-of-Gaussians (DOG) filters provided a simple model for explaining simultaneous brightness contrast (SBC), grating induction and the Hermann Grid. The DOG model (and isotropic contrast models in general) cannot, however, account for another important group of brightness effects including the White (1979) effect and a variant of SBC (Todorovic, 1997). Blakeslee & McCourt (1999; 2001) subsequently developed an oriented difference-of-Gaussians (ODOG) model that could account for both groups of induction effects. Here we test the ODOG model on several additional sets of brightness illusions that cannot be explained by isotropic contrast models. These include the Wertheimer-Benary effect in various forms, and a group of corrugated Mondrian stimuli (Adelson, 1993; Todorovic, 1997).

Modeling spatial Updating During Head-free Gaze Shifts

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To remember target locations across eye movements their retinal stimulation sites must be remapped (updated) to the new retinal locations. During head-free gaze shifts this updating process must also account for the head rotation and the resulting eye translation, depending on target depth. We modeled the remapping process for head movements. In the model, target locations relative to the eye are instantaneously updated using feedback signals coding eye and head motion. The model shows correct updating for 3-D rotations of eyes and head. Simulations also show correct translational updating. Subsequent behavioral experiments confirmed that humans correctly update visual space during active torsional head movements. Current research aims to elucidate whether the updating mechanism also incorporates translational-depth geometry.

Motion Sensitivity With and Without Stationary Signals

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In order to investigate the effect of the stationary surround (zero velocity signals) on the integration area of motion perception, we measured velocity thresholds to motion discrimination in three types of random dot kinematograms (RDKs) varying the stimulus size. In the first RDK, the dot velocity was modulated by a Gaussian function with constant dot contrast (VmRDK), which contained the stationary dots outside the Gaussian blob in the display of 7x7 degrees. In the second RDK, the luminance contrast of dots was defined by a Gaussian with constant dot velocity so that no dot was presented outside the Gaussian blob (CmRDK). In the third RDK, both velocity and luminance contrast were varied using the same Gaussian (VCmRDK). Results showed that sensitivity was highest to VmRDK when the sigma of Gaussian was between one and two degrees. This indicates the presence of zero velocity signals plays an important role to see motion perhaps due to relative motion components of the stimulus against the stationary.

Process of Distance-in-Depth Perception Moved by an Approaching Object

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We investigated how an observer perceives the distance-in-depth moved by an approaching object. Subjects observed expanding squares successively displayed twice on a CRT simulating approaching objects. Then, they were required to estimate the ratio of the moved distance-in-depth of the first square (S1) and that of the second one (S2). The expanding rate of S1 and S2 were in accordance with a linear function or a sinusoidal function. The initial size, the end size, moving time were the same between S1 and S2. The results showed that subjective distance-in-depth of squares that expanded in accordance with a linear function was larger than that of squares expanding in accordance with a sinusoidal function. That result suggests that subjects could not perceive the distance-in-depth when the expansion was in accordance with a sinusoidal function because there was the phase in which the expansion rate was under the detection threshold when the expansion was in accordance with a sinusoidal function. This indicates that the subjects perceived the distance-in-depth of an approaching object using the expansion motion of the retinal image.

A Probabilistic Model of Change Blindness

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During saccades we fail to see even marked displacements in a scene. This 'change blindness' has been taken as evidence that our transsaccadic memory is poor. But here we argue that transsaccadic integration is based on optimal inference, and that change blindness is a consequence. Using retinal and extraretinal signals our neural networks learned to form statistically optimal interpretations. Their behaviour matched main features of human change blindness. By showing that change blindness is consistent with transsaccadic integration, these results clarify the inferential mechanisms underlying visual perception.

How does an Oblique Viewpoint Affect on Performance of Wayfinding and acquisition of Cognitive Map?

M. Ohmi, Kanazawa Institute of Technology, MATTO Laboratories, JP

We investigated effects of various viewpoints from an oblique one with semi-bird's eye view to a frontal one, on performance of wayfinding and acquisition of cognitive map in virtual maze with a hexagonal layout and with many landmarks. The results showed that time to spend for wayfinding was significantly shorter with oblique viewing condition. On the other hand, there was statistically significant improvement of quality of acquired cognitive map with frontal viewing condition. This trend was heightened for larger size of virtual maze. These results suggest that wayfinding and learning of cognitive map are processed separately by different mechanisms.

Effects of Collinearity and Coplanarity on Lightness Perception

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Is retinal or perceptual collinearity a prerequisite for the basis of perceptually coplanar ratio principle of lightness perception? Lightness perception was measured by presenting a margin of a target's retinal collinearity to a dihedral edge of background plain. The results showed 1) a prerequisite for coplanar ratio principle is retinal collinearity of the target to the background regions, and 2) a target without perceptual coplanarity produced the perception of lightness predicted by coplanar ratio principle. The latter suggests redefining coplanarity as the belongingness of a target surface to the background plain in the phenomenally similar/quasi-same but not identical plain.

Quantitative Models of Multiple Processing Levels

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Recent models of intermediate-level visual processing in cortex often incorporate a normalizing process sandwiched between two linear processing stages, with late noise added just prior to the decision stage. Olzak & Thomas (1999, Vision Research, 39, 231) developed such a model to fit a series of discrimination results. However, a quantitative model that incorporates early noise and no inhibition or normalization can also account for those data. A new test of the two models with concurrent-response rating data demonstrates that only an early noise model can fit observed correlations in neural noise, but is less satisfactory conceptually and physiologically.

An Examination of Possible Causes of the Jitter Advantage for Vection

S. Palmisano, D. Burke, C. Godsell and D. Hennessy, University of Wollongong, NSW, Australia

Adding 'global perspective' jitter to radial optic flow has been shown to facilitate the induction of visual illusions of self-motion in depth (Palmisano, Gillam & Blackburn, 2000). This is a surprising finding, since jittering displays simulate a self-motion that should be accompanied by vestibular stimulation (observer motion in depth on a platform oscillating in horizontal and/or vertical dimensions). This jitter advantage has been found to persist over a wide range of jitter amplitudes, directions and temporal frequencies. In the current experiments, we show that this jitter advantage for vection persists: (1); when flow has no additional changing-size cues to motion in depth; (2) when flow simulates motion parallel to the frontal plane; and (3) when the jitter has a constant as opposed to a randomly-determined amplitude. These findings further demonstrate the robustness of this jitter effect and do not support reduced adaptation and improved motion in depth accounts of this phenomenon.

Are there Temporal Limits for Post-matching Stereoscopic Processing?

S. Palmisano[1], R.S. Allison[2] and I.P. Howard[2], [1]University of Wollongong, Australia and [2]Centre for Vision Research, York University, Toronto, ON

In this study, we examined the effects of image decorrelation on the detection of a depth grating in static and dynamic random-dot stereograms (RDS). Static displays presented a single RDS over 1.6s (dot-lifetime was 1.6s; 7% dot density), whereas Dynamic displays presented 20 RDS over 1.6s or 520ms (dot-lifetime was 80ms in the former and 26ms in the latter type of dynamic display; each RDS had a 7% dot density). If observers were given a reasonable amount of time to process a static RDS, image decorrelation appeared to pose few problems for surface detection. However, as dot life-times decreased in dynamic RDS, performance was found to decline significantly (even though equivalent numbers of dots were available in both Dynamic RDS conditions). Since 20 and 80 ms dot-life times were sufficient to achieve dot-matching in the presence of substantial decorrelation noise (Tyler & Julesz, 1978), we conclude that this finding indicates a temporal limit for extracting extract and integrate disparity samples from across the visual field.

Feature Search: "Pre-Attentive" or "Spread-Attention" Performance?

M. Pavlovskaya[1], H. Ring[1], Z. Groswasser[1] and S. Hochstein[2], [1]Loewenstein Rehabilitation Hospital, Raanana, [1]Sackler School of Medicine, Tel Aviv University & [2]Hebrew University, Jerusalem, Israel
We address a long-standing conflict in the visual search literature by studying search performance of neglect patients using laterally presented search arrays, and comparing performance on feature and conjunction search tasks. The issue relates to whether feature search is performed "pre-attentively" i.e. supposedly independently of attention (Treisman and Gelade, 1980), or with "spread attention" i.e. irrespective of the number or eccentricity of the elements, but demanding attention, nevertheless (see Treisman 1988). If neglect has to do only with focusing attention, and if feature search were a pure pre-attentive task, we would expect that left-neglect patients would have no problem in performing a feature task in the left visual field. Five neglect patients and six normal controls were tested with stimulus arrays composed of 3x3, 5x5 or 7x7 elements presented centrally, or in the left (LHF) or right hemifield (RHF) at three possible eccentricities. Array centers were at 0° or 2.5-6.5° of visual angle from the fixation cross. We found neglect effects not only for conjunction but also for feature search, suggesting that feature search, too, depends on attention, albeit on spread attention, and that this type of attention, too, is affected by neglect.

Visual Systems Research and Development for Distributed Mission Training

B. J. Pierce and G. Geri, AFRL/HEA, Mesa, AZ
This poster describes the visual research and development program at the Air Force Research Laboratory in Mesa, Arizona. Research activities are tied closely with visual development activities. The goals of the research program are to define the functional requirements for visual systems to be used in high-fidelity flight simulators, to specify design goals of visual systems under development, and to quantify the relationship between visual system capability and training value. Research is ongoing in the following areas:

1. Visual systems specifications / evaluations / measurement standards
2. Image generator evaluations / database cueing requirements
3. Network transport delay effects on visual performance
4. Head mounted display artifacts and simulation requirements

In addition to an overview of R&D activities, the poster provides a summary of recently completed research on differences in the perceived size and speed, of objects presented on collimated versus non-collimated displays, and on the effects of object and observer motion on estimates of time-to-contact.

Eye Dominance and Tracking Eye Movement

S. Prime, Dept. of Psychology, Simon Fraser University, BC
Bahill and LaRitz (1984) studied the eye movement strategies of baseball batters during a simulated batting scenario. They suggested that ball tracking was performed primarily by the dominant eye. The purpose of the current study was twofold. The first was to investigate whether or not there are differences between the dominant eye and the non-dominant eye with regard to tracking performance. The second purpose was to compare the tracking performance and eye dominance differences of a group of Simon Fraser University softball players and a group of non-softball players. Participants in the experiments were required to track a moving target at different speed levels. Tracking performance was measured using the root mean square error (RMSE). The results of the experiments indicated that subjects tracked targets with significantly less error with their dominant eye rather than with their non-dominant eye. In addition, some participants tracked more accurately when the target moved in the left-right direction as opposed to the right-left direction. This difference was not significant, however, for the softball players. And softball players' tracking performance was better overall than that of the control group of non-softball players. On this basis, I argue that dominant eye tracking superiority is due to proprioceptive signals, a major component in the control of tracking eye movements, being processed more efficiently than is the case when non-dominant eye tracking occurs.

Disparity Tuning of the Transient-Disparity Vergence System

M. Sato, M. Edwards, C. M. Schor, School of Optometry, University of California, Berkeley, USA
The effects of sensory adaptation to binocular disparities on the transient vergence system were estimated from percentages of vergence responses made in the correct direction. The test and adaptation disparities ranged from -5 deg to +5 deg. The results show that there were substantial individual differences in vergence performance and effects of adaptation. Adaptation to individual disparities caused reduced performance to either broad or narrow ranges of disparity. For example, adapting to 1 deg uncrossed disparity could reduce performance to the entire 5 deg range of uncrossed test disparities or for only the 1 deg uncrossed disparity. The latter example demonstrates that crossed and uncrossed disparities are mediated by numerous channels which have narrow disparity tuning rather than a single broad channel.

The Saliency of Proximal Mode Perception in Children

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Children's sensitivity to proximal mode perception as compared to adults under reduction and non-reduction conditions was investigated. Forty-three children (5 - 6 yrs) and 46 adults (17 - 26 yrs) participated in three conditions. Subjects judged object size under complete reduction conditions (a); judged the size of a reduction standard with a non-reduction comparison object located at two comparison distances (b) and one distance (c).

Children extracted extensity as accurately as adults under (a) complete reduction conditions and in general, were ***more accurate*** when comparing (b) reduction versus non-reduction objects at two distances (sign test: $p < 0.05$) and (c) one distance, (2 feet: $p < .005$); (8 feet: ($p < 0.1$).

Children are as accurate as adults at extracting extensity information and findings suggest that the saliency of the proximal mode in children leads to their poor performance in traditional size constancy experiments.

Contextual Influences on Guidance in a Visual Search Task

J. Shen and E. M. Reingold, Department of Psychology, University of Toronto, Toronto, ON

The current study examined contextual influences on guidance in a visual search task with a distractor ratio manipulation (Shen, Reingold, & Pomplun, 2000). Participants were asked to look for a search target among a fixed number of distractors that shared either colour (same-colour distractors) or shape (same-shape distractors) with the target. In each trial the display either contained very few same-colour distractors (colour-search display) or very few same-shape distractors (shape-search display). Visual context was manipulated by varying the relative frequency of these two types of displays within a block of trials (Experiments 1 & 2) or by using a priming manipulation (Experiment 3). Results suggested that guidance in visual search was influenced not only by the salience of display items but also by the context within which search displays were presented.

The Correlation Between Mental Representations of the Visual World

W.A. Simpson, H.K. Falkenberg, V. Manahilov, Vision Sciences Dept, Glasgow Caledonian University, Glasgow UK

We see because we have a mental representation of the stimulus. The nature of this representation can be examined in a visual detection experiment where the observer must decide if a faint signal was presented. The results of such experiments show that observers perform a template-matching or cross-correlation operation: they compare the noisy received stimulus with a mental representation of the known signal to be detected. By testing the ability of observers to detect superimposed pairs of oppositely drifting sinewave gratings, we measured the cross-correlation between the mental representations used to detect each component. Humans misrepresent visual spatio-temporal patterns as being more similar than they really are. This explains why human visual discrimination can be poor for stimuli that are highly visible.

Frequency-Tagging the Visual scene to Investigate Neural Correlates of Perceived Color in Simple and Complex Contexts

R. Srinivasan and M. A. Murias, Department of Cognitive Sciences, University of California, Irvine

A number of psychophysical studies have demonstrated that the perceived color of a surface depends both on its physical properties and on its visual context. However, relatively little is known about the neural mechanisms underlying contextual influences on visual perception. This is primarily a consequence of the practical difficulties in simultaneously recording from neurons that respond to different parts of the visual field, and from neurons in different areas of the visual system. We have developed a new experimental paradigm, termed frequency tagging, to isolate stimulus-specific neural responses to different parts of an image. The visual scene is "tagged" by flickering each element at a distinct frequency to elicit a steady-state neural response at the stimulus-specific flicker frequency. These steady-state neural responses can be simultaneously detected in EEG or MEG recordings. In this study, we apply this to approach to investigate brightness induction in a simultaneous contrast display and White's illusion. In both displays, as perceived brightness of a surface is inversely correlated to magnitude of the steady-state response evoked by the surface. The results suggest that brightness induction in White's illusion and simultaneous contrast operate on similar neural mechanisms which are amplified

Enucleated Observers Show Enhanced Sensitivity to Radial Frequency Patterns at Reduced Contrast Compared to Monocularly Viewing

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Previous research has shown that unilaterally enucleated observers have better sensitivity to letters (González, et al., 1997; Reed et al., 1996, 1997) and gratings (Nicholas et al., 1996) defined by luminance-contrast than monocularly-viewing normal controls and that they have similar sensitivity to binocularly-viewing controls. The perception of form defined by other attributes such as texture-contrast and relative motion is not equivalently better in unilaterally enucleated observers (Steeves et al., 1998). In this experiment we asked two questions. First, if unilateral enucleation selectively improves sensitivity to letters and gratings defined by luminance-contrast, does it also affect sensitivity to small deviations from circularity--radial frequency (RF) patterns (Wilkinson, Wilson, & Habak, 1998) compared to monocularly and binocularly-viewing controls? Second, does reducing binocular inhibitory interactions that may be caused by wearing an eye-patch during monocular testing eliminate performance differences between monocular controls and unilaterally enucleated observers?

We tested twelve control observers viewing binocularly and dichoptically (using a stereoscope with a luminance-matched grey field shown to the non-viewing eye to reduce binocular inhibitory interactions), four control observers viewing monocularly with a dark eye-patch and seven unilaterally enucleated observers. Sensitivity to RF patterns was measured at 100, 25, 12.5 and 6.25% contrast. Sensitivity to RF patterns was equivalent in enucleated observers and binocular controls. and both groups showed statistically superior performance to that of the eye-patch controls at low contrast. The performance of the dichoptic control group fell between that of the binocular and eye-patch conditions. The previously reported enhanced sensitivity to luminance-defined form in enucleated observers also occurs for low contrast RF patterns. Binocular inhibitory interactions contribute to, but do not fully account for this effect.

What Does the Disparity Vergence System See?

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Disparity vergence movements occur reflexively and unconsciously. Voluntary effort influences the horizontal component of vergence, but not the vertical component. Vertical disparity vergence responses thus reflect a part of our visual system that is "below" perception. We have used eye movement recordings to ask the question, "What does disparity vergence see?" Using luminance gratings, we found that vergence contrast sensitivity for was similar to psychophysical sensitivity, except that vergence showed an abrupt cutoff at 4 to 8 cycles per degree. High frequency gratings or filtered noise produced no vertical vergence, but were clearly visible and did produce voluntary, horizontal vergence.

Static and Dynamic Measures of Convergence Accommodation in Pre-school Children

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Convergence accommodation measures in pre-school children and adults were examined. Forty-three pre-school children (Mean age = 4.0+1.31 yrs) and eight young adults (Mean age = 23+0.2 yrs) with 20/20 VA were studied. Stimulus CA/C (sCA/C) ratios and movement time were assessed using a photorefractor while subjects viewed a DOG target. The Mean sCA/C ratios and movement time did not differ significantly between adults and children (0.61D/M.A, 744+69msec and 0.50 D/M.A, 787+216msec). The presumed differences in lens (Plant) characteristics between pre-school children and young adults do not appear to impact static or dynamic measures of convergence accommodation.

Experimental Testing on an Anchoring Theory of Lightness Perception

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Gilchrist et al. (1999) indicated that for understanding lightness perception, we should mind the relationships among all parts of the visual field. They used the term 'framework' from Gestalt theory and presented a new theory called Anchoring Theory. By measuring the lightness of the surfaces of 3 dimensional spatial arrangements in various stimuli, we examined the propriety of Anchoring Theory. The stimuli were systematic variations on Gilchrist's (1980) stimulus. The results suggested that there are complicated relationships between the local frameworks (subordinate frameworks of the entire visual field).

The effect of Vantage Point Location on Perceived Space in Linear Perspective Images

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Shifts of the vantage point of the viewer induce changes in perceived 3-D layouts conveyed by some 2-D images, such as in the phenomenon that depicted roads in paintings 'turn' as the viewer moves. A geometric analysis provides predictions of the structure of these changes in accord with the rules of linear perspective. In an experiment observers viewed from three different vantage points an appropriately constructed 2-D drawing and performed judgements involving perceived directions, sizes and angles of features in the depicted 3-D space. The results can in part be accounted for by the linear perspective analysis, but reveal also effects of conflicting depth cues and visual angle.

The Processing of Local and Global Information in Natural Images

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What does the human visual system take in at a glance? We test whether the global coherence of a natural image aids in the recall of the local components of the image. We employ a database with over 10,000 natural images. Each image is divided into 36 100x100 pixel sub-images. In the first condition, the observer views the full intact image for a variable amount of time (global as well as local information is available), a coloured random noise mask for 500 ms, and then two sub-images (each 100x100 pixels) either from the previously viewed image or a novel image. The observers indicate which sub-image was just presented. The second condition is identical to the first with the exception that the positions, of the 36 sub-images, are randomly scrambled. In this condition, only local information is available to the observer. We used an adaptive psychophysical technique (QUEST) to estimate the presentation duration of the test image that required subjects to achieve a criterion level of 82% correct. We compare the results from the two conditions to determine whether the short-term recall of a sub-component of a natural image is aided by the global coherence of the image.

Luminance Adaptation and Perceptual Filling-in

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A grey target peripherally presented within dynamic random noise (DRN) perceptually fades from view (or "fills-in") following a period of steady viewing. To gain insight into the neural mechanisms responsible for this perception we investigated whether luminance adaptation occurs in the presence of perceptual filling-in.

Observers were required to detect the presence of a small, bright test probe presented at the target's centre (eccentricity = 10 deg). Luminance increment thresholds were obtained for 2 conditions: (1) No adaptation - test intervals were presented after trial initiation; (2) Adaptation - observers viewed the stimulus until they reported target disappearance, and then viewed the test intervals. Detection thresholds were obtained for a range of target luminance values.

Surprisingly, luminance increment thresholds were lower with adaptation (condition 2) than when observers simply viewed the test (condition 1). This result could indicate gain control in the neurones that encode the presence of the target. Alternatively, it may be related to transient detection and not related to perceptual filling-in per se.

Dynamics of Travelling Waves in Visual Perception

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Nonlinear wave propagation is ubiquitous in nature, appearing in chemical reaction kinetics, cardiac tissue dynamics, cortical spreading depression, and slow wave sleep. Wave propagation is also evident in perception in the form of sweeping waves of visibility that occur when the two eyes receive radically different stimuli. Here we introduce a novel technique to measure the speed of rivalry dominance waves propagating around a large, essentially one-dimensional annulus. When mapped onto visual cortex, propagation speed is independent of eccentricity. Propagation speed doubles when waves travel along continuous contours, thus demonstrating effects of collinear facilitation. A neural model with reciprocal inhibition between two layers of units driven by the dissimilar stimuli provides a quantitative explanation of dominance wave propagation in terms of disinhibition. Dominance waves thus provide a new tool for investigating fundamental cortical dynamics.

High Dynamic Range Video

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In a typical real-world scene, the dynamic range (the ratio of irradiances between the darkest and and brightest spots of the scene) can be quite large, it can even span several orders of magnitude. This is a lot more than the dynamic range of the digital video camera and of the computer monitor. So spots in the scene that are above the dynamic range of the camera will be saturated in the image, and spots below the range will be under-exposed. To fight this problem, we can alternate between low and high setting for the camera shutter speed; information at both images is used to estimate the radiance of the corrseponding spot in the scene (pixel-by-pixel). This allows us to widen the dynamic range of our video camera. To display information, tone mappings are used, so we have video images with sharp contrast and good preservance of details. Sponsored by OGS ST scholarship and MD Robotics.