Welcome to

VSS 2006

The Sixth Annual Meeting of the

Vision Sciences Society

May 5 – 10, 2006
Hyatt Sarasota
Sarasota, Florida

Program cover image design by Sagit Ganel

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5:30 – 8:30 pm	Poster Session A	*Municipal Auditorium*
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Saturday, May 6

7:00 am - 5:30 pm	Onsite and Pre-Registration Check In	*Hyatt Ballroom Foyer*
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Sunday, May 7

7:30 am - 5:30 pm	Onsite and Pre-Registration Check In	*Hyatt Ballroom Foyer*
7:30 – 8:00 am	Complimentary Coffee Service	*Hyatt Ballroom Foyer*
8:00 am – 7:15 pm	Exhibits Open	*Municipal Auditorium*
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Monday, May 8

7:30 am - 1:00 pm	Onsite and Pre-Registration Check In	*Hyatt Ballroom Foyer*
7:30 – 8:00 am	Complimentary Coffee Service	*Hyatt Ballroom Foyer*
8:00 – 11:00 am	Exhibits Open	*Municipal Auditorium*
8:00 – 9:30 am	Morning Talk Session 1	*North and South Hyatt Ballrooms*
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11:00 am – 12:45 pm	Morning Talk Session 2	*North and South Hyatt Ballrooms*
6:30 – 9:30 pm	Demo Night	*G.WIZ Science Museum*

Tuesday, May 9

7:30 am - 6:00 pm	Onsite and Pre-Registration Check In	*Hyatt Ballroom Foyer*
7:30 – 8:00 am	Complimentary Coffee Service	*Hyatt Ballroom Foyer*
8:00 – 9:45 am	Morning Talk Session 1	*North and South Hyatt Ballrooms*
8:00 – 11:00 am	Poster Session I	*Municipal Auditorium*
11:00 am – 12:30 pm	Morning Talk Session 2	*North and South Hyatt Ballrooms*
Noon – 3:00 pm	Poster Session J	*Municipal Auditorium*
12:30 – 1:00 pm	Lunch Break	
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4:00 – 4:30 pm	Complimentary Coffee & Beverages	*Hyatt Ballroom Foyer*
4:30 – 6:00 pm	Afternoon Talk Session 2	*North and South Hyatt Ballrooms*
4:30 – 7:30 pm	Poster Session K	*Municipal Auditorium*
9:00 pm – 3:00 am	Club Vision	*Hyatt Ballroom South*

Wednesday, May 10

7:30 am - Noon	Onsite and Pre-Registration Check In	*Hyatt Ballroom Foyer*
7:30 – 8:00 am	Complimentary Coffee Service	*Hyatt Ballroom Foyer*
8:00 – 9:30 am	Morning Talk Session 1	*North and South Hyatt Ballrooms*
10:00 am – 11:45 pm	Morning Talk Session 2	*North and South Hyatt Ballrooms*

Poster Schedule

Poster Session	*Date*	*Setup Begins*	*Session*	*Author Presents Time*	*Take-Down Complete*
A	Friday, May 5	5:00 pm	5:30 - 8:30 pm	6:30 - 7:30 pm	9:00 pm
B	Saturday, May 6	7:45 am	8:00 - 11:00 am	9:30 - 10:30 am	11:30 am
C	Saturday, May 6	11:30 am	12:00 - 3:00 pm	1:00 - 2:00 pm	3:30 pm
D	Saturday, May 6	3:30 pm	4:15 - 7:15 pm	5:30 - 6:30 pm	7:30 pm
E	Sunday, May 7	7:45 am	8:00 - 11:00 am	9:30 - 10:30 am	11:30 am
F	Sunday, May 7	11:30 am	12:00 - 3:00 pm	1:00 - 2:00 pm	3:30 pm
G	Sunday, May 7	3:30 pm	4:15 - 7:15 pm	5:30 - 6:30 pm	7:30 pm
H	Monday, May 8	7:45 am	8:00 - 11:00 am	9:30 - 10:30 am	11:30 am
I	Tuesday, May 9	7:45 am	8:00 - 11:00 am	9:45 - 10:45 am	11:30 am
J	Tuesday, May 9	11:30 am	12:00 - 3:00 pm	1:00 - 2:00 pm	3:30 pm
K	Tuesday, May 9	3:30 pm	4:30 - 7:30 pm	6:00 - 7:00 pm	7:45 pm

Poster Session A

Friday, May 5, 2006

Eye Movements: Pursuit and Vergence (101-107), Face Recognition (108-115), Perceptual Organization: 2D Shape (116-124), Working Memory (125-142), Binocular Rivalry/Bistability/Awareness (143-156), Change Detection (157-164), Oscillations, Correlations, Synchrony (165-173), Human Factors (174-180)

Poster Session: 5:30 - 8:30 pm ***Municipal Auditorium***
Author presents: 6:30 - 7:30 pm

Eye Movements: Pursuit and Vergence

A1 *101* Version and Vergence Eye Movements in Optokinetic Nystagmus Induced by Optic Flow

Dongsheng Yang[1] (yangd@upmc.edu), Mingxia Zhu[1], Richard W. Hertle[1]; [1]Department of Ophthalmology, University of Pittsburgh, Children's Hospital of Pittsburgh

Purpose. Vergence eye movements (EM) have been reported to be induced by radial optic flow(OF) (Busettini et al 1997, Yang et al 1999). However, it has also been reported that OF elicits versional optokinetic nystagmus (OKN) (Lappe et al 1998). We designed and used a simple OF that simulates natural viewing conditions to evoke a new type of OKN containing both version and vergence components. Methods. OF were generated on a PC monitor controlled with VEX-REX (LSR/NEI/NIH). The size of the stimuli was 30X30cm and viewing distance to its center was 30cm. Self-movements of a forward/backward translating observer over a textured horizontal plane were simulated. The subject seated still and EM responses to the OF were recorded with an infrared eye tracking system and analyzed off-line. Results. EMs had an OKN pattern characterized by an ocular following slow phase and a corrective quick phase. Version and vergence components were showed by extracting horizontal and vertical EM components in each eye. The slow phase and quick phase of vergence and version were analyzed for velocity and amplitude. Conclusion. Robust version and vergence EMs which are part of a novel OKN response can be induced by OF stimuli. The OKN of this type provides a new approach to study the interaction of the vergence and version. These reflexive vergence associated with OKN may be used to study development of the oculomotor system and objective evaluation of binocular function in children.

Acknowledgment: The study is partly supported by NEI grant EY015797

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A3 *103* Pursuit eye movements to isoluminant targets

Doris I. Braun[1] (doris.braun@psychol.uni-giessen.de), Neil Mennie[1], Karl R. Gegenfurtner[1]; [1]Psychology, Giessen University, Giessen, Germany

Isoluminant stimuli are perceived to be moving slower than comparable luminance stimuli.Here we investigate whether smooth pursuit eye movements show an analogous slowing.Eye movements were measured with a Purkinje image eye tracker while viewing 1 cpd sine wave gratings or small Gaussian spots of light that moved at four different speeds between 1 and 8 deg/s. Pursuit was determined in response to targets defined by luminance contrast (10%) and compared to pursuit for targets at or near the point of isoluminance. We obtained similar pursuit eye movements for both types of targets. Steady state eye speed was reduced by about 10% for isoluminant targets only at high temporal frequencies. Eye movement acceleration was not affected. The biggest difference was obtained with respect to latency which was 30 to 80 ms longer at isoluminance. Compared to the dramatic slowing of 30% or more that we observed psychophysically with these stimuli, there was hardly any impairment for steady state pursuit eye movements. Furthermore, the largest effects for pursuit were obtained at high temporal frequencies, where no perceptual slowing of isoluminant stimuli was found. At low temporal frequencies, eye movement steady state speed was not affected, even though the same stimuli were sometimes perceived at 30% of their veridical speed when subjects were fixating. When psychophysical judgments are made during pursuit, speed is perceived veridical for all stimuli. We conclude that the mechanisms that cause the perceptual slowing of isoluminant gratings are not involved in the generation of pursuit eye movements.

Acknowledgment: Supported by: Deutsche Forschungsgemeinschaft GE 879/7

A4 *104* Contributions of visual areas V2 and V3 to the analysis of depth and motion signals guiding smooth eye movements

Carlos R. Ponce[1] (carlos_ponce@student.hms.harvard.edu), Stephen G. Lomber[2], Richard T. Born[1]; [1]Department of Neurobiology, Harvard Medical School, Boston MA, [2]School of Behavioral and Brain Sciences, University of Texas at Dallas, Richardson TX

The middle temporal (MT) visual area is a critical source of motion and disparity signals used to guide smooth eye movements. It receives major cortical inputs from visual areas V1, V2 and V3, among others. To explore the relative contributions of these inputs, we reversibly inactivated parts of V2 and V3 while measuring smooth eye movements in awake behaving macaques. We implanted three cryogenic loops within the lunate sulcus covering a region approximately 18 mm (medio-lateral) by 8 mm (dorsal-ventral), which allowed us to create a putative V2/V3 scotoma in the contralateral inferior quadrant. Inactivation of this region caused corresponding retinotopic deficits in the initiation of smooth pursuit, short-latency vergence and ocular following responses. These deficits were most pronounced for high stimulus velocities (>30 degrees/s, corresponding to spatial displacements above 0.5 degrees). Vergence was similarly impaired: the only significant changes in horizontal vergence velocity were for eye movements elicited by large binocular disparity steps (> 0.8 degrees). These results suggest that V2 and V3 are important in the processing of visual information used to generate eye movements, contributing most to the analysis of motion signals involving large spatial steps. As directional interactions measured in V1 neurons occur over smaller retinotopic distances (Conway and Livingstone, 2003; Pack et al., in press) the larger receptive fields in V2 and V3 appear to extend the spatial range of visual motion processing.

Acknowledgment: Phillip Hendrickson

A5 *105* **Combining 1D visual motion and 2D predictive signals to control smooth pursuit eye movements**

Anna Montagnini[1] (Anna.Montagnini@incm.cnrs-mrs.fr), Miriam Spering[2], Guillaume S. Masson[1]; [1]Institut de Neurosciences Cognitives de la Méditerranée, CNRS & Aix-Marseille University, France, [2]Experimental Psychology, Justus-Liebig-Universität Giessen, Germany

Purpose: Pursuit of a tilted bar has a complex dynamics: tracking is initiated in the direction orthogonal to the bar (1D motion signals) before slowly converging on the actual 2D object motion trajectory. We investigated how 1D and 2D motion signals are combined with internal signals (eye velocity memory or object velocity prediction) related to 2D object motion. Methods: Eye movements were recorded in 4 subjects using the scleral search coil technique. Subjects were asked to track a single oblique line (length: 10°) moving horizontally (rightward/leftward) at 10°/s. Results: In a first experiment, the tilted line was transiently blanked (200ms) during steady-state tracking. The decrease of eye speed during target blanking was corrected shortly after target reappearance, using 2D target velocity and not 1D edge velocity. However, when the line was rotated by 90° at reappearance, a small but significant tracking direction error in the (new) 1D motion direction was observed. Corrective saccades were directed in the same direction. To test the contribution of visual and predictive signals we presented blocks of line motion (400ms duration) always with same orientation/direction. We found strong anticipatory eye movements in the global (2D) motion direction of the bar. However, ~100ms after target motion presentation, a consistent tracking error in the oblique direction was again observed. Stimulus predictability had very small effect on the amplitude of 1D-driven responses. Conclusion: Pursuit is driven by independent visual and internal signals related to object motion that do not interact to resolve ambiguity in the visual inflow.

Acknowledgment: PRA European Network

A6 *106* **High spatial frequency superiority of motion aftereffect for smooth pursuit eye movements**

Kazumichi Matsumiya[1] (kmat@riec.tohoku.ac.jp), Satoshi Shioiri[1]; [1]Research Institute of Electrical Communication, Tohoku University

[Purpose] After the adaptation to the moving stimulus that is composed of high and low spatial frequency sinusoidal gratings, the observers perceive motion aftereffect (MAE) of the high spatial frequency component (high spatial frequency superiority of motion aftereffect). We investigated whether smooth pursuit eye movements also follow the pattern of MAE percept. [Experiment] An adaptation stimulus was composed of two drifting gratings with different spatial frequencies. One of the two spatial frequency components moved in the left direction, and the other moved in the right direction. The adaptation stimulus was presented for 20 s and followed by a stationary test grating of either spatial frequency. When MAE disappeared, the observers pressed one of the two keys to indicate the duration and direction of MAE. We measured eye movements while MAE was being seen. [Results] Smooth pursuit eye movements were observed in the same direction as the direction of MAE observed, which was in the direction opposite to the high spatial frequency drifting grating for both high and low spatial frequency tests. [Discussion] These results suggest that the system for pursuit eye movements also has high spatial frequency superiority of MAE as well as perception.

A7 *107* **A Novel Automated Method for Marking Catch-Up Saccades**

Andrew J Toole[1] (toole.2@osu.edu), Nick Fogt[1]; [1]The Ohio State University College of Optometry

Purpose: Smooth pursuit (SP) eye movements are used to track moving targets. If target velocity exceeds ~60deg/s or the target is unpredictable, high velocity catch-up saccades (CS) occur. To study SP eye movements or CS separately, a method is needed to differentiate them. Here we demonstrate a novel objective criterion for marking CS utilizing the derivative of ocular acceleration (dA).Methods: Search coils were used to monitor eye position during tracking of an unpredictable 2D pursuit target (0.24-1.25Hz). Horizontal and vertical components were analyzed separately. Automated software was developed to determine the start and end of CS. The start of the CS was the peak dA point prior to the peak velocity point of the CS, and the end was the minimum dA point following the peak velocity point. One experienced author visually marked the start and end of 21 horizontal and 26 vertical saccades from the same eye trace. Results: Comparisons (paired t-test) were made between CS start and end times as determined with the automated method and visual inspection. Small but significant differences occurred for start (mean difference = 7.1msec, $p<0.0005$) and end (mean difference = 6.7msec, $p<0.0005$) times. Conclusion: The automated method is an accurate, rapid method for determining the start and end of CS. Because start times were later and end times earlier with visual inspection, the small differences between the automated and visual inspection methods are probably due to difficulties in visually detecting the subtle changes in acceleration at the beginning and end of CS.

Acknowledgment: Support: NIH: T32EY13359, AFOSR grant #F49620-02-1-0050

Face Recognition

A8 *108* **Pigmentation is important for recognition of familiar faces**

Richard Russell[1] (rrussell@fas.harvard.edu), Pawan Sinha[1]; [1]MIT Department of Brain and Cognitive Sciences

Recent studies using unfamiliar face recognition tasks have found evidence that pigmentation and shape information are about equally important for face recognition. However, it is possible that the information subjects can discriminate or remember is not the same as what they actually do use to recognize people in the real world. Of course, it is this latter kind of recognition that is of greatest interest. We investigated subjects' ability to recognize photographs of their friends. The subject pool consisted of 30 undergraduates who all lived in the same dormitory, and saw one another on a daily basis. These individuals were photographed and later comprised the subjects in a recognition experiment. Two sets of stimuli were created: 1) An averaged face was warped in two dimensions into the shapes of individual faces, and 2) Individual faces were warped into the shape of the averaged face. In set 1, the faces contained the shape cues of the original individuals, but had generic pigmentation cues, while in set 2, the faces contained the pigmentation cues of the original individuals, but had generic shape cues. Subjects viewed these images, and were asked to name the individual whose photograph had been manipulated to produce them. Afterward, subjects viewed the original photographs and named them. Subjects performed better using pigmentation information alone than shape information alone, but better still when both kinds were available (in the original photographs). These results provide evidence that pigmentation is at least as important as shape for face recognition.

A9 *109* **Where are kin recognition cues in the face?**

Maria F Dal Martello[1] (mdm5@nyu.edu), Laurence T Maloney[2,3]; [1]Department of General Psychology, University of Padova, [2]Department of Psychology, New York University, [3]Center for Neural Science, New York University

Observers accurately judge children's degree of kinship given facial photographs (Dal Martello & Maloney, VSS2002). We report two experiments intended to determine where in the face the cues signalling kinship fall. Since the upper face changes less than the lower during development (Enlow & Hans, 1996), we hypothesized that observers would rely on age-invariant features in the upper face. **Stimuli:** 30 pairs of photographs, each photograph portraying a child's face with background removed. Half were of siblings, half, unrelated. The children's ages spanned 14 years. **Observ-**

ers: 220 observers judged each pair as siblings or not. We summarized performance in each condition by signal detection *d'* estimates. **Experiment 1 Conditions:** Full Face visible (FF); Upper Half face visible (UH); Lower Half face visible (LH). Different observers participated in each condition. **Results:** Performance in FF (*d' = 1.19*) and in UH condition (*d''=1.12*) did not differ significantly (*p = n.s.*). Performance in LH (*d' = 0.41*) was significantly lower (*p < 0.0001*) than that in other conditions. **Experiment 2 Conditions:** Full Face visible (FF); face visible except for a small mask over the eye region (ME); face visible except for the masked mouth (MM). **Results:** Performance in the masked conditions (ME *d' = 0.82*; MM *d' = 1.11*) was not significantly different from that found in FF (*d' = 1.02*). **Conclusion:** Observers (correctly) use kinship cues in the upper half face but, surprisingly, the eye region either provides little information or cues available in that region are redundant with other facial cues.

Acknowledgment: Support: NIH EY08266

A10 *110* Voices, not arbitrary sounds, prime the recognition of familiar faces

Isabelle Bülthoff[1] (isabelle.buelthoff@tuebingen.mpg.de), Fiona N Newell[2]; [1]Max Planck Institute for Biological Cybernetics, Germany, [2]Trinity College, Ireland

Our previous studies have shown that memory for a face can be affected by the distinctiveness of a voice to which it had been paired (Bülthoff & Newell, ECVP2004). Moreover, we showed that voices can prime face recognition, suggesting a tight, cross-modal coupling between both types of stimuli. Further investigations however, seemed to suggest that non person-related audio stimuli could also affect memory for faces. For example, faces that had been associated with distinctive instrumental sounds were indeed better recognized in an old/new task than faces paired to typical sounds. Here we investigated whether these arbitrary sounds can also prime face recognition. Our results suggest that arbitrary audio stimuli do not prime recognition of faces. This finding suggests that attentional differences may have resulted in better recognition performance for faces paired to distinctive sounds in the explicit old/new task. Voices are easier to associate closely to faces. We also investigated whether the voice priming effect found earlier might be based on the use of different first names in each audio stimulus, that is, whether the effect was based on semantic rather than perceptual information. We repeated the priming experiment using the same voice stimuli, but name information was removed. The results show that there is still a significant priming effect of voices to faces, albeit weaker than in the full voice experiment. The semantic information related to the first name helps but is not be decisive for the priming effect of voices on face recognition.

A11 *111* Face recognition algorithms surpass humans matching faces in images that vary in illumination

Alice J. O'Toole[1] (otoole@utdallas.edu), P. Jonathon Phillips[2], Fang Jiang[1], Janet Ayyad[1], Nils Pénard[1], Hervé ABDI[1]; [1]The University of Texas at Dallas, [2]National Institue of Standards and Technology

We compared the accuracy of seven state-of-the-art face recognition algorithms with human performance on the same task. Humans and algorithms determined whether two face images, taken under different illumination conditions, were pictures of the same person or of different people. The algorithms tested were participants in the Face Recognition Grand Challenge (FRGC) test organized by the National Institutes of Standards and Technology. In that competition, algorithms matched identities in 128 million pairs of face images. For the human experiments, we sampled 120 "easy" and 120 "difficult" face pairs from the FRGC dataset, using similarity scores derived from a control algorithm based on a principal components analysis of the aligned and scaled face images. In three experiments, which varied only in exposure time (Exp. 1 - unlimited; Exp2. - 2s, Exp. 3 - 500ms), humans rated face pairs according to the likelihood that the two people were the same. ROC curves from the humans and the algorithms were compared. Three algorithms outperformed humans at matching face pairs prescreened to be "difficult" (cf., Liu, in press; Xie et al., 2005) and all but one algorithm surpassed humans on the "easy" face pairs. Although illumination variation continues to challenge face recognition algorithms, several current algorithms compete favorably with humans-even if they appear to perform poorly in absolute terms.

Acknowledgment: Work supported by TSWG funding.

A12 *112* When does an unfamiliar face become familiar? The effect of image type and familiarity on recognition from novel viewing conditions

Dana A. Roark[1] (danar@utdallas.edu), Hervé Abdi[1], Alice J. O'Toole[1]; [1]University of Texas at Dallas, School of Behavioral and Brain Sciences

Little is known about the learning experiences that promote robust face recognition performance for highly familiar faces. This is because most face recognition research uses exclusively famous or exclusively unfamiliar faces as stimuli. In a previous study (Roark et al., in press), we found large gains in person recognition from low quality video, following multiple exposures to high resolution, frontal-view faces with neutral expressions. In the present experiment, we tested whether familiarizing participants with other types of face images (expressive faces and 3/4-view faces) would similarly improve performance. These kinds of images provide participants with faces that are potentially more socially engaging and offer better viewpoint information (cf. the 3/4 advantage) compared to neutral frontal-view faces. Participants learned faces from close-up images under controlled illumination and were tested with whole-body images under uncontrolled illumination. During learning we varied both the number of times participants viewed each face (1, 2, or 4 times) and the presentation type of the faces (neutral, smiling, or 3/4 view). We found equivalent and strong pure repetition effects for expressive, 3/4 view, and neutral frontal faces. These results suggest that the familiarity advantage we found previously is not dependent on a particular facial image type, but rather, is easily attainable from multiple exposures to any high-quality image. The repeated availability of a high-quality image seems to allow person recognition to tolerate large discrepancies in image format.

Acknowledgment: This work was supported by funding from TSWG awarded to AO'T and H.A.

A13 *113* Effect of head rotation on viewpoint dependence in face discrimination

Yunjo Lee[1] (ychlee@yorku.ca), Claudine Habak[1], Hugh R. Wilson[1]; [1]Centre for Vision Research, York University, Toronto, Canada

Our previous work found that discriminating the identity of *static* face views was viewpoint-dependent: thresholds for faces of different views increased with angular difference from the front view (Lee, Matsumiya & Wilson, submitted). In the present study, we extend this work to rotating faces. Optical imaging studies in monkeys have demonstrated that face-evoked spots in IT move systematically in one direction across the cortex as the stimulating face is rotated (Wang et al., 1996, 1998). The continuous mapping of different face views may allow one face view to be generalized to neighboring views through horizontal excitation (Wang et al., 1998). Thus, the present study addresses this question psychophysically and investigates whether seeing various views of the same face in motion reduces the viewpoint dependence of neighboring views. A match-to-sample task was used: in each trial, a movie of a rotating face was presented for 240msec (sample), followed by a random noise mask for 240msec, then two static faces- views not included in the movie- were shown side by side (match faces). The observer's task was to choose which of the two faces matched the sample identity. The sample face rotated from 0.7° to 6°, 6° to 0.7°, 14° to 19.3°, or 19.3° to 14°. Match face views consisted of 0°, 6.7°, 13.3°, and 20°. As predicted, seeing the face rotating in a particular direction aids identity discrimination of neighboring views along the direction of rotation.

A14 *114* **The 3/4 view effect and the rotation information in infants' face recognition**

Emi Nakato[1] (enakato@komazawa-u.ac.jp), So Kanazawa[2], Masami K Yamaguchi[3]; [1]Department of Psychology, Komazawa University, 1-23-1 Komazawa, Setagaya-ku, Tokyo, 154-8525, Japan., [2]Department of Psychology, Shukutoku University, 200 Daiganji, Chiba-city, Chiba, 260-8701, Japan., [3]Department of Psychology, Chuo University, 742-1 Higashinakano, Hachioujii-City, Tokyo 192-0393, Japan.

Recently, human adults face studies had indicated that the facial angle was one of the important factor in face recognition; Bruce & Valentine (1987) showed that 3/4 views had a superiority in face recognition, and Pike et al. (1997) indicated that the rotation information could facilitate face recognition. On the contrary, there were no studies to show such effects in infants. Fagan (1979) showed that 7-month-old infants could discriminate unfamiliar faces on different pose. In this study we investigated whether the 3/4 view effect and the effect of the rotation information would in exist infants around these age.Eleven female face images were taken by steps of 9 degrees from the frontal view to the profile view. These face images were presented in regular frame-order (the rotation condition) or in random frame-order (the random condition). First, infants were familiarized with a female face either in the rotation or the random condition for 80 sec. Following the familiarization, infants were tested with a pair of familiar and unfamiliar female 3/4 views for two 10 sec trials. These 3/4 views were novel views, that is opposite views, from the familiarization.Results showed that only 6- to 8-month-olds could identify familiar female on the novel 3/4 view in the rotation condition. It suggests that the rotation information promotes recognition of the novel 3/4 view around 7-month-olds. The rotation information could help to produce the 3D structural images (Pike et al., 1997). These infants might have such 3D structural image of the face.

Acknowledgment: Supported by RISTEX, Japan Science and Technology Agency, and a Grant-in-Aid for scientific research (15500172) from the Japan Society for the Promotion of Science.

A15 *115* **Similarities and differences between humans' and Squirrel monkeys' (Saimili sciureus) facial recognition strategies**

Ryuzaburo Nakata[1,2] (ryu3@din.or.jp), Yoshihisa Osada[1]; [1]Rikkyo University, [2]JSPS Research Fellow

PURPOSE: Previous research has shown both squirrel monkeys and humans can identify individual faces of their own species more easily than those of other species. But it is unclear whether both species utilize the same cues to identify individual faces. This is the question we explore in this research.

METHOD: Subjects were two squirrel monkeys and two humans. The stimuli were faces of squirrel monkeys and humans, which were unfamiliar to subjects. In the training phase, subjects were trained to discriminate between two squirrel monkey faces or between two human faces so as to achieve a performance of 80% correct. In the test phase, we introduced 4 types of probe stimuli that showed only some facial features of the training stimuli (1:configuration of eyes, 2:mouth and nose, 3:only one eye, 4: outer facial boundary).

RESULTS AND DISCUSSION: Both species can identify individual faces of their own species better than those of other species. The configuration of eyes had a significant effect (binominal test < .05) on the identification performance of both species. Furthermore, monkeys unlike humans could use outside features of monkey faces. These results suggest that squirrel monkeys may have two strategies for facial processing. One strategy is similar to that of humans (processing eye configurations), while the other is specific to squirrel monkeys (the use of external features that are discriminative for squirrel monkey faces). This divergence of facial processing may due to the differential of their processing demands environments, specifically the con-specifics.

Acknowledgment: This work was supported by RARC(Rikkyo Amusement Research Center) and JSPS Research Fellowships for Young Scientists

Perceptual Organization: 2D Shape

A16 *116* **Early processes mediate Café Wall illusion**

Yusuke Tani[1] (tani@l.u-tokyo.ac.jp), Takao Sato[1]; [1]Department of Psychology, the University of Tokyo

We conducted two psychophysical experiments to show that mechanisms mediating Café Wall illusion are situated within lower levels of the visual system.The stimuli for the two experiments consisted of three sinusoidal gratings and two gray lines that were presented on a CRT screen. The task for both experiments was to judge the direction of illusory tilt of gray lines (2AFC). In the first experiment, each stimulus was divided into two parts, the top and bottom gratings and the middle. Subjects observed them through a mirror stereoscope and fused them as one figure. The stimulus subtended 5.7(H) x 4.4(V) deg, and the spatial frequency for the gratings was 0.35 cpd. In the second experiment, the stimuli were flickered in counterphase. The gratings' spatial frequency appears doubled at higher temporal frequencies because of the frequency doubling illusion (Kelly, 1966). We examined whether the apparent frequency, thus phase difference induced by the frequency-doubling illusion affected the direction of illusory tilt. The stimuli subtended 8(H) x 4.48(V) deg, and the spatial frequency for the grating was 0.25 cpd. The modulation frequency was varied between 5 and 60 Hz.In the first experiment, the dichoptically presented Café Wall figure did not, or very faintly, if any, induce the illusory tilt. In the second experiment, the physical, not the apparent phase difference determined the direction of the illusory tilt.These results suggested that Café Wall illusion occurs at a level before binocular fusion, and this could be earlier than the cortex.

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A17 *117* **The Brain knows about the Oblique Effect**

Tobias Borra[1] (t.borra@fss.uu.nl), Ignace T.C. Hooge[1], Frans A.J. Verstraten[1]; [1]Psychonomics Division, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands

Vertical and horizontal orientations are perceived more precisely than oblique orientations (the oblique effect). Visual perception of object orientation is thought to be mediated by salient axes of symmetry and elongation (Boutsen & Marendaz, 2001). We expect that in objects with multiple salient axes, observers will select the axis affording the best orientation discrimination. This will result in lower JNDs in object orientation when one or more of the salient axes are either vertical or horizontal, compared to salient axes that are oblique. We designed three experiments, using dot-stimuli to prevent interference of local and global contours; a two-dot 'line' stimulus, a three-dot 'triangle' stimulus and a four-dot 'square' stimulus, with one, three and four salient axes, respectively. Observers were presented with two temporally separated stimulus orientations and were instructed to judge the orientation of the second stimulus compared to the first. We measured JNDs for various object orientations using interleaved staircases.The results suggest that observers use different object axes, depending on the axial orientation. This results in the predicted lower JNDs for the oblique stimulus orientations where the salient axis is vertical or horizontal. We conclude that observers are capable of selecting the most informative axes when judging visual object orientations.

A18 *118* **No Lateral-Vertical Asymmetry in the Processing of Mirror Images in the Monkey**

Luke Woloszyn[1] (luke_woloszyn@brown.edu), David L. Sheinberg[1]; [1]Department of Neuroscience, Brown University, Providence, RI 02912

Mirror image confusion refers to the phenomenon whereby views of visual objects reflected about a central axis are easily confused. Behavioral

studies in various animal species have led to the conclusion that lateral mirror images are inherently more confusable than vertical mirror images. None of these studies, however, used large batteries of complex, unfamiliar visual patterns as test stimuli. In this study we trained two monkeys to perform a delayed match-to-sample task in which the non-match item was sometimes either a lateral or vertical mirror reflection of the sample. To eliminate any contribution of prior experience, we developed a stimulus generation method that ensured that novel objects containing no axis of symmetry could be used on a trial-by-trial basis. Across a large number of test sessions, we found no evidence that monkeys are more likely to confuse horizontally reflected mirror images than their vertical mirror image counterparts. This trend was seen throughout many days of experimental testing, during which both monkeys showed steady overall task improvement. We attribute the lack of exaggerated lateral versus vertical mirror image confusion to the use of both novel and complex stimuli, and suggest that previously observed biases in mirror image confusion are likely a result of either attention or experience, but not inherent perceptual biases.

A19 *119* A neural model of symmetry perception for curved shapes.

Frederic J.A.M. Poirier[1] (poirier@hpl.cvr.yorku.ca), Hugh R. Wilson[1]; [1]Centre for Vision Research, York University

Introduction. Using global shape cues, humans discriminate circles from radial frequency (RF) patterns at hyperacuity levels (Wilkinson, Wilson & Habak, VR1998). Here, we extend our neural model of RF perception (Poirier & Wilson, VSS2005) to account for human perception of symmetry in biologically-relevant shapes (Wilson & Wilkinson, VR2002).Model. Object position is estimated using large-scale non-Fourier V4-like concentric units, which encode the center of concentric contour segments across orientations. Further processing occurs relative to the estimated object center, providing translation invariance. Shape information is retrieved using curvature mechanisms' responses to visual contours. Curvature mechanisms are scaled with distance from object center, providing scale invariance. Curvature responses were highest at points of maximum curvature, encoding their number, amplitudes, and locations. Symmetry was defined as the correlation of neural curvature responses on either side of a symmetry axis, and the symmetry axis' orientation was defined as the orientation at which symmetry peaked. Results. Symmetry perception for faces and complex shapes depends on whether curvature extrema positions are symmetrical (Wilson & Wilkinson, VR2002), which depends on the phase-alignment of the component RFs used to create the shape. In our model, symmetry decreased faster with phase-misalignment for stimuli associated with low thresholds in psychophysical experiments. Discussion. This represents the first model of symmetry shape perception for biologically-relevant shapes (e.g. faces) defined as complex RF patterns. Our model is compatible with recent data on V4 and IT population coding (e.g. Brincat & Connor, NatNeuro2004; Pasupathy & Connor, NatNeuro2002).

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A20 *120* Sensitivity to geometry in male and female children and adults in the U.S. and in an Amazonian indigene group

Ariel D. Grace[1] (agrace@wjh.harvard.edu), Veronique Izard[2], Kristin Shutts[1], Stanislas Dehaene[2], Elizabeth S. Spelke[1]; [1]Psychology Department, Harvard University, [2]INSERM-CEA Cognitive Neuroimaging Unit, Service Hospitalier Frédéric Joliot

Research on cognitive sex differences reveals a male advantage in certain tasks of spatial ability but the extent, development, and universality of this advantage merit further exploration. We tested adults and 6-10-year-old children in Boston and in a set of Munduruku villages in the Brazilian Amazon on a new measure of sensitivity to a variety of geometrical relationships in visual arrays of points, lines, and figures (Dehaene, Izard, Pica & Spelke, in press; after Franco & Sperry, 1977). On each of 45 trials, participants saw five arrays depicting the same geometrical property in otherwise variable figures, and a sixth, randomly placed array that lacked the target property. Their task was to detect the outlying figure. Overall, performance did not differ by sex in any sample. U.S. adult males and females showed equal overall performance, although two items testing chirality showed a marginal male advantage, consistent with the findings of many studies of "mental rotation" (Hyde, 2005). U.S. children also showed no overall sex difference, but males performed reliably better on one item testing chirality, whereas females performed reliably better on two items testing symmetry and polygons. In the Munduruku sample, there was again no overall sex difference, but males performed slightly better on symmetry items. Most important, item by item performance of the males and females was highly correlated in both U.S. and Munduruku samples and in both children and adults. These correlations provide evidence for strong invariance in core sensitivity to geometry across age, culture, and gender.

A21 *121* Estimation of Three-Body Center of Mass: Effects of Size Ratio and Lightness.

Jay Friedenberg[1] (friedenberg@optonline.net), Bruce Liby[1]; [1]Manhattan College

Undergraduates estimated the center of mass for three equidistant black-filled dots varying in size. The triangular configuration appeared at different orientations. When one dot was larger than the other two, size ratio alone influenced the results and the arm of the response distribution pointed to the largest dot. When two dots were large and equally sized, the distribution pointed downward and toward the dot nearest 180 degrees. When all dots were the same size, responses aligned along the triangle's horizontal symmetry axis. A combination of three factors explains the results: size ratio, extrinsic vertical and horizontal spatial axes and the orientation of the triangle's intrinsic symmetry axes. In a second experiment we varied dot lightness while holding size ratio constant. There was no strong grouping effect of dots with shared lightness values at least at the sizes and distances we employed. This suggests that size is more important than lightness in determining a participant's subjective perception of mass.

A22 *122* Apparent Motion, Phase Relations, and the Perception of Form

Thomas Malloy[1] (malloy@psych.utah.edu), Gary Jensen[1]; [1]Department of Psychology, University of Utah

Gregory Bateson construes mental process as the flow and transforms of differences in a system. Stuart Kauffman uses NK Boolean systems to model the emergence of order in biological evolution. Because the Boolean base (0, 1) maps to Bateson's idea of difference, we simulate Bateson's epistemology with a Kauffman Boolean system. Bateson's asserts that knowledge (in this case visual form) emerges from the relations among multiple (at least two) descriptions, where a description is here defined as a flow of dynamic and systemic process that encodes differences. We therefore propose a perceptual model in which visual form emerges from the phase relations between two such descriptions. Though we are not modeling neural activity per se but rather an abstract difference-based epistemology, to be concrete we can say the first description might correspond to retinal activity; in that case retinal activity is modeled as a discrete dynamic system that falls into different attractor cycles with different fundamental frequencies. The second description is a representational process based on apparent motion phenomena. Using Java Applets we demonstrate how dynamic form perception might emerge from the phase relations between the first and second descriptions; that is, we will demonstrate how changing the phase relations between two flows of Boolean difference will cause different forms to pop out. Moreover, two classes of forms, fundamental and derived, emerge from these phase relations. Our demonstrations suggest that the phase relations that produce apparent motion can also produce visual form perception.

Preview Applets at: www.psych.utah.edu/dynamic_systems/exemplar1 and at: www.psych.utah.edu/dynamic_systems/exemplar2

URL: www.psych.utah.edu/dynamic_systems/exemplar1

A23 *123* Shape can bias angle perception: an angle illusion

Graeme J. Kennedy[1] (Graeme.Kennedy@gcal.ac.uk), Harry S. Orbach[1], Gunter Loffler[1]; [1]Department of Vision Sciences, Glasgow Caledonian University, Glasgow, G4 0BA, UK

Introduction: There are numerous examples of geometric illusions based on the distortion of angles (e.g. Zöllner Illusion). We present evidence for what we believe to be a novel illusion where angles are misjudged depending on the triangular shape containing the angle.

Methods: A temporal 2AFC paradigm was used to measure angle discrimination. Individual trials showed an isosceles and a scalene triangle (various scalene shapes given by different side length ratios) and subjects were asked to judge which of the two contained the more obtuse angle. The point of subjective equality, defined as the angle that yielded a judgement of "more obtuse" in 50% of the trials, was determined from psychometric functions. Five reference angles were tested.

Results: For a reference angle of 60 degrees, angles embedded in isosceles triangles were judged to be 7.3, 15.2 and 17.4 degrees larger than angles embedded in scalene triangles with side length ratios of 1.7:1, 3.0:1 and 5.7:1, respectively. This illusion holds for different reference angles: for angles of 30, 50, 60, 90 and 120 degrees respectively, angles in isosceles triangles were judged to be 10.4, 18.0, 15.2, 12.3 and 11.9 degrees larger than angles in scalene triangles (side length ratio 3:1).

Conclusions: An angle embedded in an isosceles triangle is judged substantially larger than the same angle embedded in a scalene triangle. The effect that the global triangular shape has on the local angle judgement is paradoxical: a shorter side opposite the angle yields a larger angle judgement.

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A24 *124* Bayesian estimation of the shape skeleton

Jacob Feldman[1] (jacob@ruccs.rutgers.edu), Manish Singh[1]; [1]Dept. of Psychology, Center for Cognitive Science, Rutgers University - New Brunswick

Skeletal representations of shape have attracted enormous interest ever since their introduction by Blum (1973). But computation of the shape skeleton is notoriously problematic, (e.g. extremely sensitive to noise in the bounding contour). In conventional approaches, the shape skeleton has generally been defined by a fixed geometric construction and computed via a deterministic procedure. We introduce a new probabilistic approach to computing the shape skeleton, in which the shape is conceived as the outcome of a stochastic generative process in which a skeleton is randomly generated, and then sprouts "ribs" of random lengths, whose endpoints when joined define the shape's bounding contour. This stochastic shape model includes a prior probability density over shape skeletons (a generalization of our previous work on contour information), and a likelihood density over shapes given a skeleton. Then computation of the shape skeleton becomes a conventional Bayesian estimation problem, in which the observer estimates the skeleton that maximizes the posterior probability of the observed shape (the "MAP skeleton"). Equivalently, the procedure can be seen as minimizing the description length of the shape, i.e. the sum of the negative log prior (complexity) of the skeleton plus the negative log likelihood of the shape given the skeleton. In this approach, small deformations along the bounding contours do not lead to substantial changes in the skeleton, but rather are modeled as noise in the stochastic rib-length function. We present examples showing that the MAP skeleton corresponds closely to the intuitive branching structure for a variety of shapes.

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Working Memory

A25 *125* Visual Short-Term Memory and Context Memory for Grating Contrast

Ling Lin[1] (llin3@uci.edu), George Sperling[1]; [1]Department of Cognitive Sciences, University of California, Irvine

To study the decay of visual Short-Term Memory for contrast, we adapt a paradigm original used by Lu, Williamson and Kaufman (Science, 258, 1668-1669, 1992) for the study of auditory STM for loudness. We explicitly create an intermediate-term memory of the average contrast of all the stimuli in the session (context memory). The STM of the contrast of a particular stimulus decays to the context memory. In Experiment 1, a 0.27 sec exposure of a narrow-bandwidth Gabor patch of contrast 0.3 is followed after a variable delay by a second Gabor patch whose contrast is randomly chosen from a set which has a mean contrast of 0.34 in HIGH sessions and a mean of 0.26 in LOW sessions. Observers judge which stimulus, 1 or 2, has the higher contrast. Experiment 2 uses a roving standard. Experiment 3 uses a fixed standard and broad-bandwidth stimuli. Results. Context stimuli have no effect on simultaneous judgments but influence judgments more-and-more as delay increases. STM for the contrast of fixed-contrast narrow-bandwidth Gabors is poor. With a roving standard or with fixed-standard broad-bandwidth Gabors, exponential decay of STM to context memory occurs with a time-constant of several seconds that depends on the observer. The Standard Deviation of judgments does not vary across delays. The constancy of SD across delays suggests that the same memory comparison register is used in all conditions; the contents consist of decreasing proportions of STM and increasing proportions of context memory as delay increases.

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A26 *126* The Updating of Object-Position Binding in Visual Short-Term Memory

Andrew Hollingworth[1] (andrew-hollingworth@uiowa.edu), David L. Sacks[1]; [1]The University of Iowa

The object file framework of Kahneman et al. (1992) holds that representations of an object's properties (e.g., visual form or identity) are indexed to a spatial location, which is updated with changes in object position. The primary evidence supporting these claims came from position-specific priming effects in letter naming. The timecourse of priming, the maintenance of object-file representations across saccades, and position effects in visual short-term memory (VSTM) raise the possibility that object-file representations and VSTM object representations might be one and the same. However, traditional object-file experiments did not require memory to perform the task and thus cannot speak to this possibility. In the present study, we examined the updating of object-position binding in a change-detection paradigm that required VSTM. Participants saw a set of empty boxes. The boxes were filled by objects (either color patches or real-world objects). The objects were removed, and the boxes moved to trade positions (yielding the same spatial configuration before and after movement). The objects reappeared, and memory was tested by change detection. At test, the objects either appeared in the updated positions, in their original positions, or in positions corresponding to neither of these (no correspondence). Change detection was faster and more accurate in the updated-positions condition than in the no-correspondence condition, providing initial evidence that object files and VSTM are indeed the same system. Intriguingly, performance in the original-positions condition was also superior to that in the no-correspondence condition, suggesting multiple position-bound representations per object or severe capacity limits on updating.

A27 *127* The relationship between fMRI adaptation and repetition priming of visually presented objects

Tzvi Ganel[1] (tganel@bgu.ac.il), Claudia LR Gonzalez[2], Kenneth F Valyear[2], Jody C Culham[2], Melvyn A Goodale[2], Stefan Köhler[2]; [1]Department of Behavioral Sciences, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel, [2]Department of Psychology and CIHR Group on Action and Perception, University of Western Ontario, London, Ontario N6A 5C2, Canada

The neural correlates of fMRI adaptation and repetition priming provide useful insight as to how visual information is perceived and stored in the brain. Yet, although both phenomena are typically associated with reduced activation in visually responsive brain regions, it is presently unknown whether they rely on common or dissociable neural mechanisms. In an event-related fMRI experiment, we manipulated fMRI adaptation and repetition priming orthogonally. Subjects made comparative size judgments for pairs of visual stimuli that depicted either the same or different objects; some of the pairs presented during scanning had been shown previously and others were new. This design allowed us to examine whether object-selective regions in occipital and temporal cortex were sensitive to adaptation, priming, or both. Critically, it also allowed us to test whether any region showing sensitivity to both manipulations displayed interactive or additive effects. Only a partial overlap was found between areas that were sensitive to fMRI adaptation and those sensitive to repetition priming. Moreover, in most of the object-selective regions that showed both effects, the reduced activation associated with the two phenomena were additive rather than interactive. Together, these findings suggest that fMRI adaptation and repetition priming can be dissociated from one another in terms of their neural mechanisms.

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A28 *128* Effects of decay and interference on visual working memory for color

Rachel S. Sussman[1] (sussman@fas.harvard.edu), Yuhong Jiang[1]; [1]Harvard University

Aim: Given visual working memory's limited capacity, there must be rules which govern when information is thrown out of memory. This series of experiments examines the roles of decay and interference in that process. **Method:** Participants viewed two arrays of 8 colors separated by a lag, and compared the color at a location indicated by a central arrow cue presented 400 ms before the test array. Decay was measured by varying the lag between the first display and the cue from 400 - 1600 ms. Interference was examined by comparing three conditions: (1) the cue was presented alone, (2) the central cue was accompanied by a peripheral cue consisting of a bicolor square at the cued location, (3) the cue was accompanied by a circular array of bicolor squares with a blank space at the cued location. **Results:** Accuracy declined only slightly over the 1600 ms lag. However, accuracy was impaired by about 15% in conditions 2 and 3 (interference) relative to condition 1 (no interference). Since this interference occurs up to 1600 ms after the initial display, it must target memory retrieval rather than memory encoding processes. Moreover, since the interference is present even when no stimulus is shown at the cued location (condition 3), it must not be spatially specific. **Conclusion:** Interference with visual working memory is distinguished from more familiar perceptual masking processes by its action over long time lags and its apparent insensitivity to spatial location. Given new visual input, VWM seems obligated to update its content.

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A29 *129* A Dynamic Neural Field Approach to Multi-Item VisualWorking Memory and Change Detection

Jeffrey S. Johnson[1] (jeffrey-johnson-2@uiowa.edu), John P. Spencer[1]; [1]University of Iowa

Many visually-guided behaviors rely on the ability to maintain visual information in working memory. To date, however, there are few formal models of visual working memory (VWM) that directly interface with the empirical literature on this basic cognitive system. In particular, no current theories address both the maintenance of multiple items in VWM *and* the process of change detection within a neurally-plausible framework. Here we describe such an approach, along with data from a change detection study that confirms a novel prediction of our model.

Our model builds upon the Dynamic Field Theory of spatial working memory developed by Spencer and colleagues (Spencer & Schöner, 2003), and consists of a 1D feature WM field (e.g., color WM) coupled to a 1D "novelty" field. Neurons within each field interact via a local excitation/lateral inhibition function that allows them to form multiple, self-sustaining activation peaks in response to input. Critically, these peaks remain even when input is removed. Change detection arises from the interaction between the WM and novelty fields. These fields are coupled together in an inhibitory fashion that leads to emergent decisions about change when test stimuli are presented.

Simulations of the model have generated several novel predictions. For example, the model predicts *enhanced change detection when items are highly similar*- a counterintuitive prediction that has been confirmed in a recent study comparing color change detection accuracy for similar vs. distinct colors. We present these findings and contrast the DNFT with theories of VWM that rely on synchronous oscillations.

A30 *130* Colour-Specific Deficits in Explicit Visual Working Memory: A Case Study

Pauline M Pearson[1] (p.pearson@uwinnipeg.ca), Lorna S Jakobson[2]; [1]Department of Psychology, University of Winnipeg, Winnipeg, MB, Canada, [2]Department of Psychology, University of Manitoba, Winnipeg, MB, Canada

We previously described an individual, QP, who developed a selective deficit in colour working memory and imagery subsequent to a closed head injury. Most surprising was the fact that this deficit appeared to affect her ability to recall or imagine red but not blue. In the present study, we conducted a comprehensive assessment of QP's colour discrimination performance (Cambridge Colour Vision Test). This test revealed that the axis ratio(1.5) and length(0.0098) of QP's colour discrimination ellipses, as well as the lengths of the protan(0.004), deutan(0.004) and tritan(0.006) confusion vectors, were all within the normal range. To determine how specific her colour memory deficit was, we repeated our original delayed match-to-sample colour memory task using two new hues: green and yellow. QP's ability to recall both of these hues over an 8 s delay was dramatically impaired. Unlike memory for red, which we had previously shown was most affected when the target and distractors were quite similar in hue, QP's difficulties with green and yellow were evident even when target and distractor were perceptually quite different. Together with the previously reported data, the present findings suggest that QP's memory losses are asymmetrical about the colour axes, with the colour memory deficit for green exceeding that for red, and that for yellow exceeding that for blue. These data suggest that, consistent with recent suggestions of functional specialization for memory of different object categories and the perception of colour categories, there may be functional specialization for memory of different colour categories.

A31 *131* Neural dissociation of visual working memory consolidation and maintenance.

J. Jay Todd[1,2,3] (jay.todd@vanderbilt.edu), Stephenie Harrison[1,2,3], René Marois[1,2,3]; [1]Department of Psychology, [2]Vanderbilt Vision Research Center, [3]Vanderbilt University

Encoding of information into visual working memory (VWM), also known as short-term consolidation, is thought to represent a distinct process from maintenance of information (Jolicoeur & Dell'Acqua, 1998; Woodman & Vogel, 2004). In addition, VWM consolidation has been theorized to

occupy a central role in conscious perception. Despite the fact that it has been the focus of much behavioral work, and that it is mechanistically dissociable from VWM maintenance, the neural substrates of VWM consolidation are poorly understood. Here we used functional magnetic resonance imaging (fMRI) to determine whether VWM consolidation is neurally dissociable from VWM maintenance. Participants performed a delayed recognition task that involved encoding and maintaining a variable number of colored discs over a retention interval (9.2s) that was long enough to distinguish encoding-related from maintenance-related activity. In two independent groups of subjects, we observed load-dependent, consolidation-related activity in lateral occipital cortex. By contrast, this brain region showed no maintenance-related activity. Control experiments indicate that the consolidation-related activity cannot be accounted for by perceptual processing. Finally, although several frontal and parietal cortex regions showed evidence of both encoding and maintenance-related activity, none showed consolidation-specific activity. Taken together, these results suggest that VWM consolidation is neurally dissociable from VWM maintenance.

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A32 *132* Psychophysical Visual Memory Data and Their Neural Net Replications Indicate Sensory-Like Activity is Released from Storage

Thomy H. Nilsson[1] (nilsson@upei.ca); [1]University of Prince Edward Island

Memory matches of the hue of monochromatic light and the orientation of single lines and gratings were obtained after delays up to 24 seconds using an iterative procedure with one second stimulus presentations to control memory time. As memory time increased, there were minimal shifts in the average hue or angle of the matches but their standard deviations increased as a negative exponential function with a half-life of 20-30 seconds. Memory difference thresholds as a function of wavelength and angle resembled the sensory difference thresholds. As memory time increased, the memory discrimination functions did not decay into randomness. Rather, their shape became more exaggerated over time. This suggests that memory matching involves comparing a sensory response with activity from memory that resembles a sensory response. To determine whether the exaggeration of memory discrimination functions could arise from an increase in noise with time in memory, a neural network model of the memory matching task was constructed in QuattroPro using macro functions, random number generators, and a time-varying correlation matrix. The model demonstrates that the obtained memory discrimination functions can be replicated simply by adding noise to a stored transformation of the sensory response. This suggests that no matter how sensory information is actually stored, its retrieval produces activity that is similar to the original visual response.

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A33 *133* Control Processes in Working Memory

Andrew McCollough[1] (awm@darkwing.uoregon.edu), Edward Vogel[1]; [1]University of Oregon

Visual working memory is a highly capacity limited system maintaining only three to four objects at a time. This limitation requires mechanisms which facilitate the continual updating of the contents of working memory, which involves the addition of new items and the deletion of old items from being held in this limited space. Here we report a neurophysiological measure of this memory updating mechanism in humans. Using a visual running memory span task while simultaneously recording event related potentials we observe that the appending of sub-capacity arrays items into working memory is perfectly additive, and remains additive irrespective of temporal and spatial gaps. That is, the mean contralateral delay activity (CDA) amplitude for an array size of four is equivalent whether the items are all presented in a single array or distributed across sequential arrays, as well as whether the sequential array items appear at the same location or in different locations. The appending process also appears to be independent of maintenance mechanisms of working memory, such that there were no latency costs for adding items into working memory when the subject was already holding items in memory. Furthermore, we examined the process of voluntarily deleting of items from working memory by "swapping" them with new items and found that the efficiency of this aspect of updating is predicted by an individual's particular memory capacity.

A34 *134* A Neural Network Account of Binding Discrete Items Into Working Memory Using a Distributed Pool of Flexible Resources

Brad Wyble[1] (bw5@kent.ac.uk), Howard Bowman[1]; [1]Centre for Cognitive Neuroscience and Cognitive Systems, University of Kent, Canterbury UK

It has recently been disputed whether working memory has a fixed capacity of 4 objects. Alvarez & Cavanagh (2004), for example, demonstrate that complex items appear to consume more resources than simple ones, reducing storage capacity. However, existing models of working memory have difficulty describing a system with a feature-based capacity limit spread over multiple items.We propose a neural network model of working memory that combines slot-based theories of discrete objects (Luck &Vogel, 1997) with signal detection accounts exhibiting increasing interference as memory load increases (Wilken & Ma, 2004).In an effort to elaborate the STST account of the attentional blink (Wyble & Bowman,2005), we model the binding of types (e.g. visual features) to tokens (Kanwisher, 1987) without resorting to synaptic modification or temporal synchrony. A single pool of binding nodes is used to hold onto multiple working memory traces. Encoding an object uses fixed weights to rapidly activate a fraction of the pool representing that object's features. This portion of the pool is self-sustaining and can be used to reconstruct the features of the object. This model uses distributed representations to avoid the combinatorial explosion inherent in encoding arbitrary combinations of features. The pool can also uniquely encode multiple copies of the same item. Complex objects are harder to encode, and therefore require a larger portion of the pool, reducing the observed capacity of working memory. Our model suggests that pairs of feature dimensions which can be bound into single objects without capacity cost have separate binding pools, insulating them from mutual interference.

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URL: http://www.cs.kent.ac.uk/people/staff/bw5/mypubs/bindingpool/bindingpool.html

A35 *135* Do perceptually challenging objects consume more working memory capacity?

Edward K. Vogel[1] (vogel@darkwing.uoregon.edu), Akiko Ikkai[1], Veronica Perez[1]; [1]University of Oregon

Visual working memory (VWM) is well known to be highly capacity-limited, typically estimated to be approximately 3 simple objects. Here we examined whether this capacity is best expressed in terms of the number of items or the perceptual requirements of the memory items. To do this we examined an ERP correlate of maintenance in VWM while subjects performed a memory task with items that were either perceptually demanding or posed minimal perceptual requirements. The amplitude of the Contralateral delay activity (CDA) has previously been shown to be strongly modulated by the number of items currently held in memory. In this study, we examined whether the amplitude of this activity would be modulated by the perceptual requirements of the memory items, irrespective of the number of items in the display. We manipulated the luminance of the memory items (bright vs. dim) as well as set size (2 items vs. 4 items) in a standard VWM task. Behaviorally, performance was significantly impaired on the perceptually-challenging dim trials as compared to the

bright items. However, despite this increase in the perceptual demands for the dim memory items, CDA amplitude was not modulated by the perceptual requirements imposed by the items in the display but was primarily sensitive to the number of items in the display. These results support models that propose that the number of items and not the properties of the items primarily determines the capacity of visual working memory.

A36 *136* Short-Term Visual Memory for Motion Path

Yankun J. Shen[1] (shen4@fas.harvard.edu), Tal Makovski[1], Yuhong Jiang[1]; [1]Department of Psychology, Harvard University

Aim: When we observe an instructor's motions to learn a new motor skill, or when we try to intercept a moving object undergoing characteristic motion, we must rely on short-term visual memory (VSTM) to record motion path(s). Our apparent ability to remember motion raises several questions: 1) How much of an object's motion can we remember? 2) Does memory performance depend on how the motion path is spelled out? 3) Does memory for motion path compete with other forms of VSTM? Methods: In each trial, participants must remember the path of either an object undergoing straight-line motion with abrupt turns or a static display of its path. Results: We found that path memory declined when the object underwent more turns, despite the constant overall path length. Memory for a static path display was better than memory for a moving path display, even when we tested recall with both static and moving probes. For moving displays, apparent motion was as difficult to remember as smooth motion. This memory showed no clear primacy or recency effects. Finally, path VSTM did not compete with VSTM for the moving object's color or shape. Conclusion: Although VSTM for a moving path is constrained by path complexity, we have found no evidence that it reduces VSTM performance for other properties of the moving object. How VSTM for motion path relates to multiple-object-tracking, and whether this memory is enhanced by active motor tracing remain to be explored.

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A37 *137* Suboptimal allocation of visual short term memory resources

Thomas Carlson[1,2] (tom@wjh.harvard.edu), George Alvarez[3]; [1]Helmholtz Institute, Psychonomics Division, Universiteit Utrecht, The Netherlands, [2]Department of Psychology, Harvard University, MA, USA, [3]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Our perception of the visual world is rich and full of detail, but our ability to retain this information, even over brief periods of time, is limited. In this study, we investigated whether observers allocate these precious limited resources optimally. Three colored disks were briefly presented and then disappeared. Following a short delay, one disk reappeared with either the same or a different color, and subjects reported whether or not a change occurred. Two types of trials were tested that differed in the fidelity of encoding necessary to perform the task. In High Discriminability (HD) trials, the changes were large, requiring only low fidelity encoding of the colors. In Low Discriminability (LD) trials, the changes were smaller, and as expected, subjects performed significantly worse on the more difficult LD trials. Is this performance difference due to a fixed resolution of visual memory, or to a difference in encoding strategy between the conditions? To address this question, we next asked subjects to perform the task in mixed trial blocks biased in the number of HD and LD trials with an 80/20 ratio. Interestingly, a significant improvement in performance was observed on LD trials when tested in blocks with a greater number of HD trials. Thus, it appears that subjects were employing a suboptimal encoding strategy for blocks with a greater number of LD trials. These results indicate that there is some flexibility in memory resource allocation and that under some circumstances, observers underestimate their capacity and resort to suboptimal encoding strategies.

A38 *138* The functional units of visual working memory: Objects or locations?

Verena Niederhoefer[1] (v.c.niederhoefer@web.de), Erik Blaser[1]; [1]Department of Psychology, University of Massachusetts Boston

Purpose: To address the controversy surrounding the organizational principle of Visual Working Memory (VWM) by critically testing object- versus location-based organization. **Background:** Many recent studies have claimed that VWM is 'object-based'; that is, that it takes no more effort for a person to remember, for instance, the color, size and shape of an object than it does to just remember any single feature. However, in nearly all of these studies each object occupied a unique location. It is possible then that VWM may actually be 'location-based'. **Method:** We distinguished between these two possibilities by asking observers to make judgments about *two* objects in *one* location. In the 500 msec memory phase, observers viewed two spatially superimposed Gabors, which were sufficiently different so as to segment into two objects (Blaser, et al., 2000). After a 900 msec blank delay, the two objects reappeared. Independently, the color and/or orientation of one or both of the objects potentially changed to a new value. We required observers to make same-different judgments on both dimensions; either both with respect to one of the superimposed objects ('within' condition) or one judgment about one object and the second about the other object ('between' condition). If VWM is object-based, performance in the within condition should be superior to performance in the between condition. **Results:** Data collection is ongoing, but results thus far are suggestive: there is no significant difference between performance in the within and between conditions, supporting location-based organization.

A39 *139* The Hippocampus and the Fidelity of Representations in Visual Working Memory

Youssef Ezzyat[1] (yezzyat@psych.upenn.edu), Ingrid Olson[1]; [1]Center for Cognitive Neuroscience, University of Pennsylvania

An important question in neuroscience research is how best to characterize the role of the medial temporal lobes (MTLs) in memory. Numerous theories have been offered to explain peculiarities in memory performance among patients with lesions to portions of the MTL. Some have suggested, for example, that the hippocampus is critical for episodic but not semantic memory, or that it is critical for long-term but not short-term forms of memory. We have recently found evidence contrary to the latter, long-standing finding: MTL amnesics have impaired visual working memory for locations, faces, and colors in MTL amnesics (Olson et al., VSS 2005). One explanation for that finding is that the function of some portion of the MTL, perhaps the hippocampus, is to rapidly encode high-fidelity representations. Such representations would be necessary for accurate visual working memory because details are frequently critical to the meaning of visual information. Conversely, it is generally possible to recover the salient information (conceptual meaning) encoded in verbal stimuli without recalling the precise wording that was used; verbal working memory tasks can therefore rely on more gist-like representations. We predicted that patients with MTL damage should exhibit (a) memory resolution problems; and (b) visual working memory, but not verbal working memory deficits. Results of experiments that manipulate similarity of stimulus and probe, time between stimulus and probe, and stimulus type will be discussed.

A40 *140* The mechanism of priming of pop-out: Stored short-term memory representation or perceptual level weight changes?

Hyunkyu Lee[1] (hyunkyu-lee@uiowa.edu), Michael C. Mozer[2], Shaun P. Vecera[1]; [1]University of Iowa, [2]University of Colorado

In pop-out search, repetition of an attention-driving feature facilitates search on the current trial. This priming of pop-out is known to be due to a decaying memory trace of the attention-focus features; however there is no

explicit consensus of the locus of the memory trace that influences the current trial. We investigated two possible mechanisms of priming of pop-out: a trace of the previous feature stored in visual short-term memory (VSTM) and a trace along perceptual level features. Experiment 1 replicated the priming of pop-out effect with a task of discriminating the gap location of odd-colored Landolt C shaped objects. In Experiment 2, a VSTM load was added to the pop-out search; occupying VSTM did not interfere with the priming of pop-out effect. In Experiment 3, we intervened an irrelevant task (discriminating the orientation of a pointing object) between pop-out search trials. Results showed that even though the intervening task was not related to the current pop-out search task, the color of the object for intervening task influenced on the current pop-out search task. These results suggest that the priming of pop-out might not be due to a memory trace in VSTM, but rather might be due to the perceptual level feature weight changes for attended objects.

A41 *141* Top-down attentional shift in object working memory task: A distinction between 'what' and 'where' in visual working memory still remains uncertain.

Jee-Won Ahn[1] (anji@yonsei.ac.kr), Su Keun Jeong[1], Min-Shik Kim[1]; [1]Department of Psychology, Yonsei Unviersity, Korea

Olson and Marshuetz (2005) argued that memory for 'where' influenced memory for 'what'. In their experiments, participants performed a probe change detection task to detect whether a single face within a white box was same or different, irrelevant of its position. Response slowed down only when the face changed its position within the box on the probe display (Local-Change), but not when the face and the box maintained their relative position (Global-Change), or when the face and the box retained their initial locations (No-Change). Olson and Marshuetz interpreted these results that the information of relative location was incidentally conveyed into memory even when only non-spatial information was required to be encoded. The present study explored a more plausible explanation for Olson and Marshuetz's findings. In the original experiments, the number of trials corresponding to the No-Change and Global-Change condition was greater than the Local-Change condition. We assumed that this inequality among conditions might enable participants to expect the location of the face probe within the box. To exclude this possibility, we controlled the number of trials across the conditions with or without the relative position change. With this manipulation, response was delayed only in the Global-Change condition, contrary to the results of Olson and Marshuetz. Such discrepancy suggests that the benefit of keeping the relative position in object working memory task is due more to a top-down attentional shift, than an incidental encoding of relative location.

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A42 *142* Visuospatial and object working memory in naturalistic scene change detection.

Bonnie L. Angelone[1] (angelone@rowan.edu), Melissa R. Beck[2], Kariann Amante[1], Kimberly E. Sikorski[1], Angela A. Materna[1]; [1]Rowan University, [2]Naval Research Laboratory

Previous research suggests that working memory plays an important role in visual search and change detection tasks. In fact, studies have shown that when visuospatial working memory is occupied by a task, visual search performance is compromised (Woodman & Luck, 2004). However, when an object working memory task is used to occupy working memory, visual search is efficient (Woodman, Vogel & Luck, 2001). Thus, different systems within working memory may have differential effects on visual search performance. In addition, research in our lab has shown that a concurrent object working memory task disrupts incidental change detection performance. Observers completed a working memory task in which they were asked to search the change detection video for a visual cue. Change detection was similar when observers had to store a complex visual cue compared to a simple visual cue. Building on this prior research, the present study examines change detection performance when different aspects of working memory are occupied. Observers complete a change detection task concurrently with a spatial or object working memory task similar to that used in previous research. If change detection in naturalistic scenes requires similar working memory mechanisms as visual search, visuospatial working memory and not object working memory will lead to increased change blindness.

Binocular Rivalry/Bistability/Awareness

A43 *143* Why do we see binocular rivalry? – Evidence from people who see it fused

Yoram S. Bonneh[1] (yoram.bonneh@weizmann.ac.il), Uri Polat[2], Misha Tsodyks[1]; [1]Department of Neurobiology, The Weizmann Institute of Science, 76100 Rehovot, Israel, [2]Department of Medicine, Goldschleger Eye Research Institute, Tel-Aviv University, Sheba Medical Center, 52621 Tel-Hashomer, Israel

Why don't we normally see a plaid when presented with two orthogonal gratings one in each eye? A common answer is that the system implements a physical constraint of one image being projected to the two eyes at one place and time. This constraint could be pre-wired and fixed or alternatively, acquired and modifiable. Here we provide evidence for the latter by reporting three types of observers who see fused plaids where normals see binocular rivalry (BR). One type (two observers) with a history of corrected strabismus and currently normal vision, had a high voluntary control over BR and most strikingly could perceive a fused plaid when instructed to do so for most (50-80%) of the time (e.g. 4 cpd, 40% or uneven contrast). Another type (one observer) had a 10 deg. opposite torsion in each eye following an accident, which caused him diplopya and constant perception of dichoptic plaids. The third type (four observers) consisted of individuals with strabismic amblyopia who could not perceive BR, but perceived dichoptic plaids when the contrast of the dominant eye was appropriately reduced. These cases suggest that rivalry reflects the natural outcome of a system that adapts to the statistics of the external input. Rare stimuli (such as local dichoptic plaids) are poorly represented while extensive exposure to such stimuli as in the cases reported here makes them interpretable and visible. To account for our observations we propose a computational model of BR, based on the ideas of statistical inference and representational learning.

A44 *144* Psilocybin slows binocular rivalry switching through serotonin modulation

Olivia Carter[1,2,3] (ocarter@wjh.harvard.edu), Jack Pettigrew[2], Felix Hasler[3], Guy Wallis[4], Franz Vollenweider[3]; [1]Vision Sciences Lab, Harvard University, [2]Vision Touch & Hearing Research Centre, University of Queensland, [3]Neuropsychopharmacology and Brain Imaging, University of Zurich Psychiatric Hospital, [4]Perception and Motor Systems Lab, University of Queensland

Binocular rivalry refers to the fluctuations in visual awareness/suppression that occur when different images are simultaneously presented to each eye. To explore the role of serotonin (5-HT) in binocular rivalry, this study investigated the affects of the hallucinogenic 5-HT1A&2A receptor agonist psilocybin (the active compound in "magic mushrooms"), alone and after pretreatment with the selective 5-HT2A antagonist ketanserin in ten healthy human subjects. Psilocybin significantly reduced the rate of binocular rivalry switching and increased the proportion of transitional/mixed percept experience. Ketanserin pretreatment blocked the majority of psilocybin's "positive" psychosis-like hallucinogenic symptoms, but had no influence on the psilocybin induced slowing of binocular rivalry switching or the "negative" symptoms associated with reduced arousal and vigilance. This finding directly links binocular rivalry switching rate to arousal and attention and suggests that psilocybin induced slowing of binocular rivalry is not 5-HT2A mediated, but instead may reflect a 5-HT1A mediated reduction of serotonin release from the brainstem raphe nuclei.

A45 *145* Unseen Objects Influence Estimation of Average Size

Sang Chul Chong[1] (scchong@yonsei.ac.kr), Randolph Blake[2]; [1]Graduate Program in Cognitive Science and Department of Psychology, Yonsei University, [2]Department of Psychology, Vanderbilt University

Statistical regularities have an influence on perception, as shown by visual search and visual learning[1-3]. Here we asked whether objects rendered invisible by binocular rivalry could nonetheless contribute to perception of average size within an array of different sized objects. First, we tested whether observers could estimate the mean size of an array distributed between the two eyes. Two arrays each containing 12 circles were briefly presented on either side of fixation. Observers judged which array had the larger mean size, under three presentation conditions 1) both arrays presented to a single eye, 2) one array presented to one eye and the other array to the other eye, 3) circles from both arrays randomly presented to one eye or the other. Accuracy was equivalently good for all three conditions, implying that mean size is computed at a central, post-binocular site. In the main experiment, observers performed the same task, this time with some circles (either 0, 4, 8, or 12 circles) suppressed from consciousness by the presence of high contrast rival targets in the opposite eye (we verified suppression's effectiveness). In a comparison condition we physically removed circles but left the rival targets, thus mimicking suppression's effect on visibility. Accuracy in the mean discrimination task was higher when some physically present circles were blocked from consciousness than when those circles were physically missing. Thus, statistical regularity *can* be extracted from a scene containing items that themselves fall outside of conscious awareness.

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A46 *146* Interactions between binocular rivalry and perceptual filling-in of visual phantoms

Emma Ferneyhough[1] (emma.ferneyhough@vanderbilt.edu), Ming Meng[2], Frank Tong[1]; [1]Psychology Department, Vanderbilt University, [2]Psychology Department, Princeton University

By investigating the interactions between binocular rivalry and filling-in, it may be possible to gain insight into how selective and constructive visual mechanisms interact to determine the outcome of conscious perception. Previously, we have shown that visual phantoms lead to neuronal filling-in of activity in V1 and V2, which can be dynamically gated by rivalry suppression (Meng, Remus & Tong, Nature Neuroscience, 2005). Here, we used psychophysical methods to study the temporal dynamics of filling-in by using flash suppression to trigger the phenomenal suppression or appearance of visual phantoms. In one condition, two vertical phantom-inducing gratings (separated by a horizontal gap) were presented to one eye for several seconds, followed by a dichoptic mask that consisted of two horizontal gratings presented to corresponding locations of the other eye. Observers reported when the visual phantom disappeared. In the opposite condition, two horizontal gratings were followed by two vertical phantom-inducing gratings, and observers reported when the phantom appeared. Stimulus contrasts and durations were adjusted to maximize dichoptic masking, and the gap size varied from 2-5 degrees. Although the onset of vertical grating masks eventually led to phantom filling-in, more time was required for filling-in to occur across larger gaps. In contrast, the horizontal masks led to equally rapid suppression of the visual phantom, independent of gap size. This asymmetry in the time required for perceptual completion and suppression of visual phantoms suggests that mechanisms involved in rivalry suppression precede those involved in phantom filling-in.

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A47 *147* How to enhance the incidence of stimulus rivalry

Min-Suk Kang[1] (min-suk.kang@vanderbilt.edu), Randolph Blake[1,2]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center, Vanderbilt University

When two orthogonal gratings are rapidly flickered and repetitively swapped between the eyes, observers can experience slow alternations in perceptual dominance that transcend multiple swaps. Called stimulus rivalry, this intriguing phenomenon exemplifies a form perceptual bistability that does not require eye-of-origin information and, thus, reveals visual competition between alternative image interpretations. As originally described, stimulus rivalry is experienced within a rather narrow range of stimulus conditions, and this led us to examine whether that range could be expanded. Here we report a novel condition that promotes the incidence of stimulus rivalry. In the original stimulus rivalry paradigm, dissimilar patterns are rapidly and repetitively turned "on" and "off" while being exchanged between the eyes. In our first experiment, we replaced the "off" periods with dioptic presentation of a composite of the two rival targets, reasoning that this composite would reduce the impact of visual transients by establishing continuous stimulation in both eyes. Indeed, stimulus rivalry occurred over a wider range of spatial and temporal frequencies. A second experiment examined why the composite might work by measuring the incidence of stimulus rivalry for brief rival presentations immediately following prolonged adaptation to a static composite, a flickering composite or a gray background. Observers experienced stimulus rivalry significantly more often following both static and flickering adaptation, compared to the gray background. These findings expand the range of conditions yielding stimulus rivalry and offer suggestive reasons why stimulus rivalry circumvents interocular competition in the first place.

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A48 *148* Dynamical properties of second-order processing in binocular vision and rivalry

Jeounghoon Kim[1] (miru@kaist.ac.kr), Athena Buckthought[2], Hugh R. Wilson[2]; [1]Korea Advanced Institute of Science & Technology, Taejon, Korea, [2]Center for Vision Research, York University, Toronto, Canada

The importance of second-order processing in binocular vision has been documented for a decade. We investigated the dynamical properties of second-order binocular processing as analogous to those of motion processing revealed in motion aftereffects.

We examined possible binocular rivalry in second-order patterns with a static (sSO) or dynamic carrier (dSO). For the carrier, uncorrelated (both between eyes and over time) static or dynamic random dot fields whose contrasts were modulated at 1.5 cpd sinewave with orientations of ±45, ±15, or ±7.5 deg were used. The dominance durations for dSO were about twice as long than those for the comparable first-order luminance gratings at orientations of ±45 and ±15 deg while there was no rivalry at ±7.5 deg. However, for sSO, the perceptual alternations were much slower and hardly perceptible. The perceived depth (tilt) for sSO and dSO at small orientation disparities was measured and about 50% more disparity was needed to match the depth of sSO to that with dSO.

We also investigated possible hysteresis effects in the transition between depth and rivalry for sSO and dSO. A sequence of the sSO or dSO with orientation disparities (0-40 deg) was presented in ascending or descending order. There were substantial hysteresis effects for dSO but the effects were greatly reduced for sSO.

The results suggest that second-order processing in binocular vision and motion have similar dynamical properties. An expansion of current neural models incorporating first-order and delayed second-order visual processing can readily explain our results.

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A49 *149* **Visibility modulation of rivalrous color flashes in the flash-suppression paradigm: Stimulus-specific modulation dominates over a wide range of temporal parameters**

Eiji Kimura[1] (kimura@bun.L.chiba-u.ac.jp), Satoru Abe[1], Ken Goryo[1]; [1]Dept. of Psychology, Faculty of Letters, Chiba University

When two dissimilar flashes are presented dichoptically, observers usually experience binocular rivalry. Without changing the rivalrous flashes themselves, their visibility can be modulated by presenting a monocular stimulus prior to the rivalrous flashes (visibility modulation, VM). The VM has been demonstrated, mainly with spatial patterns, to occur in an eye-specific fashion ("flash suppression"; Wolfe, 1984, Vision Research), but also in a stimulus-specific fashion (Ikeda & Morotomi, 2000, Psychologia). To elucidate further the nature of the VM, we investigated it using rivalrous red and green flashes by systematically varying temporal parameters of the preceding and test stimuli. We found that the VM occurred with preceding stimuli of longer duration (> 200 msec). Moreover, it occurred mostly in a stimulus-specific fashion; e.g., a green preceding stimulus phenomenally suppressed a green flash regardless of the eye to which it was presented, and thus the test flash appeared predominantly red. Eye-specific VM was observed only when the test duration was short (around 30 msec) and the ISI was also short (< 50 msec). Because similar modulation could not be observed when only the test flash ipsilateral (or contralateral) to the preceding stimulus was presented, light adaptation or forward masking is not a likely explanation for the VM. The VM probably reflects binocular interactions underlying binocular rivalry and the present results suggest that the nature of the interactions changes with temporal parameters. The VM in the flash-suppression paradigm may provide a good tool to explore how eye and stimulus rivalries occur depending upon stimulus parameters.

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A50 *150* **Stimulus flicker alters interocular grouping during binocular rivalry.**

Tomas Knapen[1] (t.h.j.knapen@phys.uu.nl), Chris Paffen[1], Ryota Kanai[2], Raymond van Ee[1]; [1]Helmholtz institute, Utrecht University, the Netherlands, [2]Division of Biology, California Institute of Technology

When the two eyes are presented with sufficiently different stimuli, the stimuli will engage in binocular rivalry. During binocular rivalry, a subject's perceptual state alternates between awareness of the stimulus presented to the right eye and that presented to the left eye. There are instances in which competition is not eye-based, but instead takes place between stimulus features, as is the case in flicker & switch rivalry [1]. This has been taken as evidence that binocular rivalry can occur at multiple levels of the visual processing hierarchy, i.e. at lower, monocular levels, and higher, eye-independent levels. In this view [2], ~20 Hz flicker decreases the relative weight of the lower, monocular levels, thereby increasing the relative importance of the eye-independent levels. Here we investigate interocular grouping using a Diaz-Caneja stimulus in conjunction with synchronous stimulus flicker. Our results indicate that stimulus flicker increases the total duration of interocularly bound percepts, and that this effect occurs for a range of temporal flicker frequencies. Furthermore, the use of contrast-inversion flicker causes a decrease of total dominance duration of the interocularly bound percepts. We conclude that different flickering regimes can be used to differentially stimulate lower and higher levels of visual processing involved in binocular rivalry. 1.Logothetis, N.K., Leopold, D.A., and Sheinberg, D.L. (1996). What is rivalling during binocular rivalry? Nature 380, 621-624.2.Wilson, H.R. (2003). Computational evidence for a rivalry hierarchy in vision. Proc Natl Acad Sci U S A 100, 14499-14503.

A51 *151* **A neural basis for perceptual memory during binocular rivalry in humans**

Philipp Sterzer[1,2] (p.sterzer@fil.ion.ucl.ac.uk), Geraint Rees[1,2]; [1]Wellcome Department of Imaging Neuroscience, University College London, [2]Institute of Cognitive Neuroscience, University College London

During binocular rivalry, two incompatible monocular images compete for perceptual dominance, with each being in turn visible for a few seconds while the other is suppressed. Why a percept should persist in awareness despite strong competition is unclear. Here, we investigated the hypothesis that a mnemonic process is involved in perceptual maintenance by measuring brain activity during temporary removal of rivalrous stimuli, when the stimulus perceived on reappearance tends to be the one in awareness as they disappeared.In a behavioral experiment, we demonstrated in 14 human subjects that percept maintenance across periods of stimulus removal was specific to binocular rivalry between monocularly presented face and grating stimuli, compared to a replay condition where the same stimuli where shown in physical alternation.The same group of subjects also underwent fMRI at 3T. During both rivalry and replay, activity in the fusiform face area (FFA) was greater during face as compared to grating perception, replicating previous findings. Critically, FFA activity during periods of stimulus removal was higher when the last stimulus in awareness before disappearance was a face, rather than a grating. This face-specific signal was specific to rivalry, as FFA activity following physical alternations of the stimuli did not show such a difference. Moreover, the individual tendency to maintain a face percept across periods of stimulus removal strongly correlated with activity in prefrontal and parietal regions previously implicated in working memory.In conclusion, our findings provide evidence for a new type of involuntary perceptual memory that stabilizes rivalrous visual perception.

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A52 *152* **Visual choice dynamics: Explaining repetition and predicting alternation of bistable percepts driven by stimulus ON/OFF timing**

Andre' J. Noest[1] (a.j.noest@bio.uu.nl), Raymond van Ee[2], Richard J.A. van Wezel[1]; [1]Functional Neurobiology Dept., Utrecht University, Padualaan 8, NL-3584-CH Utrecht, The Netherlands, [2]Dept. Physics of Man, Utrecht University, Princetonplein 5, NL-3584-CC Utrecht, The Netherlands

How does the visual system choose among multiple percepts evoked by ambiguous or inconsistent stimuli? Spontaneous percept-switching under steady viewing is broadly explained by slow neural adaptation and noise disrupting fast cross-inhibition that stabilizes either percept in the short term, but this does not explain why interrupting the stimulus often causes the same percept to reappear across many ON/OFF-cycles. In fact, we find that most existing proposals for explaining such percept repetition actually predict the converse: stimulus-locked percept alternation. We construct and analyze the simplest type of neural model that robustly captures both the spontaneous switching and the onset-induced choice process, and find that the choice dynamics depends crucially on how adaptation interacts with a hitherto neglected near-threshold neural input baseline (or slow coupling). Choice- and switching-events correspond to qualitatively different dynamical processes generated by a single, effectively 1-layer neural network (capable also of describing the percept-coding activity of several hierarchically coupled neural stages). Our model not only offers the first mechanistic explanation of how interruptions cause percept repetition, but also predicts other choice sequences. For example, stimulus-locked alternation of percepts is predicted for stimulus OFF-times well below the adaptation time. Our psychophysical experiment confirms this. No top-down signals are required to determine each choice of percept, but they may modulate parameters that shift the ON-OFF time regime in which the various sequences occur. The model also provides a mechanistic basis for `priming' and `bottom-up attention' effects on the resolution of perceptual ambiguities.

A53 *153* **Reversing how to think about ambiguous figure reversals: Spontaneous alternating by uninformed observers**

Stephen R Mitroff[1] (mitroff@duke.edu), David M Sobel[2], Alison Gopnik[3]; [1]Center for Cognitive Neuroscience, Department of Psychological and Brain Sciences, Duke University, [2]Department of Cognitive and Linguistic Sciences, Brown University, [3]Department of Psychology, University of California, Berkeley

Ambiguous figures, such as the Necker Cube or 'duck-rabbit,' are a special class of images that can give rise to multiple interpretations. Traditionally, switching between the possible interpretations of an ambiguous figure, or reversing one's interpretation, has been attributed to either top-down or bottom-up processes (e.g., either attributed to having knowledge of the nature of the ambiguity or attributed to a form of neuronal fatigue). However, here we present evidence that is incompatible with both sorts of explanations. Five- to nine-year old observers participated in four tasks – an ambiguous figures reversal task, two 'Theory of Mind' tasks, and a Piagetian number conservation task (the last being used as a measure of general cognitive abilities). Going against purely top-down explanations, one third of the observers reversed the ambiguous figures when completely uninformed about the ambiguity. Further, going against purely bottom-up explanations, those children who made these 'spontaneous' reversals were more likely to succeed on a high-order theory of mind task, even when factoring out general cognitive abilities. These findings suggest that reversing between the possible percepts of a bi-stable image can occur spontaneously and raise the possibility of there being necessary, but not sufficient, cognitive conditions for reversals to occur.

A54 *154* **Perceptual Bistability Modulated By Priming**

Rashmi Sundareswara[1] (sundares@cs.umn.edu), Christopher S Kallie[1], Paul R Schrater[1]; [1]University of Minnesota

Perceptual bistability for stimuli like the Necker cube refers to the phenomenon of spontaneously alternating percepts while viewing the same image of a wire cube. Theories about the source of bistability can be roughly divided into two categories: 1) switching is driven by non-inferential bottom-up processes like neural fatigue; 2) switching results from a change in interpretation between two highly likely possibilities. Based on the notion that Necker cube percepts are driven by an inferential process, we hypothesize that the higher the subjective probability of a particular interpretation/orientation, the more likely the observer will report that interpretation. The goal of our experiment was to try to bias the perception of the Necker cube's orientation by priming observers with images of unambiguously oriented objects, whose orientation corresponded to one of the two Necker cube percepts. Four different primer object images were presented for 5 seconds and varied in number, shape, size, and location, and were followed by a 10-15 second presentation of the Necker Cube. Perceptual state was recorded via button press at pseudo-random times indicated by beeps. The primer biased the initial percept strongly toward the orientation of the cube consistent with the primer for 0.5 to 5 seconds, suggesting that perceptual switching is consistent with an inferential process. These empirical results can be interpreted in a broader context of Bayesian models of perceptual inference implemented via sampling over time.

A55 *155* **Effects of feature changes of faded objects on its reentry to our awareness**

Daisuke Yoshino[1] (dyoshino@hi.is.uec.ac.jp), Yutaka Sakaguchi[1]; [1]The University of Electro-Communications

Perceptual fading could be induced immediately if an additional transient stimulus was presented near a target object (Kanai & Kamitani, 2003, Sakaguchi, 2004). The present study asked how faded objects came back to our awareness utilizing this immediate fading effect. In one experiment, we tested that the fading state was extinguished by changes in the target's shape (i.e., contour) or in its feature (i.e., color). The result showed that the target reappeared and came back to awareness by a slight change either in its shape or color. This cancellation was triggered even by change in a small part of the target region. In another experiment, we investigated the nature of color adaptation of a faded object. A colored object was brought into a fading state by the immediate fading effect. After a while, the fading was canceled by making the object color achromatic. Then, the revived achromatic object was perceived as if it were colored by the complementary color. This means that color adaptation proceeded automatically unaccompanied by awareness. Putting above facts together, it can be said that two different kinds of visual processing go on for the faded object: One that necessarily brings the object back to our awareness (i.e., physical change in the object feature), and one that proceeds without disturbing the fading state (i.e., color adaptation). This may suggest that our perceptual system could dissociate the external and internal changes of the object.

URL: http://www.hi.is.uec.ac.jp/illusion/fading.html

A56 *156* **The involvement of the superior colliculi in hemispherectomized subjects with blindsight.**

Sandra E Leh[1] (sandra@bic.mni.mcgill.ca), Kathy T Mullen[2], Alain Ptito[1]; [1]Cognitive Neuroscience Unit, Montreal Neurological Institute and Hospital, McGill University, Montreal, Canada, [2]Vision Research Department of Ophthalmology, McGill University, Montreal, Canada

Purpose: The ability in cortically blind patients to respond to visual stimuli without consciously experiencing has been termed 'blindsight'. The goal of this study is to investigate the involvement of the superior colliculi (SC) in mediating blindsight in hemispherectomized (HS) subjects.

Methods: We used the achromatic properties of collicular cells, which receive no input from S-cones, to design a reaction time test of a spatial summation effect (SSE), in which reaction times to two bilaterally presented stimuli are significantly faster compared to a single one. Achromatic (SC-visible) and blue/yellow (SC-invisible) gabor patches (1cpd, spatial =1cycle, temporal =250ms) were displayed on a CRT monitor and isolated either the achromatic or the S-cone opponent (blue/yellow) pathway. Stimuli were presented 10^{o} in the right, left, or in both visual fields. Stimulus onset-time was randomized at 0/500/1000ms with an ITI of 2000ms. Fixation was monitored with an eye tracker. Three HS subjects with and two without blindsight were tested.

Results: Subjects with blindsight showed a SSE to achromatic stimuli confirming the presence of blindsight. Presentation of blue/yellow stimuli, however, failed to alter reaction times demonstrating that their blindsight is colour-blind for blue/yellow stimuli. HS subjects without blindsight showed no SSE to either achromatic or blue/yellow stimuli.

Conclusions: Blindsight, at least in HS subjects, is color blind, and hence we conclude that it is mediated by the SC. Furthermore, by testing HS subjects we could reject the possibility that spared islands of visual cortex subtend blindsight.

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Change Detection

A57 *157* **Examining the factors that influence change detection**

Daniel J. Simons[1] (dsimons@uiuc.edu), Michael S. Ambinder[1], Xiaoang Irene Wan[1], Gabriel Nevarez[2], Eamon Caddigan[1]; [1]University of Illinois, [2]Cardiff University

A core conclusion from the change blindness literature is that change detection is enhanced when attention is exogenously cued to the change region (Scholl, 2000) or when attention is directed to the changed region due to its perceived salience (Wright, 2005) or semantic importance (Rensink et al, 1997). Most studies have examined the contribution of only one such factor, typically with a single change detection task and relatively few

images. We explored the factors that predict change detection using a large set of images, multiple tasks (flicker, one-shot, etc), and both judged and image-based measures of importance, salience, and magnitude. Judged salience predicted change detection performance, even after controlling for semantic centrality. Yet, semantic centrality made little contribution to detection performance after accounting for judged salience, suggesting that center-of-interest effects might be driven by image salience. However, salience judgments were only minimally correlated with the results of an automated salience analysis, suggesting that factors other than image salience contributed to judged salience. Interestingly, image-based salience of the original but not the changed image predicted change detection performance in the one-shot task. Image-based salience had less predictive value for the flicker task, suggesting the use of different attentional strategies in performing these tasks. We consider the implications of a variety of measures of change magnitude and centrality for the generalizability of inferences about the mechanisms of change detection across images and tasks.

A58 *158* No Evidence (So Far) of Accruing Representations of Change Over Time

Cathleen M. Moore[1] (cmm15@psu.edu), Lyndsey K. Lanagan[1]; [1]Pennsylvania State University

Background. Finding a changing item within a visual scene is difficult. A standard paradigm involves two versions of a scene, an original and one with some item changed (e.g., moved, altered in color, removed, etc.), presented in succession with a blank display between them. Observers may require many seconds to find these changes, yet in most cases the change is eventually found. Does the representation of change develop over the course of the search or is there no representation of change until it is attended? **Methods.** A priming procedure was incorporated into the standard paradigm. On some trials, a given change was presented for a variable number of cycles (0,1,5), often too few for the observer to find the change. The original change then stopped and a different change was presented until the observer found it. On a later trial, the original change was presented again until the observer found it. If final change-detection time is shorter for longer sub-detection exposure periods, it would indicate that some representation of the change had accrued over the course of the search. **Results.** Final change detection times were not reliably shorter for any sub-detection exposure periods compared to no exposure periods. **Conclusions.** There is no evidence of an accruing representation of change, suggesting that change is not represented until the changing item is attended. Alternatively, the priming procedure is insufficiently sensitive to detect an accruing representation. Converging tests of this question using alternate methods are underway.

159 Abstract withdrawn.

A59 *160* Capacity limits for the detection of changing visual features

Alex Burmester[1] (aburmester@hms.uq.edu.au), Guy Wallis[1]; [1]University of Queensland

Evidence that visual perception is subject to various forms of induced blindness has been taken to suggest that observers do not build a complete, spatio-topic representation of their visual environment. Instead, it has been suggested that induced blindness and other phenomena related to selective processing are indicative of capacity limits acting at one or more levels in the visual system. Capacity limits in visual attention have traditionally been studied using static arrays of elements from which an observer must detect a target defined by a certain visual feature or combination of features. In the current study, we use a visual search paradigm, with accuracy as the dependent variable, to examine capacity limits for different visual features undergoing *change* over time.Stimuli used in these experiments were gabor gratings placed in a circular ring around a central fixation point. In Experiment 1, detectability of a single changing target was measured under conditions where the type of change (size, speed, color), the magnitude of change, the set size and distractor homogeneity were all systematically varied. Psychometric function slopes were calculated for different experimental conditions and 'change thresholds' extracted from these slopes were used in Experiment 2, in which multiple supra-threshold changes were made, simultaneously, either to a single or to two or three different stimulus elements.Together, these experiments examined the interactive effects on processing capacity of changing different stimulus features one at a time and changing several (which are distributed either within a single object or across objects) simultaneously.

A60 *161* The role of attention in change blindness.

Fumihiko Taya[1] (taya@csl.sony.co.jp), Ken Mogi[1,2]; [1]Sony Computer Science Laboratories, Inc., [2]Tokyo Institute of Technology

Change blindness is a phenomenon where subjects fail to detect even a large change in the visual scene. Studies on change blindness have proved useful for understanding attention, perception and visual short-term memory (vSTM). It has been suggested that focused attention is necessary for the detection of a change, while not sufficient. When changes were applied during blinks, subjects failed to notice a change even when they were looking at the positions of modified stimuli (looking without seeing). The reason why such a change fails to be registered remains to be clarified. One possibility is that the preserved representation is sparse so that the detailed information necessary for detecting the change is lacking, even when the attention is focused on the modified position, e.g., when the modified property is not relevant to the facing task. Another possibility is that the change is detected unconsciously but fails to be consciously perceived. Here we recorded the eye movements while the subjects saw flicker stimuli in which the original and modified images alternated repeatedly, separated a blank. By conducting a series of statistical analysis on the eye-tracking data, we investigated the relationship between the eye positions and the positions of detected changes, testing whether subjects were attracted to the changes unconsciously, and clarifying which aspects of the stimuli are crucial in the change detection. Based on the data, we discuss the role of attention and other cognitive factors contributing to the failure or capture of changes in the visual scene.

162 Abstract 162 moved to poster G17.

A61 *163* Influence of Local Context in Change Detection

Steven Kies[1] (skies@uci.edu), Charles Chubb[1]; [1]University of California, Irvine, Cognitive Sciences Department

Purpose. To assess the influence of target context on performance in a change detection task. Method. On each trial, the observer viewed two briefly flashed, 6-by-6, random checkerboards separated by a 1 sec. ISI and judged (with feedback) whether they were different. The observer was aware that the difference (if there was one) was always in the contrast polarity of a single square. We fit a model in which probability of detection depended on several features of the local context: Feature1 was present if the squares abutting the target on the right and left were equal in contrast; Feature2, if the squares abutting the target above and below were equal in contrast; Feature3, if the squares diagonally adjacent to the target on the upper left and lower right were equal in contrast, and Feature4, if the squares diagonally adjacent to the target on the lower left and upper right were equal in contrast. Results. Features 1 and 2 strongly increased the probability of detection. Features 3 and 4 moderately facilitated detection provided Features 1 and 2 were absent; however, they suppressed detection if either of Features 1 or 2 were present. Conclusion: Detection of a change in a random checkerboard is strongly influenced by the local context in which the change occurs. In particular, changes that alter the topology of the local pattern are better detected than those that do not.

A62 *164* Change detection in patterns depends on pattern shape and element arrangement

Christian Kempgens[1] (cke7@gcal.ac.uk), Gunter Loffler[1], Harry S Orbach[1]; [1]Department of Vision Sciences, Glasgow Caledonian University, UK

Purpose:Models predict performance for detection of change in multi-element patterns in terms of the number of elements (set-size), irrespective of pattern shape and element arrangement. We set to investigate this assumption. Methods:Stimuli were composed of D6 patches (set-sizes of 1, 8 and 35) positioned as if on the contour of specific shapes (a circle or an eight-lobed sinusoidally deformed circle (RF8)). Mean eccentricity was 2.7° around fixation. The orientation of individual patches was arranged either to be tangential to the contour or random (same absolute orientations but random location). Subjects (n = 3) indicated in which of the sequentially presented stimuli one patch had changed its orientation.Results:A decrease in performance with increasing number of elements in the random condition showed the expected set-size effect. Interestingly, no set-size effect was observed when the elements were tangential to a circle. When they were tangential to the RF8 contour, performance decreased from 1 to 8 elements (as in the random condition) but, paradoxically, improved on average when increasing from 8 to 35 elements.Conclusions:Our results show two new factors determining change detection. First, the difference in performance between random vs. tangential conditions suggests that change detection does not only depend on set size but also on the arrangement of elements. Second, the difference between circular vs. RF8 shapes indicates that the shape of the pattern plays an important role in change detection.

Oscillations, Correlations, Synchrony

A63 *165* Stimulus-Dependent Response Correlations between Rabbit Retinal Ganglion Cells

Susmita Chatterjee[1] (susmitac@usc.edu), David.K Merwine[1], Norberto .M Grzywacz[1,2]; [1]Department of Biomedical Engineering,USC,Los Angeles,CA, [2]Neuroscience Graduate Program,USC,Los Angeles,CA

Synchronous firing of directionally selective (DS) cells in the rabbit retina is stimulus dependent (Amthor et al., 2005, in press). Millisecond time-scale correlation is strongest for responses to the movement of bars that simultaneously cross the receptive fields of two DS cells. In contrast, although these cells respond with similar time courses to full-field stimulation, they do not exhibit significant millisecond correlation. Here, we extend the study to all classes of ganglion cell using multi-electrode array recordings. Cells were identified and automatically classified using full-field luminance steps, and moving bars and edges. Responses to full-field luminance steps did not show significant millisecond time-scale correlation within or across any cell classes. However, movement of extended bars that simultaneously crossed the receptive fields of neighboring cells often generated significant correlation. This occurred both within and across cell classes. The temporal structure of the correlations had a positive component flanked by negative components. This structure varied depending on the cell types and stimulus features Interestingly, for some pairs of non-DS cells these correlations were direction dependent. In conclusion, we find strong ganglion-cell correlations in response to extended edges, but not to full-field luminance steps. We interpret this as a possible code to indicate the contour of a single object as opposed to its interior. We hypothesize that the directional dependence seen in the correlation of some cells is not a true 'directional' signal, but is a result of the geometry of their receptive field relative to the orientation of the contour.

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A64 *166* Oscillatory activity in the tiger salamander retina

Beth M Perry[1] (bperry@lanl.gov), Xin-Cheng Yao[1], John S George[1]; [1]Biological and Quantum Physics, MS-D454, Los Alamos National Laboratory, Los Alamos, NM 87544

Sustained oscillations in the trans-retinal field potential from *Ambystoma tigrinum* were recorded in a retinal slice preparation using a three-dimensional microelectrode array (ALA Scientific Instruments, Inc, Westbury, NY). In order to reveal which retinal circuits and neurotransmitter systems might be involved in the creation of these oscillations, recordings were made in the presence and absence of TTX, bicuculline, TPMPA, CNQX, and D-AP5. Oscillatory activity was blocked by bicuculline, enhanced by TTX, enhanced by TPMPA, blocked by CNQX, and unchanged by D-AP5. We also tested the effects of the dopamine receptor agonists, quinpirole and SKF-38393, since adaptational state appears to influence the amplitude of oscillations and dopamine has been implicated in retinal adaptation. Oscillatory activity was diminished in the presence of both agonists. One model consistent with these findings is an excitatory-inhibitory network between a non-spiking amacrine cell and a bipolar cell. The bipolar cell can be directly modulated by the release of GABA from a spiking amacrine cell. The entire circuit or key neurons might be modulated by dopamine.

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A65 *167* Visual information coding by synchronized oscillations

Hiroshi Ishikane[1, 2] (ishikane@riken.jp), Mie Gangi[2], Shoko Honda[2], Shiro Usui[1], Masao Tachibana[2]; [1]Laboratory for Neuroinformatics, RIKEN Brain Science Institute, [2]Department of Psychology, The University of Tokyo

Synchronization accompanied by ã-range oscillations is generated among visual neurons in a manner that depends on certain key features of visual stimulation. Based on the correlation between this activity and perception, it has been suggested that this phenomenon may be important for perceptual integration. However, the causal relationship between them has yet to be explained. Here we show evidence for a functional role of the oscillatory synchronized activities in frog's visual information processing. We performed behavioral tests and multi-electrode recordings from ganglion cells in the isolated retinas. An expanding dark spot, which emulates an approaching predator, generated synchronized oscillatory discharges among OFF-sustained ganglion cells (dimming detectors) and elicited escape response. Intraocular injection of pharmacological agents changed the escape rate to the stimulus. These behavioral changes were ascribed not to changes in discharge rate but to modulation of synchronized oscillations. Furthermore, the pharmacological agents did not affect the expanding dark spot-induced responses in retinal ganglion cells other than dimming detectors. Thus, we conclude that synchronized oscillations encode escape-related information in frogs. The escape rate of frogs and the strength of synchronized oscillations increased as stimulus size or continuity increased. For escape behavior, the size and/or continuity of an object may be perceptually integrated by synchronized oscillations.

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A66 *168* Superior colliculus modulates oscillatory activity of neuronal responses in primary visual cortex

Boris Ebisch[1,3] (ebisch@mpih-frankfurt.mpg.de), William H. Barnes[2,3], Yvonne Egenolf[3], Stephen G. Lomber[2], Ralf A.W. Galuske[1,2]; [1]Max Planck Institute for Brain Research, Frankfurt/Main, Germany, [2]School of Behavioral and Brain Sciences, The University of Texas at Dallas, USA, [3]Technical University Darmstadt, Department of Biology, Darmstadt, Germany

The superior colliculus (SC) of mammals receives multisensory input and is supposed to play an important role in mediating spatial visual attention. Behavioral studies show that deactivation of cat SC results in a complete visual neglect of the contralateral hemifield, impairment of learning, and impairment of recognizing global visual features. The SC, via pulvinar complex, is the origin of ascending projections to the visual cortex. This pathway bypasses the lateral geniculate nucleus, and therefore supports a model of two parallel visual pathways. In this model the geniculocortical system performs a detailed analysis of stimulus features and the phyloge-

netically older extrageniculate pathway via SC participates in functions of spatial attention.The goal of the present study was to reveal the influence of superior colliculus on information processing in primary visual. To this end, SC was unilaterally deactivated using cryoloops and neuronal activity in area 18 of anesthetized cats was monitored by optical imaging of intrinsic signals and electrophysiological recordings. Deactivation of the SC resulted in a decrease of response strength and led to a decrease in oscillatory activity in the gamma frequency range.Gamma oscillations and the precise timing of neuronal discharges in the millisecond range are known to be involved in attention processes and learning tasks. Thus the observed impairment of these temporal aspects of neuronal activity in area 18 is likely to form a neuronal correlate of attentional deficits observed during deactivation of the superior colliculus in behavioral experiments.

A67 *169* Neuronal Synchrony and Visual Grouping: A Multi-electrode Study in Monkey IT

Britt Anderson[1] (britt@brown.edu), Matthew Harrison[2], David L. Sheinberg[1]; [1]Dept. of Neuroscience, Brown University, [2]Dept. of Applied Mathematics, Brown University

If objects are collections of parts, then inferotemporal cortex (IT) is an excellent area to evaluate the hypothesis that cells signaling features to be perceptually bound fire with greater precision.We simultaneously recorded spiking and LFP signals of 175 pairs of visually responsive IT cells while a monkey performed button presses to image pairs. The image pairs were only informative about the button press when they fell on the same colored background. This task allowed us to use new images on a daily basis and to confirm from behavior that responses were not based on single images.We found significant increases in spike rates and raw synchrony counts when viewing informative image pairs. IT neuron responses to the same stimuli varied depending on whether the stimuli were in a salient configuration. Controlling for spike rates changes (by calculating the spike field coherence (sfc) and a jitter statistic) we observed a decorrelation of the sfc for fixations of image pairs in their grouped/salient configurations. There was also a decrease in synchrony, after controlling for rate, when first viewing an image pair in a salient/informative configuration. Synchrony measures correlated with performance. Contrasting trials where the monkey was correct with trials where he erred revealed that for both informative and uninformative configurations a greater proportion of cell pairs showed increased synchrony on correct trials.In general, we found that synchrony counts in IT are significantly affected by grouping, but that these changes can largely be explained by overall changes in response rates.

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A68 *170* Does spike synchrony provide a better code of stimulus angle than average firing rate?

Walter J. Jermakowicz[1,2] (walter.j.jermakowicz@vanderbilt.edu), Xin Chen[2], Ilya Khaytin[1,2], Zhiyi Zhou[5], Melanie Bernard[5], A. B. Bonds[5], Vivien A. Casagrande[2,3,4]; [1]Medical Scientist Training Program, [2]Department of Cellular and Developmental Biology, [3]Department of Psychology, [4]Department of Opthalmology and Visual Sciences, [5]Department of Electrical Engineering and Computer Science

We compared the degree of orientation discrimination coded by neuronal firing rate with that coded using spike synchrony. A 100 electrode array was used to record single cell activity in primary visual cortex (V1) of two prosimian bush babies (*Otolemur garnetti*). Electrodes were verified to be in layers 2-4 of V1 based on reconstructions from cytochrome oxidase stained sections. Cell responses were characterized using 18 orientations of drifting sinewave grating stimuli presented at 60% contrast at the preferred spatial (0.5c/deg) and temporal (2 Hz) frequency. 306 cell pairs with overlapping receptive fields were examined for synchrony using the joint peristimulus time histogram (JPSTH) method (Aertsen 1989). As described earlier in cat area 17 (Samonds 2003), we found that neuronal synchrony conferred a distinct advantage over firing rate for discrimination between small differences in orientation (10°) but not larger differences. At 10° synchrony drops 4.16%/degree and combined firing rate drops 2.28%/degree. After normalization, comparison shows that in this range synchrony offers an advantage in orientation discriminability of 67±9% over firing rate for the same cell pairs. In the 10-60° range, synchrony drops 1.21%/degree and combined firing rate drops 2.89%/degree. For these larger differences, firing rate offers 139±15% more discriminability than synchrony. These initial results suggest that synchrony is important for fine orientation discrimination in primate V1 but not for discriminating between larger orientation differences. These results strengthen the argument that neural synchrony is important to the coding of stimulus detail.

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A69 *171* Synchronous Activity in Cat Visual Cortex Detects Structural Modifications in Natural Images

Melanie R. Bernard[1] (melanie.r.bernard@vanderbilt.edu), Zhiyi Zhou[1], A. B. Bonds[1,2]; [1]Department of Biomedical Engineering, Vanderbilt University, Nashville, Tennessee 37235, USA, [2]Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, Tennessee 37235, USA

Synchrony has been studied with artificial stimuli (gratings, rings), but its behavior in the context of natural vision remains unknown. One challenge in analyzing responses to natural stimuli lies in linking response changes to a specific stimulus attribute. Spatial, temporal, and luminance properties may affect responses in many ways. To investigate the properties of natural stimuli that encourage assembly formation, we conducted differential measurements. Our general strategy was to measure a response to a control image and then modify the image by noise-addition and polarity-reversal. Cooperative responses were compared to those from the original image and the difference represented the consequences of the imposed modification. Using a 10x10 microelectrode array, we recorded from 93 groups of neurons (each containing 3-6 complex cells) in the visual cortex of paralyzed and anesthetized cats. Dilution of structure in the image with 50% added noise reduced synchrony by 33.7% ($p < 0.004$). Synchronous activity did not change for the polarity-reversed image ($p > 0.05$), as expected due to the polarity-invariance of complex cells. Average firing rates for each cell did not change significantly when compared to the original image for either the noise-added modification or the polarity-reversed modification ($p > 0.05$). Therefore, the degradation of structure by noise was represented more strongly by synchrony than by average firing rate. We have previously shown that synchrony between cell pairs can encode co-linear and co-circular contours and the current findings suggest that synchrony may be involved in signaling higher-order stimulus features like structure in natural scenes.

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A70 *172* Synchrony Modulation in Cat Visual Cortex Reflects Structure from Coherent Motion of Random Dots

Zhiyi Zhou[1] (zhiyi.zhou@vanderbilt.edu), Melanie R. Bernard[1], A. B. Bonds[1,2]; [1]Department of Biomedical Engineering, Vanderbilt University, Nashville, Tennessee 37235, USA, [2]Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, Tennessee 37235, USA

Spatial features (orientation or spatial continuity) modulate synchronous activity in the visual cortex. Using moving dot patterns, we found that synchrony also detects structures generated purely by coherent motion. A 10x10 microelectrode array recorded from areas 17-18 in paralyzed and anesthetized cats and synchrony was quantified using the JPSTH (Aertsen et al. 1989). We compared responses to drifting sinusoid gratings and moving dot patterns. For dot stimuli, 10% of the background was covered by randomly distributed bright dots. In "figure" regions consisting of periodic bars, some of the dots drifted coherently, while all remaining dots both inside and outside these regions moved in random directions. The figure

regions themselves moved, creating the perception of a drifting grating pattern. 203 cell pairs showed synchrony under drifting grating stimulation, and of these 63 cell pairs showed synchrony under random dot stimulation. For those pairs, a Student's t-test revealed that the synchrony amplitude for a random dot stimulus with 100% coherence is lower than that for the drifting grating stimulus (P<0.001) but higher than that for the dot stimulus with 70% coherence (P<0.001). The average firing rate for drifting gratings was twice that from random dot stimuli with 100% coherence, but the average firing rate for dot stimuli with 100% coherence did not differ significantly from those with 70% coherence (P>0.01). Synchrony detects temporally correlated structure even without clearly defined contours, but spatial integrity increases the synchrony strength. Synchrony, but not firing rate, is sensitive to the coherency level of temporally correlated structure.

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A71 *173* Watching the brain oscillating : A neural correlate of illusory jitter

Kaoru Amano[1,2] (amano@brain.k.u-tokyo.ac.jp), Derek Arnold[3], Alan Johnston[4], Tsunehiro Takeda[1]; [1]The University of Tokyo, [2]NTT Communication Science Laboratories, [3]The University of Sydney, [4]University College London

Moving borders defined by small luminance changes (or by colour changes), placed in close proximity to moving borders defined by large luminance changes, can appear to jitter at a characteristic frequency (Arnold & Johnston, 2003). To reveal the neurophysiological substrates of this illusion we measured brain activity using magnetoenceohalography (MEG). In conditions 1–3, vertical green bars, superimposed upon larger red squares, moved across a black background. The green bars were either (1) darker, (2) isoluminant with, or (3) brighter than the red squares. In condition 4, vertical green bars moved across an isoluminant red background. In condition 5, physical jitter was added to dark green bars centered in a moving red square to mimic illusory jitter. In conditions 1-4, subjects indicated if the green bar appeared to jitter. If illusory jitter was reported, subjects then matched the illusory jitter rate to the frequency of an adjacent physical jitter. The matched frequency for each subject was used in condition 5. Illusory jitter was only perceived in condition 2 and its frequency was ~10 Hz. We also found that neural oscillations around 10 Hz were significantly enhanced in condition 2 relative to all other conditions. As these oscillations were enhanced relative to isoluminant motion (condition 4) and physical 10 Hz jitter (condition 5), we believe that the enhanced activity is related to illusory jitter generation rather than to jitter perception or to isoluminant motion per se, supporting our hypothesis that MISC is generated within cortex by a dynamic cortical feedback circuit.

Human Factors

A72 *174* High dynamic range displays and the "blue light hazard".

James A. Ferwerda[1] (jaf2@cornell.edu), Aries Arditi[2]; [1]Program of Computer Graphics, Cornell University, [2]Arlene R. Gordon Research Institute, Lighthouse International

Recent advances in electronic display technologies have led to the development of high dynamic range (HDR) displays that can produce a much wider luminance range than conventional devices [Seetzen04]. Peak luminances on the order of 8500 cd/m2 and contrasts approaching 30,000:1 are possible. HDR displays have the potential to revolutionize both basic and clinical vision research because they allow controlled presentation of images that accurately reproduce the wide variations in luminance we experience in the real world. HDR displays hold particular promise for low vision testing, since many impairments are exacerbated by extreme lighting conditions. However one concern about using HDR displays, is recent evidence that exposure to short-wavelength light, even at moderate levels, can cause irreversible damage to the eyes of people with retinal disease (the "blue light hazard") [Glickman02, Cideciyan05]. To assess the potential phototoxicity of HDR displays we have conducted a radiometric analysis of a commercial display that consists of an LCD panel transilluminated by an array of high intensity LEDs. We have determined the display's spectral radiance and evaluated its output with respect to international phototoxicity guidelines [Sliney05]. While our analysis indicates that the display poses no known hazards, for additional safety we have developed an approach to reducing the display's short-wavelength output to negligible levels, while only moderately reducing its luminance. The results of this project have important implications for the use of existing HDR displays in vision research and for the design of future HDR displays.

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A73 *175* Calibrated LCD stimulus presentation for visual psychophysics in fMRI

Hans Strasburger[1] (strasburger@med.uni-goettingen.de), Torsten Wüstenberg[1]; [1]Dept. of Medical Psychology, Georg-August University Göttingen

Standard stimulus presentation techniques using liquid crystal (LCD) or cathode-ray tube (CRT) technology show drastic distortions in luminance and contrast characteristics across the screen and across gray levels. Common gamma-correction does not address screen inhomogeneity. Moreover, the common luminance measurement and calibration techniques are not applicable in the vicinity of an MRI scanner. With the aid of a fiber optic, we measured in our monitor screen luminances for the full space of screen position and image gray values. On that basis we developed a compensation technique that involves both luminance homogenization and position-dependent gamma correction. For fine resolution across the screen, the technique uses interpolation of gamma-curve coefficients rather than the luminance interpolation used elsewhere and thus achieves high precision with fewer parameters. Implemented in MATLAB® the calibration can be applied to both images and movies. By the technique described, images displayed to a subject in functional MRI can be specified with high precision by an image matrix of target luminance values rather than by local gray value.

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URL: www.hans.strasburger.de

A74 *176* Navigating in a web site: label-following vs. layout-following strategies

Sara Rigutti[1] (rigutti@psico.units.it), Walter Gerbino[1]; [1]Department of Psychology and B.R.A.I.N Centre for Neuroscience, University of Trieste, via Sant' Anastasio 12, 34134 Trieste, Italy

Cognitive models of web navigation emphasize the use of a label-following strategy based on the correspondence between the meaning of labels and user information goals. In a previous study we demonstrated that the information-seeking behavior is driven by page layout rather than by semantic cues alone (Rigutti & Gerbino 2004) and suggested that users adopt a layout-following strategy based on implicit knowledge: the navigation bar [at the page top] shows the generic information categories of a hierarchical site, while the embedded links [within the working area] show the basic information. To further test this hypothesis we ran an experiment in which users were asked to search for a visual target within a simulated web page. Targets belonged to either generic or basic information categories displayed in one of six possible spatial positions: three in the top area within the navigation bar and three in the working area within the embedded links. Labels neighboring the target might define either congruent or incongruent information contexts. Target position affected response times.

When information context was congruent, responses to targets in the top area [within the navigation bar] were faster if the information target was generic rather than basic; while the opposite was true for target in the working area [within the embedded links]. When the information context was incongruent, no matter on target position, a superiority of basic vs. generic information targets was found. Results are consistent with the idea that the layout following strategy is an effective component of the information-seeking behavior.

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A75 *177* Viewing compromised visual stimuli causes dry eye symptoms: role of the orbicularis muscle

James E Sheedy[1] (jsheedy@optometry.osu.edu), Sowjanya Gowrisankaran[1]; [1]Ohio State University College of Optometry

Purpose: Two types of asthenopia (internal and external) have been previously identified: internal asthenopia is a pain or ache inside the eye caused by accommodative and convergence stress; external asthenopia is dry eye-like symptoms (irritation and burning) caused by adverse visual stimuli such as glare or reading compromised images. This study investigates the role of the orbicularis muscle in external symptoms. Methods: Twenty subjects read seven passages under the following asthenopia-inducing conditions: glare, reduced contrast, small font, mixed astigmatic refractive error, upward gaze, accommodative stress and convergence stress. Orbicularis activity was recorded using surface electromyography (EMG). Video images were analyzed for the amount of squint. Results: Refractive error (p=0.0001), glare (p=0.0001), reduced contrast (p=0.007), small font (p=0.034) and up gaze (0.001) resulted in significant increase in EMG power and amplitude. Refractive error (p=0.0001) and glare (p=0.0001) also caused significant squint. Conclusion: An increase in orbicularis EMG occurred in all conditions that are associated with external asthenopia. However only those conditions that benefit from squint (refractive error and glare) caused measurable squint. Accommodative and convergence stress, which cause internal asthenopic symptoms, resulted in neither a significant EMG nor squint response. The results indicate that muscular tension in the orbicularis is caused by conditions that compromise the visual stimulus, but the ocular aperture is decreased only for those that benefit from it. These results suggest that orbicularis tension is a reflex response to adverse visual conditions and is related to dry eye-like symptoms.

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A76 *178* Station-point violations and their effect on size perception in minimal access surgery

Joerg W Huber[1] (j.huber@surrey.ac.uk), Ian RL Davies[2], Neil Stringer[2], Chris O'Neil[2]; [1]School of Human & Life Sciences, Roehampton University, London SW15 4JD, GB, [2]Department of Psychology, University of Surrey, Guildford, GU2 7XH, GB

Curiously, in tele-presence applications such as minimal access surgery there is no control or recommendation over where the surgeon views the monitor from. The retinal image produced by viewing the monitor only replicates the retinal image produced under normal direct viewing if viewed from a single point, the 'station-point'. If the image is being used to control delicate actions, mis-perceiving the layout could have serious consequences. Experiment 1 assessed the consequences of station-point violation by comparing shape judgments made at the correct station-point and half or double the station-point distance. Isosceles triangles varying in their height to base ratio, drawn on a flat surface, were viewed on a monitor fed by a camera pointing at the surface. This surface with the triangles on was either normal to the camera or inclined away at one of three angles. The subjects' task was to decide which triangle was equilateral. The result was that accuracy of shape judgments declined as the angle of the surface increased, but station-point violation had no effect, implying that observers were compensating for station-point violation. In Experiment 2, additional depth information was provided but although shape judgments were more accurate, the station-point still had no effect. Experiment 3 tested the effect of violating the station-point through viewing the monitor obliquely (45° rotation around the vertical axis). Now, accuracy for oblique viewing was significantly worse than for normal viewing, and in a manner consistent with the optical changes resulting from station-point violation.

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A77 *179* Gabor discrimination and laser disability glare

Leon N McLin[1] (leon.mclin@brooks.af.mil), Laura E Barnes[2], Brenda J Novar[1], Gary L Martinsen[2], Paul V Garcia[1]; [1]Northrop Grumman Corporation, San Antonio, TX, [2]Air Force Research Laboratory/HEDO, Brooks City-Base TX

Disability glare impairs vision and is caused by both intraocular scattering and veiling luminance from extraocular stray light such as scatter from a canopy. The FAA is concerned about increasing incidents of laser exposures of aircraft and is investigating the effects of lasers on the vision of pilots. This study examined the effect of green laser irradiance on orientation discrimination of Gabor patches up to 55 degrees from a laser glare source. Stimulus viewing was centrally with the left eye. Nine subjects participated. They viewed the stimuli with central vision through a Cessna canopy, with and without the laser blocked by a 6 degree opacity. Blocking the central beam source separates the effect of extraocular scatter from intraocular scatter. The stimuli were Gabor patterns, 50% contrast, tilted left or right. Laser irradiance varied from 0.6 microwatts/cm^2 to 600 microwatts/cm^2, in 0.5 log steps. One degree targets were obscured at 5 degrees from the laser source by 60 ìW/cm^2 (12 lux) with a 30 cd/m^2 background and 6 ìW/cm^2 with a 3.2 cd/m^2 background. With the laser source blocked and a canopy present, 190 ìW/cm^2 were required to obscure the 1 degree stimuli at 5 degrees for the dimmer background and 19 ìW/cm^2 for the brighter background. Large 10 degree targets on axis with the laser source were obscured by 60 ìW/cm^2 with a 30 cd/m^2 background and 6 ìW/cm^2 with a 3.2 cd/m^2 background. The results were evaluated in terms of the CIE disability glare functions.

A78 *180* Improvement in upper-extremity motor-function in hemiparetics usingrobot-assisted repetitive motion therapy with video games

Flavio DaSilva[1] (flavio.dasilva@asu.edu), Nanci E Wechsler[2], Michael McBeath[1], Thomas Sugar[1], Eric Amazeen[1], Clark Presson[1], James Koeneman[1]; [1]Arizona State University, [2]Midwestern University-College of Health Sciences

Conventional neurodevelopmental therapy for hemiparetics consists oftherapist-assisted repetitive manipulation (RM) of the affected limb for onehour, 2-3 times a week over a period of several months. In this study weinvestigate robot-assisted RM in conjunction with a video game designed toproduce more of a sense of agency and increased levels of neural engagement.We suggest that by activating as many neural circuits as possible involvedin sensation, proprioception, self-perception, movement and attention, thepotential for rehabilitation is maximized. We tested ten recovering strokesurvivors with varying degrees of hemiparesis. All participants receivedeach of the following four conditions over a four-month period withhour-long, biweekly therapy sessions. (i) Control: A non-treatment period,(ii) Robot Only: Externally-controlled, robot-assisted movements of theeffected arm, (iii) Mirror Illusion: Illusory motion of the affected arminduced through movements of the good arm made in front of asagittally-oriented mirror, and (iv) Robotically-Mirrored Motion:Actively-controlled, robot-assisted movements of the effected arm thatcopied motion of the unaffected arm. Each robot was connected to a videogame, which increased attention by engaging participants in purposefulmovements. To varying degrees, each treatment induced the sometimes illusorysense of agency, which appeared to further engage the patient and enhanceenjoyment of therapy. The findings support gains in upper extremityfunctionality due to treatments facilitating higher levels of neuralengagement. The results confirm the clinical value of both robotic-assistedtherapy and an integrated therapy structure that allows patients toexperience purposeful, if illusory control of movement.

Saturday Talk Sessions

Saturday, May 6, 2006

Motion and Eye Movements (181-186), Face Perception: Neural Mechanisms (187-192), Eye Movements, Brain Activity, and Attention, (193-198), Perceptual Organization (199-204), Natural Images and Position Encoding (205-211), Motion: Cortical Mechanisms (212-218), Spatial Vision I (219-223), Temporal Processing (224-228)

Motion and Eye Movements

Saturday, May 6, 8:00 - 9:30 am

Hyatt Ballroom North

Moderator: Concetta Morrone

8:00 *181* **Phase lags and gain ratios in motion perception during smooth pursuit eye movements**

Jan L. Souman[1,2] (jan.souman@tuebingen.mpg.de), Tom C.A. Freeman[3]; [1]Max Planck Institute for biological Cybernetics, Tuebingen, Germany, [2]Helmholtz Institute, Dept. of Psychonomics, Utrecht University, the Netherlands, [3]School of Psychology, Cardiff University, Wales, United Kingdom

During everyday viewing we rarely keep our eyes still. Our visual system has to take these eye movements into account in order to create a veridical percept of object motion. When we make smooth pursuit eye movements, the perceived velocity of a moving object can be obtained by summing two signals, one estimating retinal image velocity and the other estimating eye velocity. Previous studies have shown that the gains of these two signals differ. Here we investigate whether they also differ in their latencies. Observers compared the peak velocity of sinusoidally moving dot patterns viewed during sinusoidal smooth pursuit eye movements and during fixation. The relative gains and phases of the two signals were estimated from the amplitude matches by fitting a simple linear model. At VSS2005, we showed that the model described the data well for most observers, but the estimated signal gains and phases showed considerable variability. Also, the gain ratio was very low for most observers, suggesting they ignored eye-velocity information and judged instead the relative motion in the display. Here, we tested whether removing the vertical edges in the stimulus window, using a large-field cylindrical screen, promoted head-centred judgements. Using this display, observers seem more able to judge head-centred sinusoidal motion consistently during smooth eye pursuit. Relative signal gain was comparable to that previously reported in the literature. Moreover, the results suggest that retinal motion signals lag eye-movement signals by a small amount.

Acknowledgment: Travel grant R 56-485 from the Dutch Organization for Scientific Research NWO

8:15 *182* **Pursuit Eye Movement, Motion Adaptation and Two Types of Velocity Aftereffect**

Tom CA Freeman[1] (freemant@cardiff.ac.uk); [1]School of Psychology, Cardiff University

One means of judging velocity during pursuit is to compare signals encoding retinal motion with information about the eye movement. Some authors argue the latter is based exclusively on extra-retinal signals originating from the motor-control system. Others argue for a compound reference signal comprising extra-retinal and retinal components. Recent support for the compound reference comes from Haarmeier & colleagues. They demonstrated that simultaneously adapting to pursuit and retinal motion changed perceived motion during pursuit, even when net adaptation directions were counterbalanced across trials (Haarmeier et al, 2001, Neuron, 32, 527). They confirmed that counterbalancing eliminated classical motion aftereffect (MAE) and suggested simultaneous adaptation therefore recalibrates a compound reference as opposed to changing retinal motion encoding. Here I question this conclusion. Counterbalancing direction eliminates MAE but not the way retinal speed is encoded (the velocity aftereffect, VAE). I suggest that simultaneous adaptation in fact induces two types of VAE, one retinal and one extra-retinal, which compete to determine perceived velocity during pursuit. I first show that retinal VAE persists following counterbalanced simultaneous adaptation, tested using a speed-matching technique. I then show that Haarmeier et al's original effect can be predicted by separately adapting to pursuit or retinal motion. This is tested using their motion-nulling method, in which stimulus velocity is adjusted post-adaptation until it appears head-stationary during pursuit. Preliminary data also suggest that the reported direction-selectivity is specific to retinal VAE only. The results provide little evidence in favour of a compound reference.

8:30 *183* **Visual contextual effects on smooth pursuit eye movements**

Miriam Spering[1] (miriam.spering@psychol.uni-giessen.de), Karl R. Gegenfurtner[1]; [1]Experimental Psychology, Justus-Liebig-Universitaet, Giessen, Germany

Stationary and moving textured backgrounds have been shown to reduce initial velocity and steady-state gain of smooth pursuit eye movements [e.g., Kimmig, Schwarz, & Miles, J. Neurophys., 68(6), 2147-2164 (1992)]. We recorded eye movements from human observers to a small bright Gaussian dot that moved horizontally at 12 deg/s. The visual context in the vicinity consisted of two vertical sinusoidal gratings, one above and one below the stimulus trajectory that were either stationary or moved at the same speed as the target, into the same or opposite direction. We observed that during pursuit initiation, eye velocity was increased/decreased by up to 50% when the context gratings moved into the same/opposite direction as the target. The effect was persistent but smaller (25% velocity change) throughout the steady-state tracking phase. In a second experiment, the moving context changed speed to 0, 6, or 18 deg/s during the steady-state phase and remained stationary, slower, or faster until the end of the trial. This perturbation only had an effect on steady-state eye velocity when the gratings moved along with the target. At about 70 ms after perturbation, eye velocity increased/decreased by about 20% for an increase/decrease in contextual velocity. We conclude that a visual context flanking the stimulus trajectory can produce the same effect on pursuit performance than a full-field textured background.

8:45 *184* **The initial ocular following responses (OFRs) to competing visual motions: Contrast-dependent nonlinear interactions and their dependence on spatial frequency and speed.**

Boris M Sheliga[1] (bms@lsr.nei.nih.gov), Edmond J FitzGibbon[1], Frederick A Miles[1]; [1]Lab Sensorimotor Research, Natl Eye Inst/NIH, Bethesda, MD, USA

We used the electromagnetic search coil technique to record the initial (open-loop) OFRs elicited in human Ss by horizontal apparent motion applied to vertical grating patterns composed of two sinusoids. The two sinusoids always shifted in opposite directions and their contrasts were varied independently over the range 0-64%. We previously reported (VSS 2005) that when the contrast of one sinusoid was less than about half that of the other, the sinusoid with the higher contrast dominated initial OFRs and the sinusoid with the lower contrast had almost no influence: winner-take-all. When their contrasts were more similar, both sinusoids exerted an influence on initial OFRs: vector sum/averaging. We attributed this nonlinear dependence on the relative contrasts of the two sinusoids to mutual inhibition between the neural elements processing the two motions. In those experiments the two sinusoids differed in both spatial frequency and speed (ratio, 3:5), and in the present experiments the two sinusoids had either (a) the same spatial frequency and different apparent speeds (ratio, 2:1) or (b) the same apparent speed and different spatial frequencies (ratio, 2:1). The nonlinear dependence on the relative contrasts of the two sinusoids was still apparent but less dramatic, so that dominance by one or other sinusoid now required a larger difference in their contrasts: average increase, 174% (range, 145-259%). These results suggest that the postulated mutual inhibition is stronger between neural elements that differ in their tuning for spatial frequency or speed.

Acknowledgment: Support Contributed By: NEI Intramural Program

9:00 *185* **Localization of visual targets during optokinetic eye movements**

Andre Kaminiarz[1] (andre.kaminiarz@physik.uni-marburg.de), Marc Rohe[1], Bart Krekelberg[2], Frank Bremmer[1]; [1]Dept. Neurophysics, Philipps-University Marburg, Germany, [2]CMBN,Rutgers University, Newark, USA

Previous psychophysical studies demonstrated a perceptual distortion of space during smooth and saccadic eye movements. Both types of eye movements are voluntarily controlled. In this study we asked how accurately human subjects can localize flashed visual targets during reflexive eye movements namely optokinetic nystagmus (OKN).Nine subjects participated in the experiments, which were performed in complete darkness. Eye movements were sampled at 500 Hz. In blocks of trials subjects performed either baseline or eye movement tasks. In baseline trials subjects freely viewed a homogeneous gray monitor for 4000 ms. After 3500 ms a visual target was flashed for 10 ms at one of five possible locations. During eye movement trials a random dot pattern was moving to the right or left for 6000 ms and reliably elicited an OKN. After 5500 ms the target was presented. At the end of each trial subjects indicated the perceived horizontal or vertical target location with respect to a ruler.Localization during baseline trials was biased towards a location centered on the vertical meridian in head centered space. During OKN we observed an additional shift in direction of the slow eye movement. This bias decreased shortly before a saccade and temporaryly increased afterwards. Mean error as well as modulation of localization error around the time of saccades increased with rising background motion speed. Control experiments showed that localization errors were mainly due to eye movements. Our results therefore indicate that localization of visual targets is influenced during reflexive eye movements.

Acknowledgment: Supported by DFG (FOR-560-Br-2282/2 and GRK-885

9:15 *186* **Modulation of retinotopy of human MT complex by gaze position.**

MC Morrone[1,4] (concetta.morrone@hsr.it), G D'Avossa[1,5], M Tosetti[2], DC Burr[3,4]; [1]Università "Vita e Salute", Milan, [2]Fondazione "Stella Maris", Pisa, [3]Università degli Studi di Firenze, Firenze, [4]Istituto di Neuroscienze CNR, Pisa

Gaze direction affects visually evoked activity in extra-striate and parietal areas of the macaque, and the strength of several visual aftereffects in humans. Here we examine the effect of gaze on BOLD responses in human MT complex (hMT). During fMRI scanning, subjects were required to discriminate the direction of motion of a brief weak motion signal embedded within a square random noise display of 7 X 7 degrees. Subjects gazed in one of three directions (centre or 10° left or right, monitoring eye position) with stimuli displayed 10° left or right of fixation. In separate sessions conducted during passive viewing, the retinotopic portion of area hMT was localized on the basis of a clear contra-lateral response and on the selectivity to coherent optic flow motion. In retinotopic regions of the occipital lobe (V1 and V2) there was no evidence of a gaze direction effect on the visually evoked BOLD response. However, in the visuo-topic portion of hMT the response was strongly modulated by gaze: indeed the response depended more strongly on spatial position on the screen than on retinal position (that varied with gaze), suggesting spatio-topic mapping. In a further condition subjects were required to make a saccade between presentations of the motion sequence: again the BOLD response showed integration of the retinotopically disparate stimuli. We suggest that gaze related modulation may support transformation of visual information from a retinal to a spatial reference frame early in the analysis of visual motion.

Acknowledgment: MIUR Prin 2003

Face Perception: Neural Mechanisms

Saturday, May 6, 8:00 - 9:30 am

Hyatt Ballroom South

Moderator: Michèle Fabre-Thorpe

8:00 *187* **Face-Selective Adaptation of the M170 Is Sensitive to Face Parts, Not Face Configuration**

Alison Harris[1] (aharris@alum.mit.edu), Ken Nakayama[2]; [1]University of Pennsylvania, Philadelphia, PA, [2]Harvard University, Cambridge, MA

Face perception is thought to differ from object recognition by its reliance on configural, rather than part-based, processing. Here we examined the relative contributions of configuration and parts to early "face-selective" processing at the M170, a magnetoencephalographic (MEG) response occurring approximately 170 ms after stimulus onset, using adaptation. Previously (VSS 2005), we demonstrated that successive presentation of two stimuli with a brief (<800 ms) stimulus onset asynchrony results in attenuation of the M170 response. This adaptation is "face-selective," with greater attenuation for faces preceded by faces than for faces preceded by houses. "Face-selective" M170 adaptation is not weakened even when the adapting face image is embedded in heavy visual noise (S/N < 20%). Our method therefore provides a new means of assessing the nature of the processing indexed by this early neurophysiological response. We measured the adapting power of face configurations versus face parts using upright and inverted faces, face-like configurations of black ovals versus scrambled non-face configurations of face parts, and isolated face parts. While face configurations alone do not produce "face-selective" adaptation, inverted faces, scrambled faces, and even isolated face parts adapt the M170 response to a similar extent as full faces. Thus, at least at the earliest stages of "face-selective" processing indexed by M170 adaptation, face parts undergo "face-selective" processing but face configurations do not. These results suggest that a part-based system precedes the putative configural stage of face processing.

8:15 *188* **The *Visual Aha!*: Insights into object and face perception using event related potentials**

James Tanaka[1] (jtanaka@uvic.ca), Carley Piatt[1], Javid Sadr[2]; [1]Dept. of Psychology, University of Victoria, British Columbia, Canada, [2]Vision Sciences Laboratory, Dept. of Psychology, Harvard University, Cambridge, Massachusetts, USA

In these experiments, a continuous presentation paradigm was used to investigate the temporal dynamics of object and face perception with event related potentials (ERPs). A sequence of noise-to-object image frames was generated using the Random Image Structure Evolution program (Sadr & Sinha, 2001, 2004). RISE allowed for the phase spectrum of the object image to be parametrically manipulated while maintaining the low level visual properties (e.g., luminance, spatial frequency, contrast) of the stimulus. When the RISE sequence was shown in a continuous presentation paradigm (500 ms per frame), there was one frame (the "*Aha!*" frame) in the series where the object appeared abruptly out of the noise background. ERPs were then employed to examine the neural correlates of the visual Aha! frame. It was found that the *Aha!* frame was accompanied by the early onset of visual ERP components at posterior recording sites and a later semantic ERP component at central locations. Activation at central sites returned to pre-recognition levels by the next frame in the sequence (*Aha!* +1) whereas posterior activity returned to baseline levels two frames later (*Aha!* +2). The distinct patterns of the activation and adaptation suggest separable contributions of visual and semantic processes to object recognition. In subsequent experiments, the RISE technique and ERPs were used to examine top-down effects in object recognition and category differences between the perception of faces and non-face objects. More generally, this line of research suggests a novel and powerful paradigm for studying the temporal dynamics of high level vision.

Acknowledgment: This work is supported by grants from the National Science and Engineering Research Council of Canada, the National Science Foundation and the James S. McDonnell Foundation (Perceptual Expertise Network)

8:30 *189* **Teasing apart meaningful from meaningless ERP differences in object categorization: a complicated story.**

Michèle Fabre-Thorpe[1] (michele.fabre-thorpe@cerco.ups-tlse.fr), Guillaume A. Rousselet[2], Marc J.-M. Macé[1], Simon J. Thorpe[1]; [1]Centre de Recherche Cerveau et Cognition, (UMR 5549) CNRS - Université Paul Sabatier, Toulouse, France, [2]McMaster University, Department of Psychology, Neuroscience & Behaviour, Hamilton, Canada

Many ERP studies have reported face responses at various latencies. So far, it has proven difficult to tease apart the contribution of low-level factors from face processing per se. VanRullen and Thorpe (J. Cog. Neurosci., 2001) used a method to isolate task-related differences by comparing ERPs recorded on the same images seen as targets and non-targets in different tasks. Here, we used a similar strategy to isolate task-related differences linked to face processing. We present results from two experiments in which subjects had to categorize briefly presented photographs of natural scenes. In the first experiment, subjects decided whether images contained animals or human faces presented at different scales. In the second experiment, subjects responded to close-up views of animal faces or human faces. Except for animals in the first experiment, all task-dependent differences were surprisingly weak and of relatively long latencies, an effect that might be related to the "by default" processing of faces up to a high-level. This contrasts strongly with the remarkably accurate behavioral responses of the subjects and their very short behavioral reaction times (Rousselet et al., J. Vis., 2003), implying that strong and early task-dependent ERP differences are not required for performing such high level visual tasks. In addition, we show that meaningful ERP differences are not necessarily correlated with reaction times. Instead, we argue that some strong differential effects occurring from 135 ms between physically different sets of stimuli almost certainly reflect processing that is nevertheless intimately related to the identification and recognition processes.

8:45 *190* **The representation of mammalian faces in human cortex**

James V Haxby[1] (haxby@princeton.edu), Ronald Bryan[1], M Ida Gobbini[1]; [1]Princeton University

The response in the fusiform face area (FFA), as measured with fMRI, does not differ for viewing mammalian faces from different species. We investigated whether distributed patterns of response in ventral temporal cortex are distinct for different species of mammalian faces and whether these distinctive patterns are restricted to the FFA or extend into ventral temporal cortex that responds maximally to non-face objects. We measured neural activity using BOLD fMRI in 16 normal volunteers while they viewed pictures of male and female human faces, monkey faces, dog faces, houses, chairs, and shoes. Data were analyzed using a split-sample correlation method for multi-voxel pattern analysis (Haxby et al. Science, 2001). Patterns of response in ventral temporal cortex distinguished human from animal faces (76% accuracy, $p<0.0001$) and monkey from dog faces (76%, $p<0.0001$). Classification performance was equivalent when analysis was restricted to voxels in the FFA (70% and 69%, respectively, $p<0.0001$ in both cases) and to voxels that responded maximally to manmade objects (74% and 73%, respectively, $p<0.0001$). Patterns of response to male and female faces could not be distinguished in any of these regions (52%, 48%, and 50%, respectively). These results show that the average magnitude of response in and outside of the FFA is a weak indicator of the information carried by neural activity. The neural representation of information that distinguishes among the visual appearances of mammalian faces is not restricted to the FFA.

9:00 *191* **Distributed representations of face expression and gaze perception in human temporal cortex.**

Andrew D. Engell[1,2] (aengell@Princeton.EDU), M. Ida Gobbini[1,2,3], James V. Haxby[1,2]; [1]Department of Psychology, Princeton University, Princeton, NJ 08544 (USA), [2]Center for the Study of Brain, Mind and Behavior, Princeton University, Princeton, NJ 08544 (USA), [3]Medical School, University of Pisa, Pisa 56127 (Italy)

The perception of facial expression and gaze-direction are important aspects of non-verbal communication. Expressions communicate the internal emotional state of others while gaze-direction offers clues to their attentional focus and intentions. Previous neuroimaging studies have independently shown that the superior temporal sulcus (STS) is more strongly activated by faces displaying expression than by neutral faces and by attending to the gaze-direction rather than the identity of a face. The distinctiveness of the neural representations of these two classes of facial gesture in the human STS has not been investigated. We used functional magnetic resonance imaging and multi-voxel pattern analysis to assess the distinctiveness of the BOLD response evoked in the STS while subjects viewed blocks of faces with differing expressions and directions of gaze. Each block comprises different individuals displaying a single facial expression (Anger, Disgust, Fear, Surprise), a single gaze direction (partial left or right, full left or right), or a neutral expression with direct gaze. Each of 8 time series contained one block of each condition. Distinct regions of activity within the STS and surrounding cortex are seen when the activity evoked by viewing expressions is directly contrasted with the activity evoked by viewing averted-gaze. In an effort to corroborate this effect we performed pattern classification on the voxels in our region of interest using a neural-net classifier. The classifier performance was significantly better than chance indicating that the neural activity in this region carries information that distinguishes these two facial gestures.

URL: http://www.csbmb.princeton.edu/mvpa

9:15 *192* **Disruption in structural connectivity in ventral cortex in congenital prosopagnosia**

Cibu Thomas[1,2] (cibu@cmu.edu), Galia Avidan[1,2], Kwan-jin Jung[3], Marlene Behrmann[1,2]; [1]Department of Psychology, Carnegie Mellon University, [2]Center for the Neural Basis of Cognition, [3]Brain Imaging Research Center, Carnegie

Mellon University and University of Pittsburgh

Congenital prosopagnosia (CP) refers to the lifelong deficit in face processing in the absence of an obvious neural deficit and in the presence of intact sensory and intellectual function. Surprisingly, imaging studies have revealed that CP individuals show normal activation in the fusiform face area (FFA) with differences from controls emerging in more anterior cortical regions, suggesting normal FFA function and a possible disruption of neural connectivity from FFA to other regions. To test this hypothesis, we examined the structural integrity of several major fiber tracts using diffusion tensor imaging (DTI) in 5 CP and 10 normal control subjects. Fiber tracking was performed using DTI studio (Mori, et al., 2002), with FA threshold of 0.20 and critical angle of 40. The fasciculi of interest (FOI) included the inferior fronto-occipital fasciculus (IFOF), the inferior longitudinal fasciculus, the forceps major and the forceps minor. The dependent measures included mean FA values within a FOI, the number of voxels that indicate the presence of a fiber, and a connectivity score derived by documenting whether the fibers in a particular FOI terminate at a predefined cortical region. The data indicate that, in contrast with the control group, there is a disruption of structural connectivity to more anterior cortical regions in the CP group. These findings provide a better understanding of the neural substrate giving rise to CP and help elucidate the role of the FFA and other cortical regions involved in normal face recognition.

Eye Movements, Brain Activity, and Attention

Saturday, May 6, 11:00 - 12:30 pm

Hyatt Ballroom North

Moderator: Eileen Kowler

11:00 *193* **Attentional enhancement along the path of a sequence of saccades**

Timothy M. Gersch[1] (tgersch@rci.rutgers.edu), Brian S. Schnitzer[1], Priyesh S. Sanghvi[1], Barbara Dosher[2], Eileen Kowler[1]; [1]Department of Psychology, Rutgers University, 152 Freylinghuysen Rd., Piscataway, NJ 08854, [2]Department of Cognitive Sciences, University of California, Irvine, 3151 SSP, Irvine, CA 92697

An important function of selective attention is to designate the target of an upcoming saccadic eye movement. Dual-task studies have demonstrated superior perceptual performance at the saccadic goal, implying that a single attentional filter is used by saccades and perception (e.g., Gersch et al., 2004). But attending exclusively to the saccadic target limits the ability to apprehend broad areas of a scene. To address the conflict between the immediate demands of saccades and the larger needs of vision, we examined the distribution of attention during saccadic sequences. Observers (n=3) made brisk sequences of oblique saccades across a 5x5 array of circles (diam 1°) following a path designated by a color cue. Attention was assessed by an orientation discrimination task using tilted 2.2 c/d Gabors presented at a random location during a randomly selected intersaccadic pause. Perceptual performance was enhanced at the goal of the upcoming saccade (as expected), but enhancement was also observed elsewhere along the saccadic path (the target of future saccades, and previously-visited locations). The overall on-path enhancement disappeared when the color cue was removed, and the saccadic path was followed from memory. In that case, enhancement was restricted to the goal of the upcoming saccade. These results show a distinction between stimulus-driven attentional enhancement, which highlights several salient locations in parallel, and "top-down" attentional enhancement, which operates serially to enhance only the upcoming saccadic goal. The concurrent, coordinated activation of both mechanisms extends the effective attentional field without compromising the accuracy, precision or timing of saccades.

11:15 *194* **fixational eye movements do not predict attentional benefits**

Todd S Horowitz[1,3] (toddh@search.bwh.harvard.edu), Elisabeth M Fine[2,3], David Fencsik[1,3], Sergey Yurgenson[2,3], Jeremy M Wolfe[1,3]; [1]Brigham & Women's Hospital, [2]Schepens Eye Research Institute, [3]Harvard Medical School

Debate about the nature of fixational eye movements (FEMs) has revived recently with the claim that microsaccades reflect the direction of shifts of covert attention (Engbert & Kliegl, 2003; Hafed & Clark, 2002). This work has demonstrated an association between cue direction and microsaccade direction, but are FEMs a reliable marker for the deployment of attention? If so, then if FEMs point to the target location, reaction times (RTs) should be faster than if they point away from the target. We hypothesized that on trials when the cue and FEM directions conflicted, attention would follow the FEM and not the cue. However, this was not the case. We used a dual-Purkinje image eye tracker to measure gaze position of three observers (two authors, one naïve) while they performed an attentional cueing experiment with three different response types: saccadic localization; manual localization; and manual detection. Similar results were obtained across all response conditions for both microsaccades (identified using the Engbert & Kliegl, 2003 algorithm) and drift (measured via average eye position). When FEMs were oriented in the cued direction, standard validity effects were observed. However, when FEMs and cues were oriented in opposite directions, RTs were slower when the FEM pointed towards the target. On uncued trials or trials with neutral cues, FEM direction did not affect RT. Cues, not FEMs, predicted behavior. Fixational eye movements may serve important functions for the visual system. However, they do not reflect the orientation of visual attention.

11:30 *195* **Spatiotemporal properties of saccadic inhibition and potential neural correlates in the macaque**

B Suresh Krishna[1,3] (ssk2031@columbia.edu), Annegret L Falkner[1,3], Michael E Goldberg[1,2,3]; [1]Center for Neurobiology and Behavior, Columbia University, New York, [2]Neurology, Columbia University, New York, [3]New York State Psychiatric Institute, New York

When a distractor flashes after the cue to make a saccade but before the saccade is executed, humans delay execution of the saccade for about 60-150 ms after the distractor appears. This phenomenon, saccadic inhibition(Reingold and Stampe 2002), provides a powerful tool to measure the time course of the effects of a task-irrelevant distractor. We now find that similarly in monkeys, for both visually-guided and memory-guided saccades that have been cued but not yet executed, flashing a distractor 100 or 150 ms after the saccade go-cue strongly inhibits saccade execution for about 60-150 ms after distractor presentation. Following this period, saccades to the originally planned goal are successfully executed. The effects of varying distractor location in humans have not been reported before. We find that, similar to the remote distractor effect (Walker et al. 1997), the distance of the distractor from the fixation point, and not the distance of the distractor from the saccade goal, appears to determine the strength of saccadic inhibition. The distractor had a strong effect even when it was flashed 20 degrees away from the fixation point. The time course of saccadic inhibition by the distractor resembles the time course of onset responses to the distractor in visually responsive neurons of the lateral intraparietal area (LIP) during the performance of this task. We have also obtained evidence for extensive lateral suppressive effects of flashed distractors in area LIP: we are now examining the role of these effects in mediating the behavioral inhibitory effect of the distractor.

Acknowledgment: This work was supported by the National Eye Institute, the National Science Foundation, the James S. MacDonnell Foundation, the W. M. Keck Foundation, and the Whitehall Foundation.

11:45 *196* **Facilitation of saccade latency with natural scene backgrounds**

Brian J. White[1] (brian.j.white@psychol.uni-giessen.de), Dirk Kerzel[2], Karl R. Gegenfurtner[1]; [1]Justus Liebig University, Giessen, Germany, [2]University of Geneve, Switzerland

Saccadic eye movements have been traditionally studied using very basic stimuli (e.g., a spot of light on a uniform background). We compared perceptual versus saccadic performance within a semi-naturalistic context: A saccade target (a Gabor at one of several spatio-temporal frequencies) was embedded in a stationary background texture known to have similar statistical properties as natural images (i.e., pink noise). Observers made a saccade to the target presented left or right of fixation at an eccentricity of 8 deg, on either the structured background or a uniform gray background. Target contrast was varied. After each trial, observers made a 2AFC as to the target's location (left versus right). We compared psychometric functions for targets in either background, and then examined saccade latency at points of equal detection performance. At a given level of equal detection performance, latencies were often reduced by as much as 80 ms for targets appearing in the structured background. Furthermore, the pattern was very similar with images of natural scenes as backgrounds. The results support the idea that natural contexts can facilitate a saccadic response.

Acknowledgment: B.J.W. was supported by the Bundesministerium für Bildung und Forschung (Project "Modkog": 620 00 177).

12:00 *197* On the spatio-temporal limits of retinal motion compensation, and why they are the undoing of temporal binding

Guy Wallis[1,2] (gwallis@hms.uq.edu.au); [1]University of Queensland, [2]Max Planck Institute for Biological Cybernetics

If two images are displayed in rapid cyclical order, they are perceived as a single, fused image. However, recent studies describe how perceptual grouping can be influenced by minor temporal offsets of this sort. It has been suggested that this effect reveals the presence of a neural "temporal binding mechanism" which would serve to keep multiple mental representations of one object distinct from those of other, simultaneously perceived objects. An alternative explanation is that fixational eye movements are responsible for converting the temporal offsets into spatial ones, and that it is the disjointed form of the resultant stimulus that influences perception.In order to test this possibility, a regular grid of dots was shown to six observers. In accord with earlier studies, an imperceptibly brief temporal offset in the presentation of specific dots was sufficient to bias their perceived grouping. Eye movement recording revealed a significant interaction ($P<0.01$) between eye movement amplitude and the size of this bias. As a result, the reported sensitivity to very brief temporal asynchrony is open to reinterpretation in terms of a purely spatial mechanism, thereby undermining support for the temporal binding hypothesis.The results also reveal a failure of the eye's motion compensation mechanism to couteract the motion-induced spatial offset. This suggests that either: (i) The mechanism's integration time window is too long, or (ii) The mechanism's spatial resolution is too low. I will argue why I believe the former is correct, and what this tells us about image-based motion compensation.

12:15 *198* A large gender difference in smooth pursuit precision

Jeremy B. Wilmer[1] (wilmer@wjh.harvard.edu), Ken Nakayama[1]; [1]Harvard University

Gender differences have been shown on a variety of motor coordination tasks.[1] Tasks emphasizing gross motor ability, such as blocking and catching balls, favor males, whereas tasks emphasizing fine motor ability, such as quick placing of pegs in holes, favor females. Little is known about the mechanisms underlying these differences as the tasks that have been studied are complex and difficult to break down into component parts. We have employed an oculomotor pursuit task, along with accompanying psychophysical tasks, allowing us to differentiate mechanisms that might contribute to performance in complex tasks. We report on the precision of smooth pursuit[2] following the initial saccade to a moving target as a measure of pursuit performance. We find an overall male advantage of over one standard deviation, one of the largest sex differences reported to date. The males in our study do not perceive the speed of moving stimuli more precisely, nor do they begin to move their eyes sooner, nor do they move their eyes at a consistently higher speed. Thus the difference appears to be one specifically of pursuit precision, and not of perceptual precision, quickness to respond, or strength of motor response. For the future it is important to ask whether this difference in oculomotor precision might underlie male advantages seen in gross motor performance. 1. Kimura D. (1999) Sex and cognition. MIT Press.2. Kowler, E. & McKee, S. P. (1987) Vision Research, 27, 993-1015.

Acknowledgment: Supported by an NSF graduate research fellowship to JBW

URL: wjh.harvard.edu/~wilmer/

Perceptual Organization

Saturday, May 6, 11:00 - 12:30 pm

Hyatt Ballroom South

Moderator: Mary Peterson

11:00 *199* Parsing Visual Scenes via Dynamic Cues

Pawan Sinha[1] (psinha@mit.edu), Yuri Ostrovsky[1], Ethan Meyers[1]; [1]Brain and Cognitive Sciences, MIT

Objects encountered in daily visual experience often consist of regions that differ in color, luminance and shape. The human visual system is adept at binding together these various regions to perceive the whole object, while simultaneously separating them from those that belong to other objects or the background. How this region integration is achieved and how the visual system develops these capabilities is not well understood. We recently had a unique opportunity to investigate this question when we met an individual (SK) in India, who had an unusual visual history. At the time of our meeting, SK was 28 years old and had untreated congenital bilateral aphakia, resulting in highly compromised visual abilities. After providing treatment to SK, we studied the early stages of his visual skills. Specifically, we examined SK's performance on simple image parsing and recognition tasks. We found that prominent figural cues of grouping, such as good-continuation, junction structure and symmetry, were largely ineffective for image parsing. By contrast, motion cues were of profound significance and played two critical roles in SK's object processing abilities. First, they enabled intra-object integration, and segregation from background. Second, they facilitated the development of object representations which permitted recognition in static images. Together with data from earlier infant studies, these results suggest that motion information plays a fundamental role in organizing early visual experience.

11:15 *200* Extremal Edges Dominate Other Cues to Figure-Ground Organization

Stephen Palmer[1] (palmer@cogsci.berkeley.edu), Tandra Ghose[2]; [1]Department of Psychology, University of California, Berkeley, [2]Vision Science Program, University of California, Berkeley

Extremal edges (EEs) are viewpoint-specific tangent points of self-occlusion on smoothly curved, convex surfaces. A simple ecological analysis of viewpoint constraints shows that the curved surface producing an EE is likely to be closer to the observer than the surface on the other, non-EE side (Ghose & Palmer, VSS-05). Four experiments examined whether EEs and 3-D surface convexity operate as strong cues to depth and figure-ground organization. Experiment 1 used simple luminance profiles (e.g., the positive half of a sinusoid) to simulate shading gradients in simple bipartite displays. The results showed that observers are very likely to perceive convex surfaces and EEs as closer and figural, and that EEs are more potent than surface convexity alone. Experiment 2 showed similar effects when EEs were rendered via texture gradients of checkerboard surfaces that con-

tain neither shading and nor implicit T-junctions. Experiment 3 used shading gradients in ray-traced images of surfaces of revolution to study the effects of EEs versus other individual figure-ground cues (region size, 2-D edge convexity, surroundedness, and familiarity). The results show that EEs dominate all of these factors. Experiment 4 used ray-traced images of EE shading patterns on simpler convex surfaces ("pillows") to control for certain shading artifacts in Experiment 3. EE effects still dominated the other cues studied (2-D edge convexity, size, and their combination). The data clearly demonstrate that extremal edges are among the most powerful cues to depth across a contour and to figure-ground organization. (http://socrates.berkeley.edu/~plab/projects.htm)

URL: http://socrates.berkeley.edu/~plab/projects.htm

11:30 *201* ERP Components Index Unconscious versus Conscious Perception of Familiar Shape With Figure-Ground Reversal

Logan T. Trujillo[1] (logant@u.arizona.edu), Mary A. Peterson[1], John J.B. Allen[1]; [1]Department of Psychology, University of Arizona

We recorded human event-related potentials (ERPs) while participants viewed small, enclosed, symmetric white silhouettes on a black ground in a two-part experiment. In Part 1, observers categorized brief (175-ms) masked silhouettes as portraying familiar (n = 40) or novel (n = 40) objects. There were two types of novel silhouettes: (1) control silhouettes (n = 20) that suggested novel shapes on the outside of their edges; (2) experimental silhouettes (n = 20) that suggested familiar objects on the outside of their edges. Observers accurately classified both types as novel (> 95%); they did not see the shapes on the outside. Thus, ERP differences reflect unconscious perception of familiar shape. P1 was larger for experimental than control silhouettes at site PO4, $p < 0.05$, while a later positive potential (265 - 325 ms) was smaller for experimental than control silhouettes over bilateral occipital and parietal-occipital sites, $p < .05$. In Part 2, observers were informed that familiar shapes were suggested on the outside of some of the novel silhouettes. Then they viewed novel silhouettes for 175-ms (unmasked) and reported whether they saw a familiar shape on the outside. Observers correctly classified 73% of the experimental and 86% of the control silhouettes. No P1 differences were observed, but N1 was larger when observers correctly reported seeing versus not seeing familiar shapes on the outside of the silhouettes (ps < 0.05). Thus, P1 reflected unconscious perception of familiar shape and N1 reflected conscious perception of familiar shape. Later positive differences may reflect access to object memories.

Acknowledgment: Support: NSF BCS 0425650 to MAP UA BIO5 Graduate Research Award to LTT

URL: http://www.u.arizona.edu/~mapeters

11:45 *202* Illusory contours don't pass through the 'blind spot'

Marianne Maertens[1,2] (marianne.maertens@gmail.com), Stefan Pollmann[2], Robert M Shapley[1]; [1]Center for Neural Science, New York University, NY, NY 10003, [2]Department of Experimental Psychology, University of Magdeburg, Germany

Electrophysiological studies have shown that neurons in the primary visual cortex (V1) of macaque monkey respond to illusory contours (ICs) defined either by abutting line ends (Grosof et al., 1993) or by aligned pacmen (Lee & Nguyen, 2001). We reported that human V1 is activated by IC stimuli (Maertens & Pollman, 2005). However, it remains open to what extent V1 responses are involved in human IC perception. Here we offer psychophysical results indicating that activation of a V1 representation may be necessary for IC perception. We presented pacmen monocularly at locations such that if there were an IC, it would cross a part of the visual field that is focused on the retinal 'blind-spot'. Four observers performed the 'thin-fat' task: curvature discrimination for objects defined by ICs (Ringach & Shapley, 1996). Performance was worse when ICs would have to cross the 'blind-spot' region compared to what was obtained with inducing stimuli viewed by the corresponding (temporal) region of the retina in the other eye. One observer (MM) was trained on another IC-based task: long-distance vernier discrimination of aligned line-endings. Also on this new task, performance was significantly worse when an IC would have to pass through the 'blind-spot'. These psychophysical results suggest that the absence of a V1 cortical representation of the IC prevents the buildup of a conscious experience of the illusory contour. They also are consistent with proposals that ICs are constructed by feedback from higher visual cortical areas to V1 (Lee, 2003; Stanley & Rubin, 2003).

Acknowledgment: Marianne Maertens is currently supported by the German Academic Exchange Service.

12:00 *203* Amodal completion enhances the discrimination of Vernier offset

Walter Gerbino[1] (gerbino@units.it), Stefano Scomersi[1], Carlo Fantoni[1]; [1]Department of Psychology and BRAIN Center for Neuroscience, University of Trieste, Italy

Growing evidence suggests that amodal completion affects the discrimination of geometric features in limiting cases of spatial unification (Yin, Kellman, & Shipley 2000; Hilger, Fantoni, Gerbino, & Kellman 2005). We measured observers' sensitivity to the amount of Vernier offset of U-shaped bars perceived as either separate or completed behind a fronto-parallel occluder [with either zero or crossed disparity]. In a control condition with the occluder, joinability was disrupted by rounding T-stems. Three amounts of Vernier offset were used, leading to three possible pairs of Vernier U-shaped bars with increasing relative offset difference (0.25, 0.50, and 0.67). In each trial observers were asked to make a speeded small/large classification of the amount of Vernier offset and to rate their confidence on a 3-point scale. This allowed us to estimate the variance of the signal-plus-noise distributions, to compute reliable d' values, and to perform a test of triangle inequality. Sensitivity increased with relative offset difference. The rate of increase was maximal when bars were amodally completed, minimal when they were separate without the occluder and intermediate when they were separate with the occluder. The superiority for completed over separate bars was higher when the occluder disparity was crossed. Contrary to previous findings suggesting that Vernier acuity is unaffected by amodal completion (Levi & Mussap 1995; Green & Brown 2000), we found that the discrimination of Vernier offset is enhanced when misaligned parallel fragments are unified by amodal completion.

Acknowledgment: PRIN-COFIN 2003

12:15 *204* The human visual spline: Interpolation contours between relatable inducers follow quintic polynomials.

Jacqueline M Fulvio[1] (jmf384@nyu.edu), Manish Singh[3], Laurence T Maloney[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Psychology and Center for Cognitive Science, Rutgers University

Previously, we investigated extrapolation ("good continuation") of contours that disappear behind occluders by obtaining measurements of perceived position and orientation of the visually-extrapolated contours at multiple distances from the point of occlusion (Singh & Fulvio, PNAS2005). Here we extend the investigation to contour interpolation. Methods: Observers viewed interpolation displays consisting of two linear inducers and an occluding rectangle. On each trial, a vertical slit appeared at one of six locations within the occluder revealing a line probe. Observers iteratively adjusted the height and orientation of the probe until it appeared to smoothly interpolate between the inducers. We varied turning angle between the inducers, and vertical offset between their points of occlusion. Vertical offsets were selected such that the two inducers were either (i) symmetric and relatable (Kellman & Shipley, CogPsych1991), (ii) non-symmetric and relatable, (iii) non-symmetric and non-relatable. Results: SDs of height and orientation settings increased with both turning angle and vertical offset, indicating reduced precision in the representation of interpolated contours. Mutual consistency between height and orienta-

tion settings (the extent to which the two settings are consistent with a single smooth curve) also declined with increasing inducer offset and turning angle. The positional settings for the relatable inducers (symmetric & non-symmetric) were remarkably well fit by quintic interpolants, and yielded high consistency with the orientation settings. Surprisingly, parabolic fits were insufficient for the symmetric inducer conditions, unlike Warren, Maloney, & Landy (VR2004). For non-relatable inducers, however, fits of quintic polynomials exhibited small but consistent deviations for all subjects.

Natural Images and Position Encoding

Saturday, May 6, 2:00 - 3:45 pm

Hyatt Ballroom North

Moderator: Patrick Bennett

2:00 *205* Image Statistics for Surface Reflectance Estimation

Lavanya Sharan[1] (l_sharan@mit.edu), Yuanzhen Li[2], Edward H. Adelson[2]; [1]M. I. T. Department of Electrical Engineering and Computer Science, [2]M. I. T. Department of Brain and Cognitive Sciences

Recent work has shown that certain image statistics are diagnostic of the reflectance properties of complex real-world surfaces. We have previously demonstrated that moments and percentile statistics of the luminance histogram of an image are indicative of the diffuse surface reflectance. The same statistics measured on filtered images (center-surround and oriented filters) were also shown to be useful. We have now conducted further psychophysical studies to examine the role of these statistics in reflectance perception. Subjects viewed photographs of opaque, rough real-world surfaces (e.g. crumpled paper, clay) on an LCD monitor against a middle gray background. They rated the diffuse reflectance of each surface with reference to a standard Munsell scale. We find that subjects can, to some extent, estimate the reflectance of an isolated surface in the absence of mean luminance information, contrary to the Gelb effect. Also, the perceived reflectance of complex surfaces is somewhat robust to changes in mean luminance of the image or the surround, a tendency we term as self-anchoring. Black, shiny surfaces tend to 'self-anchor' better than others. A learning algorithm that employs informative image statistics performs very similarly to our subjects at reflectance estimation tasks. Moreover, manipulating such statistics of an image of a real-world surface strongly affects the perceived reflectance. Therefore, taken together, our results indicate that the image statistics capture perceptually relevant information.

Acknowledgment: NTT Communication Science Lab, NSF

2:15 *206* Learning the statistics of illumination and reflectance

Edward H. Adelson[1, 2] (adelson@ai.mit.edu), Mashall F. Tappen[2], William T. Freeman[2], Yuanzhen Li[1]; [1]Dept. of Brain and Cognitive Sciences, MIT, [2]Computer Science and Artificial Intelligence Lab, MIT

The Retinex model of lightness perception relies on assumptions about the statistics of the "intrinsic images." Reflectance is assumed to be piecewise constant, and illumination to be smoothly varying. This works for so-called Mondrians, but illumination isn't reliably smooth in natural scenes. Consider an image of crumpled paper, where numerous light-dark edges are caused by shading. Retinex classifies the edges as paint, but humans are not fooled. In order to discover more sophisticated statistics, we have used supervised learning on natural and synthetic scenes for which we have ground truth. Given a patch of image, the machine learns the probable constraints on the intrinsic images that made it. As with Retinex, the estimation occurs not in the pixel domain but in another domain such as the gradient domain. This system can learn to distinguish features that arise from different sources, by taking account of the neighborhood in which the feature occurs. For instance, an edge-like feature that is near a corner-like feature is more likely to be due to reflectance than one on an extended contour. The non-linear processing is used to estimate linear constraints, and the intrinsic images are retrieved with a pseudoinverse. The resulting system gives improved performance over prior systems, and suggests a variety of statistical rules that might be exploited by the human visual system.

Acknowledgment: Supported by NTT, NSF, and ONR/MURI

2:30 *207* Ribbon Analysis of Contours in Natural Images

A. David Ing[1] (ing.dave@gmail.com), Wilson S. Geisler[1]; [1]Center for Perceptual Systems and Psychology, University of Texas, Austin TX

Correctly interpreting retinal images requires distinguishing between various types of contours, including surface boundaries, within-surface reflectance changes, and shadows. There are many hypotheses about how the visual system does this, but few attempts to directly measure the relevant information in natural images. Thus, we have analyzed close-up images of foliage obtained with a calibrated 36-bit camera, which estimates relative L, M, and S cone responses with error SDs of 0.15%, 0.1% and 1%, respectively, for natural spectra. Cone responses were transformed into a logarithmic space having orthogonal dimensions: luminance, blue-yellow, and red-green (Ruderman et al. JOSA A, 15, 2036). More than 2000 leaves were hand segmented from over 60 images representing a wide range of foliage; then, within each leaf, reflectance contours and shadow contours were hand traced. To compare the different types of contour, we extracted a ribbon of pixels a few pixels wide on each side of each contour. For each color channel, and various ribbon lengths, we measured the difference in the mean, rms amplitude, and spatial coherence across each contour. We found larger rms amplitude and coherence differences across surface boundaries than across surface-reflectance or shadow contours, and larger mean differences across shadow contours and surface boundaries than across surface reflectance contours. The ribbon information was quantified by the signal-to-noise ratio (d') for deciding whether or not a ribbon was of one type as opposed to one of the other two types. The d' values were substantial for all three types of contour.

Acknowledgment: Supported by NIH grant EY11247.

2:45 *208* Contributions of fixational eye movements to visual discrimination

Michele Rucci[1] (rucci@cns.bu.edu), Gaelle Desbordes[1], Ramon Iovin[1], Fabrizio Santini[1]; [1]Department of Cognitive and Neural Systems, Boston University

During natural viewing, small eye movements prevent the maintenance of a steady direction of gaze. It is known that images tend to disappear when they are stabilized on the retina for several seconds. However, the possible functions of the physiological motion of the retinal image during the naturally brief periods of fixation remain controversial. Here, we show that fixational eye movements improve the discrimination of briefly flashed, high spatial frequency gratings. In a forced-choice discrimination task, subjects reported whether a noisy grating displayed for 1s was tilted by 45° clockwise or counterclockwise. Discrimination percentages were significantly higher in the presence of the normally moving retinal image than under retinal stabilization in the case of high-frequency gratings, but not for low-frequency gratings. Unlike previous experiments, retinal stabilization was accomplished by means of a gaze-contingent display system, which processed in real time the eye movements measured by a DPI eye-tracker. This approach enabled rigorous comparison between the two conditions of normal retinal motion and retinal stabilization. It enabled to (a) selectively stabilize the stimulus after a saccade, a condition that preserves the normal jittering of the eye, and (b) to randomly interleave trials with and without retinal image motion. These results are consistent with our recent hypothesis that fixational eye movements are part of an efficient strategy for encoding natural stimuli. According to this proposal, fixational instability enhances high spatial frequencies and attenuates low spatial harmonics in

a way that counter-balances the scale-invariant structure of natural images (Supported by NIH-EY015732-01).

Acknowledgment: Supported by NIH-EY015732-01

URL: www.cns.bu.edu/APLab

3:00 *209* The perisacadic compression of visual space – what may it have to do with spatial attention ?

Fred H Hamker[1] (fhamker@uni-muenster.de), Marc Zirnsak[1], Dirk Calow[1], Markus Lappe[1]; [1]Department of Psychology, Westf. Wilhelms-University Muenster

Several experiments have shown that the plan of making an eye movement affects visual processing. Under certain conditions briefly flashed stimuli are mislocalized towards the saccade target (Ross et al 1997, Kaiser and Lappe 2004). The physiological mechanism that causes the percept of a 'compressed' visual space is not known, but perisaccadic remapping has been suggested as one possible candidate.Based on a previous model (Hamker 2005), we have developed a quantitative model of perisaccadic perception to evaluate if the phenomenon of 'compression' is linked to attention. We assume a spatially selective corollary discharge signal. It is directed towards the saccade target in cortical space and increases the gain of cells in extrastriate areas, e.g. MT and V4. Such a spatial gradient is often found in cell recordings and typically referred to as attention related. Based on these assumptions, the model reproduces the temporal course and the 1D spatial pattern of mislocalization as measured by Morrone et al (1997) and the 2D mislocalization data of Kaiser & Lappe (2004). It further inherently predicts RF dynamics. For the selected parameters we observe a perisaccadic shrinkage and shift of RFs towards the saccade target similar as reported for V4 (Tolias et al 2004). This prediction has been experimentally verified in a discrimination task in which objects and flankers were presented at the saccade target.Concluding, our results predict that perisaccadic spatial attention and the phenomenon of a 'compressed' visual space, both originate from the same oculomotor feedback signal.

3:15 *210* Preservation of position-encoding mechanisms across the life span

Patrick J. Bennett[1,2] (bennett@mcmaster.ca), Christopher P. Taylor[1], Allison B. Sekuler[1,2]; [1]McMaster University, Dept. of Psychology, Neuroscience & Behaviour, [2]York University, Centre for Vision Research

Previous investigators (Garcia-Suarez, et al., 2004) have used position judgment tasks to investigate how the mechanisms that encode position change with age and found that older observers had more difficulty discriminating position. However, Garcia-Suarez et al.'s task required attentional-switching, which may have impaired performance in older observers. Here we re-examine whether aging affects position encoding, using a task that taps the foundation of position encoding: phase-reversal discrimination (Field, 1984; Bennett & Banks, 1991). Observers viewed horizontal compound sine wave gratings (f+2f), and discriminated stimuli where the phase of 2f differed by 180 deg (i.e., 0° vs 180°, and 90° vs 270°). In separate experiments, f was set to 0.75 cpd or to 3 cpd; f contrast was 0.1. We varied the contrast of 2f to determine 77% correct thresholds for relative phase discrimination and compound grating detection (i.e., discriminating f alone from f+2f). In both tasks, we used a match-to-sample procedure with unlimited viewing time. Stimuli were arranged on the screen in a triangular pattern with the sample centered in the top half of the screen and the two potentially matching stimuli presented in the lower half. When discrimination thresholds were normalized by detection thresholds, we found no difference between age groups at either frequency. Hence, unlike what has been found in other position discrimination tasks (Garcia-Suarez, et al., 2004), we find no effects of age on phase discrimination. Thus, the foundation of position encoding appears to be preserved across the life span.

3:30 *211* The precision of position coding in the visual cortex

David Whitney[1,2] (dwhitney@ucdavis.edu), David Bressler[1]; [1]The Center for Mind & Brain and, [2]The Department of Psychology, The University of California, Davis, USA

One of the most fundamental functions of the visual system is to code the positions of objects. Physiological studies, especially those using fMRI, widely assume that the location of the peak retinotopic activity generated in the visual cortex by an object is the position assigned to that object—this is the simplified version of the labelled-line hypothesis. Here, we employed a novel technique to compare population level BOLD responses to moving and stationary objects and found that this widely-held version of the labelled-line hypothesis is false. By spatially correlating population responses to moving and stationary stimuli in slightly different positions, we found that the voxel population in primary visual cortex can discriminate the positions of objects separated by less than 0.5 deg visual angle (approximately 0.3 mm cortical distance at ~20 deg eccentricity). This is at or better than the ability of subjects to psychophysically classify the positions of the stimuli. More surprisingly, the population of voxels in motion area MT+—a visual area traditionally thought to be only coarsely retinotopic—is able to discriminate objects separated by approximately 2 deg visual angle, revealing precise topographic coding of object position. The results further show that the position assigned to a pattern is not simply dictated by the peak response; changes at the edges of the population response carry significant position information without altering the peak response. Therefore, visually coded location is not conveyed by the topographic location of a peak response, but by the activity across a population of neurons.

Motion: Cortical Mechanisms

Saturday, May 6, 2:00 - 3:45 pm

Hyatt Ballroom South

Moderator: Andrew Smith

2:00 *212* Evidence for a motion-selective pathway from V1 to the ventral cortical stream for object recognition.

Max Snodderly[1] (msnodderly@mcg.edu), Moshe Gur[2]; [1]Meducal College of Georgia, Augusta, GA, USA, [2]Technion, Haifa, Israel

Most authors have found direction selectivity in V1 of macaques primarily in the magno-influenced layers 4Cá, 4B, and 6. Recently, we reported that direction selectivity is more widely distributed and we have proposed a new motion-selective pathway from V1 to the ventral cortical stream that is critical for object recognition. We analyzed the characteristics of V1 neurons in alert monkeys 385-695 ìm below the cortical surface, which should selectively sample layer 3. Extracellular responses to sweeping bars were recorded in 23 microelectrode penetrations while monkeys performed a fixation task. 13/31 cells were direction selective. All layer 3 cells had small classical receptive fields, sharp orientation tuning curves, and almost no spontaneous activity. Direction selective cells had smaller CRFs than the non-directional cells and they were predominantly end-stopped. Cells more superficially located in layer 2 demonstrated less selective response properties and the layer 2 cells were not direction selective. These are the first physiological data to differentiate layer 2 and layer 3 in primate visual cortex. Our results are consistent with the concept of parallel pathways coding direction selectivity in V1. One pathway dominated by magno inputs passes through layers 4Cá and 4B to join the dorsal "where" stream, and another pathway combining parvo and magno inputs passes through 4Cm and 3 to join the ventral "what" stream. This new, ventrally-directed pathway, is capable of fine-grained motion analysis that could contribute to perceiving subtle motions within objects such as faces, solving the aperture problem, and perceiving structure from motion.

Acknowledgment: NIH EY12243, US-Israel BSF grant 2003252

2:15 *213* **Remembered direction modulates responses to visual motion in MT and prefrontal neurons.**

Daniel Zaksas[1] (zaksas@cvs.rochester.edu), Nicholas P LaMendola[1], Tatiana Pasternak[1]; [1]Dept. Neurobiology & Anatomy and Center for Visual Science, University of Rochester, Rochester, NY

Neurons in area MT are active during all phases of a task where the monkeys compare the direction of two consecutive 500ms stimuli, sample and test, separated by a memory delay (Bisley et al, 2004). Here, we examined whether the remembered sample direction affects responses during the test and found significant attenuation of these responses when test direction matched that of the remembered sample. This attenuation was present only early (100-200ms) in the response and disappeared when the sample was non-coherent. This modulation by sample coherence may be a reflection of the comparison of test direction with a stored template of the sample. Furthermore, absence of modulation by sample direction later in the response suggests that decision-related signals may be carried by neurons at later stages of processing. To examine this possibility we analyzed responses in prefrontal cortex (PFC) recorded during the same task. Many PFC neurons were direction selective, though this selectivity developed about 40ms later than in MT. PFC responses to the test, like those in MT, were attenuated when its direction matched the sample. However, this attenuation began about 80ms later and persisted through the end of the test. Furthermore, it was present when the remembered sample was non-coherent, suggesting that this activity reflected the decision or upcoming motor response. Similarities in activity in MT and PFC during the test suggest a shared functional pathway, although the differences in temporal dynamics and dependence on sample coherence imply unique roles for both areas in working memory for motion.

Acknowledgment: Supported by EY11749, T32 EY07125, P30 EY01319

2:30 *214* **Categorical Representation of Visual Motion Direction in Posterior Parietal Cortex Area LIP**

David J Freedman[1] (david_freedman@hms.harvard.edu), John A Assad[1]; [1]Department of Neurobiology, Harvard Medical School, Boston, MA

Categorization is a process by which behavioral significance is assigned to sensory stimuli. While much known about neural encoding of simple visual features, less is known about how the brain determines stimulus category. We trained monkeys to group random-dot motion stimuli into two categories. 360° of motion directions were divided by a learned "category boundary". Directions between -45° and 135° were in one category while the remaining directions were in another. Monkeys performed a delayed match-to-category (DMC) task and indicated, by releasing a lever, whether two stimuli (sample and test) were in the same category. After training, the monkeys' categorization performance was excellent: they performed with >80% accuracy, even for stimuli near the category boundary.We recorded 135 LIP and 40 MT neurons during DMC task performance. A majority of neurons were direction selective (one-way ANOVA, 12 directions, $P<0.01$) during the sample or delay epoch (LIP: 97/135; MT: 40/40). However, the pattern of direction selectivity differed strikingly between LIP and MT. LIP neurons reflected stimulus category: activity was similar for directions in the same category and differed for directions of different categories. A category-tuning index revealed larger activity differences for directions in different categories and more similar activity for directions in the same category (T-Test, $P<0.001$). In MT, neurons did not group directions by their category. The category-tuning index revealed that MT neurons showed no influence of the boundary ($P>0.5$).This suggests that LIP encodes the behavioral relevance of visual motion, while MT provides a more faithful representation of motion direction.

Acknowledgment: National Eye Institute

URL: web.mit.edu/davidf

2:45 *215* **Self-motion is Represented in an Eye-Centered Coordinate Frame in MSTd**

Brian Lee[1] (brianlee@caltech.edu), Bijan Pesaran[1], Richard A. Andersen[1]; [1]California Institute of Technology, Biology, Pasadena, CA, USA

MSTd neurons are tuned to the focus of expansion of the visual image, but it is not known in which coordinate frame the tuning curves are represented. Since visual signals generated by self-motion are used to guide movement of the subject through the environment, they likely become represented in body or world coordinate frames at later stations in the visual-motor pathway. We performed experiments to determine whether focus tuning curves in MSTd are represented in eye, head, body, or world coordinates. Since MSTd neurons adjust their focus tuning curves during pursuit eye movements to compensate for changes in pursuit and translation speed that distort the visual image, the coordinate frame was determined for three separate conditions: fixed gaze, real pursuit, and simulated pursuit. It is possible that different coordinate frames are used to compensate for tuning curve shifts due to retinal and extraretinal signals. Focus tuning was determined at five eye positions, six degrees apart, along the preferred direction of pursuit. We recorded extracellular responses from 80 MSTd neurons in two rhesus monkeys (Macaca mulatta). We found that the expansion focus tuning curves were aligned in an eye-centered coordinate frame as opposed to head, body, or world-centered coordinate frames for almost all cells (fixed gaze: 77/80; real pursuit: 77/80; simulated pursuit 74/80; t-test, $p<0.05$). These results indicate that MSTd neurons represent heading in an eye-centered coordinate frame in an early part of the visual-motor pathway that integrates retinal and extraretinal signals.

Acknowledgment: Supported by the NEI, J.G. Boswell Professorship to RAA, a Career Award from the Burroughs Wellcome Fund to BP, and Howard Hughes Medical Institute Pre-Doctoral Fellowship to BL

3:00 *216* **Apparent motion speed dependence on contrast and orientation: evidence from MEG**

Jean Lorenceau[1] (jean.lorenceau@chups.jussieu.fr), Shasha Morel[1], Anne Caclin[1], Catherine Tallon-Baudry[1]; [1]LENA CNRS, 47 bd de l'Hopital, Paris, France

The perceived speed of fast (>40°/s.) apparent motion of a Gabor patch whose orientation is aligned with the motion axis is much faster than when it is orthogonal to it. Electrophysiological recordings in cat and modeling (Lorenceau & al., 2002) suggest that this perceptual bias is explained by the phase advance in the firing of V1 neurons resulting from synaptic summation of horizontal and feed-forward inputs, whose responses are read-out by MT speed selective cells. Using the same paradigm in humans, we present additional psychophysical and MEG experiments showing that: 1. At high physical speeds, perceived speed is faster at low (20%) than at high (50%) Gabor contrast, a result at odd with previous reports of lower perceived speed at low contrasts (Thompson, 1982). 2. MEG data show that: i. the latencies of the first peak responses (~90 ms.) are longer (by ~20 ms.) at low as compared to high contrast. At these latencies, response amplitude is independent of Gabor orientation; ii. At longer latencies (~160 ms.) and low stimulus contrast, the peak response amplitude is larger for a Gabor aligned to the motion axis than for a Gabor orthogonal to it, an effect not seen at high contrast. As predicted by our model, perceived speed of fast apparent motion sequences is biased in a contrast dependent way by the orientation of a target relative to its motion path, a finding well correlated to the recorded MEG activity.

3:15 *217* **Sensitivity to optic flow in human MT and MST measured with fMRI adaptation**

Andrew T Smith[1] (a.t.smith@rhul.ac.uk), Matthew B Wall[1], Angelika Lingnau[1,3], Hiroshi Ashida[1,2]; [1]Royal Holloway, University of London, UK, [2]Kyoto University, Japan, [3]University of Trento, Italy

In primates, many neurons in MSTd are sensitive to the global flow structure of a pattern of moving dots, some cells responding preferentially to expansion and others to rotation. Such cells are rare in MT. We have

explored sensitivity to optic flow in human MT and MST using an event-related fMRI adaptation paradigm, at 3 Tesla. On each trial, two brief random-dot kinematograms were presented sequentially with a gap of 2s. The first stimulus (S1, presented for 3s) is expected to reduce the response to the second (S2, presented for 1s) if they activate overlapping neural populations. In different trials, S1 and S2 contained either the same or different types of global motion. MT and MST were defined in separate experiments using the criteria of Huk et al. (J Neurosci 2002). In human MST, the compound response was smaller (indicating adaptation) when the two stimuli had the same flow structure than when they were different, suggesting specificity to global flow. The effect was large when optic flow was compared to random motion, as previously shown with more conventional paradigms (Smith et al. Eur. J. Neurosci. in press). It was smaller but robust when expansion and rotation were compared. Surprisingly, MT also showed flow specificity, even in the latter case. In V1, which is expected to respond only to local dot motions, there was no flow specificity. Our results suggest that human MT and MST both contain neurons that are selectively responsive to specific optic flow structures.

Acknowledgment: Supported by the Wellcome Trust

3:30 *218* Motion discrimination with psychophysically suppressed MT: an fMRI study

Benjamin Thompson[1] (bthom@psych.ucla.edu), Zili Liu[1]; [1]Department of Psychology, UCLA, Los Angles, California, USA

Background The MT+/V5 complex is regarded as the principal visual motion processing area in the human brain. One major mechanism MT neurons are thought to employ is opponency; excitation from one motion direction and inhibition from the opposite. Using counter-phase paired-dots it is possible to take advantage of this opponency and suppress MT activity (Qian, Andersen, & Adelson 1994). However, even for these stimuli which have balanced local motion directions, discrimination of motion-axis orientation is still well above chance (Lu, Qian, & Liu 2004). We used fMRI to investigate where in the early visual areas this discrimination might take place.

Method During an fMRI scanning protocol, participants performed a 2AFC motion discrimination task judging whether motion-axis orientation changed clockwise or anti-clockwise. Both counter-phase paired-dots and a control, in-phase paired-dots, were used.

Results MT activity was reduced by counter-phase dots relative to in-phase, whereas no other early visual areas showed differential activation by the two stimuli. Furthermore, MT activity was not significantly correlated with behavioral performance for the counter-phase condition but was the only area correlated with behavioral performance for the in-phase condition. For the counter-phase stimulus, BOLD signal in areas V2 and V3 was correlated with behavioral performance. These results support the idea that human MT has motion opponent mechanisms and also suggest that, when necessary, motion direction processing can be shifted to areas other than MT.

Spatial Vision I

Saturday, May 6, 4:15 - 5:30 pm
Hyatt Ballroom North
Moderator: James Elder

4:15 *219* Narrow-band channels optimally sum a broad band of spatial frequency information.

Christopher P. Taylor[1] (taylorcp@mcmaster.ca), Patrick J. Bennett[1,2], Allison B. Sekuler[1,2]; [1]McMaster University, Department of Psychology, Neuroscience & Behaviour, [2]York University, Centre for Vision Research

Previous work (Kersten, 1987) suggests that spatial frequency summation in one-dimensional noise patterns is well described by an ideal observer for stimulus bandwidths up to 6 octaves. However, classification image studies have shown that a two-octave wide channel is used to detect such patterns (Levi & Klein, 2005; Taylor et al., 2003). This leads to the puzzle – how does a narrow-band channel produce optimal summation over a broad bandwidth? Here we show that this puzzle can be resolved by assuming: i) stimuli are filtered by a channel whose frequency response approaches, but does not equal, zero; and ii) the dominant noise occurs prior to filtering. With these assumptions, a quantitative model predicts nearly ideal spatial frequency summation across a broad bandwidth. The model also predicts that components in comb-filtered broadband noise - i.e., noise in which every fourth frequency component carries information - should not be summed optimally. We tested this prediction by measuring detection thresholds for regular noise and comb-filtered noise using a 2-IFC task. Stimuli had a center-frequency of 5 cpd and a frequency bandwidth of 0.5-6 octaves. As before, detection thresholds for noise, expressed as r.m.s. contrast, increased with the quarter-root of the number of frequency components, but thresholds for comb-filtered noise increased with the square-root of the number of components. Hence, as predicted, optimal summation breaks down with comb-filtered noise. The results suggest that narrow-band channels may produce optimal summation of broadband noise patterns.

URL: http://psych.mcmaster.ca/taylorcp/

4:30 *220* Classification images of bandpass mechanisms across noise spectral density

Craig K Abbey[1,2] (abbey@psych.ucsb.edu), Miguel P Eckstein[1]; [1]Dept. of Psychology, University of California, Santa Barbara, [2]Dept. of Biomedical Engineering, University of California, Davis

Classification image analysis has proven to be a valuable tool for revealing features used to perform visual tasks in noise. We use this methodology to investigate how the amount of noise in a stimulus influences detection mechanisms. Experiments used to test models of detection in noise span contrast levels ranging from less than 1% to well over 10% with a corresponding range of noise spectral densities. Furthermore, experiments that vary the spectral density of a stimulus have been used as a way to determine equivalent internal noise power. The generality of these approaches depends on the assumption of a common detection strategy. We test this assumption by measuring classification images for two-alternative forced-choice (2AFC) detection of a small Gaussian target (width 8.5 min) embedded in static noise at spectral densities that range from $0.27 \cdot 10^{-6}$ deg^2 to $6.7 \cdot 10^{-6}$deg^2. Signal contrast was manipulated to maintain a performance level of approximately 85% correct. Classification images were computed from 2000 2AFC trials in low- and high-noise experiments. A spatial frequency analysis was performed by converting the spatial classification images to the frequency domain using the real part of the Discrete Fourier Transform, and averaging over radial bands of spatial frequency. The high-contrast noise classification images show a mild peak at 2-3 cyc/deg before falling off with the frequency spectrum of the Gaussian. The low-contrast noise classification images show a stronger peak at 4 cyc/deg. The different classification images we observe suggest that mechanisms of detection change with the spectral density of a stimulus.

4:45 *221* Power spectrum classification image analysis reveals localized mechanisms underlying nonlinear detection of narrowband stimuli

James H. Elder[1] (jelder@yorku.ca), Yaniv Morgenstern[1]; [1]Centre for Vision Research, York University, Toronto, Canada

Prior measurements of detection thresholds for gratings in noise have suggested that detection may be based upon linear cross-correlation with relatively small broadband filters (Kersten, 1984). Recent direct measurements of spatial summation using a classification image technique have yielded

contrary results, showing broad spatial summation over many cycles of the narrowband stimulus (Morgenstern & Elder, 2005). Here we report a computational model that partially resolves this contradiction. We show that under the standard linear cross-correlator model, classification images derived from signal-present trials yield broad summation fields locked to signal frequency and phase. However, classification images derived from signal-absent trials reveal no peak at signal frequency, indicating that the linear detection model does not apply (Ahumada & Beard, 1999). We test a number of alternative models, and show that an energy model based on broad spatial pooling of responses from local broadband mechanisms is most consistent with the human data. We show that this model is linear in the power spectrum domain, and introduce a novel classification image analysis technique that allows direct estimation of the two-dimensional bandpass transfer function of the underlying local mechanisms. These mechanisms are found to be highly localized in space, quantitatively similar in their spatial and spatial-frequency properties to neurons in early visual cortex of primate, and qualitatively similar to the broadband mechanisms inferred indirectly by Kersten (1984).

Acknowledgment: Research supported by grants from NSERC, GEOIDE.

5:00 *222* Letter identification: Evidence for scale dependence but not for fixed channels

Ipek Oruc[1] (ipek@psych.ubc.ca), Michael S. Landy[2]; [1]Dept. of Psychology, Univ. of British Columbia, Vancouver BC, Canada, [2]Dept. of Psychology and Center for Neural Science, New York Univ., New York, NY, USA

Letters are special. They form a set of shapes learned at a young age and used throughout adulthood. Therefore, the human visual system might use mechanisms specifically devoted to letter identification. Recent studies of letter identification appear to be consistent with this, such as evidence for letter channels, lack of off-frequency looking in low- or high-pass masking noise, and scale dependence. Majaj et al. (Vis Res 42:1165-1184, 2002) characterized the channels used for letter identification using critical-band masking. Observers never switched to a channel with a different peak spatial frequency to escape the effects of masking noise. We repeated this experiment, but also varied the masking noise power density. Contrary to Majaj et al., we demonstrated off-frequency looking and found that its magnitude increased with increasing noise power density. That is, Majaj et al. used insufficient noise power density to induce subjects to switch channels. Majaj et al. also found scale dependence: peak letter channel frequency (cycle/letter) varied with letter size. However, Chung et al. (Vis Res 42:2137-2153, 2002) claimed scale dependence was simply an effect of what an ideal observer would do given the equivalent input noise (from the contrast sensitivity function). We repeated the critical-band masking experiment in the presence of additional white noise (to swamp equivalent input noise), but still found scale dependence. Letter identification is scale dependent even when it no longer provides a benefit. This scale dependence is not found with, e.g., grating detection, and may indicate that letters are indeed special.

Acknowledgment: NIH EY08266 and EY16165 (to MSL)

5:15 *223* Gaussian basis functions for fitting the Gabor sector of the Modelfest data

Stanley A Klein[1] (sklein@socrates.berkeley.edu), Christopher W. Tyler[2]; [1]School of Optometry, UC Berkeley, [2]Smith Kettlewell Eye Research Institute

The Modelfest project measured 16 observers' detection thresholds on 43 diverse stimuli in human foveal vision. The project's goal was to provide a wide variety of threshold data with small standard errors for independent modelers to compare approaches. After compensating for individual differences (one parameter per subject) the threshold standard errors were impressively low, with a mean SE of less than 0.3 decilogs (7%). This small SE places extreme restrictions on spatial vision models.We previously showed (VSS, 2005) that the 24 stimuli comprising the Gabor-like sector of the Modelfest data can be very well fit by a model based on a contrast sensitivity weighted set of local Gabors plus four parameters: one specifying the transition point from full summation to probability (attentional) summation, two specifying the spatial summation slope above and below the transition, and an asymmetry parameter needed for the asymmetric summation of baguette and tiger-tail Gabors. We now extend the same model to a wider class of stimuli. Instead of local Gabors as the building blocks we use local Gaussians, appropriately placed to produce the Gabors. The local Gaussian model, using the previously found spatial pooling exponent of about 2.5, does an excellent job of fitting the previous 24 stimuli plus the three smallest Gaussians, Bessel and disk for a total of 29 stimuli. The new model achieves a substantially better fit than standard filter models, presumably because of our limited range of full spatial summation. Fitting the remaining stimuli would require assumptions about mechanism bandwidth.

Acknowledgment: This research was supported by grant EY04776-19

URL: http://cornea.berkeley.edu/presentations/

Temporal Processing

Saturday, May 6, 4:15 - 5:30 pm

Hyatt Ballroom South

Moderator: Bruno Breitmeyer

4:15 *224* Second sight: vision sustained by a secondary activation of the phototransduction cascade

Andrew Stockman[1] (a.stockman@ucl.ac.uk), Lindsay T. Sharpe[1], Michel Michaelides[1,2], Anthony T. Moore[1,2], Andrew R. Webster[1,2], Hannah E. Smithson[1,3]; [1]Institute of Ophthalmology, University College London, 11-43 Bath Street, London EC1V 9EL, UK, [2]Moorfields Eye Hospital, 162 City Road, London EC1V 2PD,UK, [3]Department of Experimental Psychology, University of Durham, South Road, Durham, DH13EL, UK

Introduction: A father and son are homozygous for a rare frameshift mutation (M280fsX291) in the gene encoding the á-subunit of cone transducin (GNAT2), the G-protein in the cone phototransduction cascade. Although this mutation should entirely abolish their cone vision, it does not. Here, we investigate the properties of their residual cone vision. Methods: We measured cone-mediated critical-flicker-fusion as a function of the radiance of a 650 nm red target, and temporal modulation sensitivity as a function of temporal frequency at a fixed time-averaged 650 nm radiance (of 10.68 log quanta s^{-1} deg^{-2}). Targets were superimposed in the centre of a 480 nm, rod-saturating background. Additional spectral sensitivity and bleaching controls were carried out to ensure that the responses were *cone* responses.Results: Both father and son retain a rudimentary cone-driven response restricted to high light levels and low temporal frequencies, which has two singular properties. First, temporal frequency sensitivity is limited by the equivalent of a simple 1st order reaction with a time constant of ~140 ms. Second, their temporal acuity is linearly related to the logarithm of the amount of bleached cone pigment.Conclusion: The results are consistent with the residual cone response being dependent on the secondary activation of the phototransduction cascade by a bleaching photoproduct produced by a first-order reaction, such as a metarhodopsin derivative or the freed opsin, which bypasses the defective á-transducin. Such a secondary activation has long been hypothesized to explain the equivalence between the visual effects of bleaches and those of steady background lights.

Acknowledgment: Wellcome Trust

4:30 *225* **Distinct Temporal Dynamics of Cone-Opponent and -Nonopponent Macaque Primary Visual Cortical Neurons**

Venkata R. Posina[1] (posina@salk.edu), Gregory D. Horwitz[1], Thomas D. Albright[1]; [1]Vision Center Laboratory, The Salk Institute for Biological Studies, 10010 North Torrey Pines Road, La Jolla, CA 92037, USA

Receptive field maps of neurons in the primary visual cortex (V1) of awake, fixating monkeys were obtained by spike-triggered averaging (STA) of checkerboard stimuli modulated along the three cone-isolating directions. Receptive field centers were within the central 5 deg. Most of the cells (81%) that we studied were cone-opponent, and 79% of these cone-opponent neurons had an L-cone signal opposed to M- and S-cone signals ("L vs. M&S" neurons). Examination of the temporal profile of STAs showed that the times-to-peak of cone-nonopponent neurons were shorter than those of cone-opponent neurons (61 vs. 73 ms). The three subtypes of cone-opponent neurons (i.e. "L vs. M&S", "M vs. L&S", and "S vs. L&M") had same times-to-peak. The times-to-peak of the three cone signals were same in most neurons. Most of the cone-nonopponent neurons (83%) were temporally biphasic, while only 22% of the cone-opponent neurons were biphasic. The times-to-peak of biphasic neurons were shorter than those of monophasic neurons. Even within the subset of biphasic neurons, the times-to-peak of cone-nonopponent neurons were shorter than those of cone-opponent neurons (54 vs. 66 ms). The temporal properties of cone-nonopponent and cone-opponent neurons are consistent with a difference in the proportion of magnocellular and parvocellular input to these two groups of V1 cells. Moreover, the observed temporal differences between cone-nonopponent and cone-opponent neurons parallel the differences between the psychophysical luminance and chromatic mechanisms.

4:45 *226* **Temporal Aspects of Contour and Brightness Processing in Meta- and Paracontrast**

Haluk Ogmen[1,2] (ogmen@uh.edu), Bruno G. Breitmeyer[2,3], Hulusi Kafaligonul[1], Steven Todd[4], Lynn Mardon[4], Ralph Ziegler[3]; [1]Department of Electrical & Computer Engineering, University of Houston, [2]Center for Neuro-Engineering and Cognitive Science, University of Houston, [3]Department of Psychology, University of Houston, [4]Department of Philosophy, University of Houston

Purpose. Existing evidence suggests that stimulus contours are processed faster than surface brightness or color. We investigate the temporal dynamics of contour and brightness visibility during meta- and paracontrast and use an updated RECOD model of visual masking to account for the findings.**Methods.** Stimuli were a 0.85 deg disk (T), surrounded by a ring (M), 0.42 deg wide and separated by 0.05 deg, centered 1.4 deg above and 1.6 deg to the right of fixation. In the brightness masking, a match stimulus the same size as T was presented symmetrically to the left of fixation. In the contour masking, T was either a complete disk or one with either a lower or upper contour deletion. **Results.** Whereas optimal metacontrast SOA was 10-15 ms in contour masking, it was 40 ms in brightness masking. In paracontrast 1) a local minimum of visibility was obtained around an SOA of -170 ms for both tasks, 2) a local enhancement of brightness visibility was obtained at an SOA of -40 ms, and c) a second period of suppression was evident, particularly in contour masking, at an SOA of -10 ms. **Conclusion.** Brightness and contour are processed by separate slow and fast cortical parvo pathways, each subject to intrachannel inhibition and to interchannel inhibition by the still faster cortical magno activity. In addition, subcortical modulatory processes activated by the paracontrast mask may enhance the parvo brightness activity to the following target. These conclusions are supported by simulations of an updated RECOD model.

Acknowledgment: NSF BCS-0114533, NIH R01-MH49892

5:00 *227* **Evidence for interacting temporal channels: spatial determinants**

John R Cass[1] (jcass@physiol.usyd.edu.au), David Alais[1]; [1]Department of Psychology, University of Sydney, Australia

Previous temporal masking studies have found that the visual system possesses independent temporal frequency (TF) channels: one low-pass and one or two higher bandpass channels peaking ~ 10Hz. Using iso-oriented targets and masks, we replicated this finding. However, when targets and masks were cross-oriented we found no evidence for the low-pass channel, but still found a high bandpass channel. The orientation-dependence of the low-pass channel suggests a cortical mechanism, whereas the orientation-invariant bandpass performance supports recent evidence that temporal masking may be mediated sub-cortically (Freeman, Durand, Kiper & Carandini, 2002). Follow-up masking experiments using (unoriented) spatio-temporally filtered noise revealed evidence for two bandpass channels (peaking ~ 1.5 and 10Hz). Interestingly, these channels appear to interact asymmetrically: high TFs mask low TFs, but not vice versa. We also varied spatial frequency using spatio-temporally filtered noise. These data indicate that while the temporal channel asymmetry is seen at several spatial frequencies, the high-pass channel shifts to higher temporal frequencies as spatial frequency is reduced, and a third intermediate temporal channel emerges. The implications of these spatio-temporal interactions for figure-ground, form and motion processing are discussed. We propose that the asymmetric temporal channel interactions may serve to equalize the 1/TF power spectrum present in natural image sequences, and may also contribute to motion deblurring.

5:15 *228* **Temporal freezing of surface properties**

Isamu Motoyoshi[1] (motoyosi@apollo3.brl.ntt.co.jp); [1]Human and Information Science Lab, NTT Communication Science Labs.

Psychophysical evidence suggests that the perception of surface properties such as color and texture is spatially regulated by, or filled-in from, signals at boundaries. I here show temporal filling-in with a new illusion in which a gradual change in visual features is frozen if caught by a surface. When a Kanizsa-type subjective figure was briefly presented (50-300 msec) on a uniform background of gradually changing color, the color inside the figure appeared to stop changing in time and to be different from the background color. When a drifting grating was used as the background, the grating inside the figure was perceived stationary and to have a lower spatial frequency than the background. Mere abrupt changes, e.g., luminance flash, were not sufficient to produce the illusion, suggesting a critical involvement of surface / object representations. These results were interpreted as indicating that the temporal-window for averaging, or filling-in, of surface feature representations is enlarged by onset / offset of the figure. This illusion can be considered as an important tool for understanding how the visual system binds features from continuous and dynamic image inputs, in the process of the filling-in both in space and time.

Poster Session B

Saturday, May 6, 2006

Attention and Working Memory (229-239), Locomotion and Navigation (240-255), Perceptual Learning (256-273, 1120), Multi-Sensory Processing (274-294), Spatial Vision: Mechanisms and Texture (295-314)

Poster Session: 8:00 - 11:00 am ***Municipal Auditorium***
Author presents: 9:30 - 10:30 am

Attention and Working Memory

B1 *229* Concurrent working memory load can reduce distraction: An fMRI study

Min-Shik Kim[1,2] (kimm@yonsei.ac.kr), Soo-jung Min[1], Kamin Kim[2], Bo-Young Won[2]; [1]Graduate Program in Cognitive Science, Yonsei University, Korea, [2]Department of Psychology, Yonsei University, Korea

Concurrent working memory (WM) load increased the interference by visual distractors during a selective attention task (de Fockert, Rees, Frith, and Lavie, 2001). However, recent studies showed that the different types of WM load can produce different effects depending on whether the load overlaps with the target or the distractor processing (Kim, Kim, & Chun, 2005; Park, Kim, & Chun, 2005). In this study, functional magnetic resonance imaging (fMRI) was used to examine whether WM load decreases distractor processing when the two overlap. Participants were asked to classify famous written names as athletes or politicians while ignoring distractor faces during a selective attention task, with holding a famous face (low WM load condition) or an unfamiliar face (high WM load condition) in WM. Activities in the frontal cortex area increased during the high WM conditions, but the occipital and temporal cortex areas showed more activation when WM load was low. More interestingly, high WM load decreased face-related activity in the fusiform face area (FFA) when the contents of WM were faces. These results suggest that dissociable systems for different types of contents have their own independent attentional capacity and that the same content-specific system subserves both WM and attentional selection.

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B2 *230* Spatial working memory load impairs signal enhancement, not attentional orienting

Suk Won Han[1] (hsw1770@yonsei.ac.kr), Min-Shik Kim[1]; [1]Department of Psychology, Yonsei University, Korea

The current study examined the effect of spatial working memory load on spatial cuing effect. It is well known that spatial working memory and spatial attention functionally overlap or share a common resource. Awh et al. (1998) showed visual selection played a critical role in the maintenance of spatial information. Based upon this finding, we expected that the improvement in behavioral performance by attention would interact with spatial working memory. Two experiments were conducted to test this hypothesis. Participants were given a transient cue predicting the location of a relevant item and they had to perform a visual discrimination task with or without maintaining four locations in working memory. Cuing effect measured by reaction time did not differ either in the presence or in the absence of spatial working memory load. However, spatial working memory load reduced cuing effect in accuracy. This discrepancy can be explained by distinction between channel selection and channel enhancement by attention (Prinzmetal et al., 2005). The benefit in RT by attention shows prioritization of the attended location (channel selection), whereas the improvement in accuracy under data-limited conditions reflects the enhancement of perceptual representation on the attended location (channel enhancement). Given the fact that spatial working memory load reduced only the attentional advantage in accuracy, we conclude that spatial working memory load impairs signal enhancement on the attended location, but seems to be irrelevant with attentional orienting per se.

Acknowledgment: This work was supported by the Korea Research Foundation Grant (KRF-2004-005-H00004).

B3 *231* Working memory training reduces working memory load effect

Heejung Kim[1] (hiddendimensions@gmail.com), Min-Shik Kim[1]; [1]Department of Psychology, Yonsei University, Korea

Cognitive control has been reported to be affected by working memory capacity and concurrent working memory load. This study examined whether and how spatial working memory (SWM) capacity and SWM training influence the effects of working memory load on cognitive control. The experiments of the present study had three sessions. In pre-test session, each participant's SWM capacity and cognitive control performance were measured; the former via a visuo-spatial serial recall test (VSRT), and the latter via a dual-task of a SWM task and a spatial flanker task. The pre-test results showed that the performance of the large SWM capacity group, regardless of the amount of concurrent SWM load, was little interfered by the distractor. However, the performance of the small SWM capacity group was heavily interfered by the distractor when SWM load was increased. For the training session, those who showed low performance in VSRT were randomly assigned into either a verbal working memory (VWM) or a SWM training group. The VWM training group performed a verbal change detection task and the SWM training group performed a spatial memory recognition task. During the post-test session following a three-day training, both groups performed the same tasks as those used in the pre-test session. The post-test results showed that the SWM training reduced the amount of flanker interference even when SWM load was high. These results demonstrate that the SWM training can reduce the SWM load effect, which results in an improved cognitive control.

Acknowledgment: This research was supported by Korean Ministry of Science & Technology 21st Century Frontier Research Program Brain Research Center Grant M103KV010021-05K2201-02110.

B4 *232* Predictive spatial working memory content guides visual search

Jang Jin Kim[1] (jjkim@yonsei.ac.kr), Min-Shik Kim[1], Marvin M. Chun[2];

[1]Department of Psychology, Yonsei University, Korea, [2]Department of Psychology, Yale University, U. S. A.

The visual system can learn invariant spatial configurations that can serve as contextual cues to guide spatial attention (Chun & Jiang, 1998). We examined whether repeatedly presented working memory (WM) arrays can serve as contextual cues. Participants performed visual search while maintaining a WM array presented at the beginning of each trial. In the learning phase, each WM array was paired with a specific target location and the paired presentations were repeated throughout the entire learning session. In the test phase, half of the parings remained constant (old condition), but the other half switched to new, unpaired locations (new condition). If associations between the representations maintained in WM and search target locations are learned and used as contextual cues, search performance should be better in the old condition than in the new condition. In Experiment 1, four color patches were used as WM stimuli and paired with specific target locations in visual search. The results showed that color WM representations in the old condition did not improve search performance. In Experiment 2, four locations were used as WM stimuli and paired with specific target locations in visual search. The results showed that spatial WM representations in the old condition improved search performance. Chance performance in a subsequent recognition test showed the learned associations were implicit. These results indicate that "contextual cueing" can occur even when the predictive context is not concurrently present, and such implicit contextual cueing of attention by WM was specific to spatial WM.

Acknowledgment: This work was supported by the Korea Research Foundation Grant (KRF-2004-005-H00004).

B5 *233* Effects of spatial and non-spatial working memory on location- and object-based attention

Wei-Lun Chou[1] (f90227011@ntu.edu.tw), Su-Ling Yeh[1]; [1]Department of Psychology, National Taiwan University

A visual object inherently occupies a location, and a spatial location cannot be marked without some entity. Such an interwoven relationship between objects and locations has made the dissociation between object- and location-based attentional selection difficult. In a series of experiments, we examine whether the two kinds of selection can be modulated by different kinds of working memory tasks, and how stimulus configuration affects such modulation. A dual-task paradigm was used, in which the primary task was associated with a location or an object, and the secondary task involved either spatial or non-spatial working memory. Results from the first two sets of experiments revealed that location-based selection was affected by a secondary task that involved spatial working memory, whereas object-based selection was affected by a secondary task that involved non-spatial working memory. Changing the configuration of the stimuli influenced the modulation effects of the two kinds of working memory tasks accordingly. As spatial and non-spatial working memory modulate location- and object-based attention respectively, the double dissociation we have obtained in this study helps to disentangle object- and location-based attention, and provides a useful index for probing either one or both.

Acknowledgment: This study is supported by the National Science Council of Taiwan, NSC94-2752-H-002-008-PAE

B6 *234* Working memory capacity influences the top-down factors in visual search

Ken Sobel[1] (k.sobel@mac.com), Matthew Gerrie[2], Mike Kane[3], Bradley Poole[3]; [1]University of Central Arkansas, [2]Victoria University of Wellington, [3]University of North Carolina Greensboro

Working memory enables us to hold a goal in mind while at the same time ignoring salient but irrelevant distractions; working memory capacity is instrumental to our ability to focus attention. The operation-span task, in which subjects try to remember several items while also carrying out arithmetic problems, is a widely used assay of working memory capacity; proficiency on this task has been found to correlate well with a wide array of other tasks that tap into top-down control of attention. However, attempts to correlate operation span with visual search performance have met with little success. We have previously shown that manipulating the salience of distractors' features can influence the relative contributions of bottom-up and top-down factors to attentional guidance in visual search tasks. By manipulating salience in this manner we were able to reveal a role for working memory in visual search.

B7 *235* Working memory load can impair neural processing of unattended information

Julie D. Golomb[1] (julie.golomb@yale.edu), Marvin M. Chun[1]; [1]Yale University

Concurrent working memory load can be increased without any effect on the neural processing of unattended scenes (Yi et al., 2004). However, different subsystems of working memory may use different processing resources, which may or may not interact with concurrent perceptual processing. To investigate this further, subjects performed foveal spatial or object n-back tasks while irrelevant scenes were presented in the peripheral background. The stimuli set consisted of nondescript shapes presented one at a time in different locations. Visuomotor stimulation was identical for all conditions; only attentional set differed. Load was manipulated by varying the number of items held in memory; behavioral performance on the low load tasks (spatial 1-back and object 1-back) was significantly better than on the high load tasks (spatial 3-back and object 2-back). To examine the effects of spatial and object working memory load on unattended scene processing, we compared event-related fMRI BOLD responses in the parahippocampal place area (PPA). PPA activation was significantly attenuated during spatial high load trials compared to spatial low load trials, supporting our hypothesis that perceptual processing involves an inherently spatial component. Interestingly, there was also an effect of object working memory load, suggesting that working memory for certain stimuli (i.e., shapes but not faces) may share processing resources with the task-irrelevant scenes (c.f., Kim et al., 2005). Thus, concurrent working memory load can interfere with visual processing of unattended scenes in the PPA, suggesting that task-related forms of working memory exert top-down influence on the attentional control of perceptual processing.

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236 Abstract 236 moved to poster D74.

B8 *237* Colour-Specific Deficits in *Implicit* Colour Working Memory: A *Visuomotor* Case Study

Loni Rhode[1,2] (umrhode@cc.umanitoba.ca), Lee A Baugh[1,2], Pauline M Pearson[3], Lorna S Jakobson[2], Jonathan J Marotta[1,2]; [1]Neuropsychology of Vision Perception and Action Lab, [2]Department of Psychology, University of Manitoba, [3]Department of Psychology, Univeristy of Winnipeg

Previous research has demonstrated that grasping can be altered through implicitly established colour-size associations (Haffenden & Goodale, 2000). After training with "large" red and "small" blue blocks, subjects open their hands wider when grasping "medium" blue probe blocks than when grasping identically sized red blocks. We examined whether QP, an individual who has a selective deficit in explicit colour working memory, demonstrates an influence of colour-size associations on grip aperture. Results from 13 right-handed control participants revealed that grip aperture was significantly wider for the blue probe block than for the red probe block (difference of 2.46 mm, $p<.05$). As with the controls, QP also increases her grip aperture for the blue block (difference 3.26 mm). To explore whether colour-size associations generalize within a colour category, light blue and light red probe blocks that were not part of the training phase were added to the test phase. In controls, differences between the light blue and light red probe blocks were not observed. In contrast, QP shows a difference for light red compared to light blue probe block

(2.66 mm). These visuomotor findings suggest that QP's colour memory deficits also affect her implicit colour memory, and that the influence of implicit color memory on visually guided grasping normally does not generalize within colour categories. Consistent with QP's difficulty in recalling specific shades of a colour, her colour-size associations do not exhibit normal specificity.

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URL: www.perceptionandaction.com

B9 *238* Rehearsal in Visual Memory

Dawn A. Morales[1] (dmorales@psych.upenn.edu), Sharon L. Thompson-Schill[1]; [1]University of Pennsylvania, Center for Cognitive Neuroscience

One prominent model of visuo-spatial working memory proposes overlapping mechanisms for the retention of spatial and visual information (Baddeley & Logie, 1999). Although several lines of evidence point to an attention-based rehearsal mechanism (Awh, Jonides, & Reuter-Lorenz, 1998) for the retention of spatial information, there is no obvious way to extend this idea to the retention of visual but non-spatial information such as color. The visuo-spatial working memory model proposes a passive cache for such visual information. One prediction from this model is that distracting auditory secondary tasks performed during the memory delay will have no effect on memory for visual information, since a passive store has no requirement for attention-demanding rehearsal of information. The logic of dual-task experiments is that if requiring completion of a second task during the memory delay for a primary task interferes with performance on the primary task, then both tasks must compete for a single resource or mechanism. We tested this idea by comparing individual observer's memory for color or pattern (Phillip's squares, Phillips & Christie, 1977) in trials with no secondary task during the memory delay with the same individual's dual-task performance. We find that memory for color is remarkably robust against the effects of secondary tasks, whereas memory for patterns is quite vulnerable. This is consistent with a model where color memory is maintained by a passive mechanism and pattern memory requires attentive rehearsal. This may prove to be the same spatial attention mechanism proposed for spatial working memory.

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B10 *239* Visual working memory matches do not always attract attention

D. Alexander Varakin[1] (alex.varakin@vanderbilt.edu), Daniel T. Levin[1]; [1]Vanderbilt University

Stimuli matching visual working memory (VWM) representations are often attended. Effects consistent with this proposal have been observed in many tasks, such as RSVP, visual search, and probe detection. However, methodological limitations make it unclear whether the effect is automatic or the result of task-specific strategies. For example, some experiments required observers to hold an item in VWM and presented a matching item over the retention interval, but did not eliminate the demand to *intentionally* search for VWM matches. The current experiments took several precautions to address these demand characteristics and reduced the opportunity for verbal rehearsal while retaining the VWM task. Subjects performed articulatory suppression and held an object in VWM. Over the retention interval two objects were simultaneously flashed on the screen followed by a response probe. On critical trials, a VWM match and a novel item were flashed on the screen. If VWM matches attract attention, then probe responses should be faster when the probe appears at the location where the VWM match appeared. In an attempt to eliminate demand characteristics, only one-sixth of the trials were critical trials. On the remaining trials two task irrelevant objects were flashed. In Experiment 1, subjects who did not intentionally search for VWM matches over the retention interval showed a match-trial *disadvantage*. In Experiment 2, subjects were instructed to "let the display determine… [their] response", in order to further reduce demand characteristics. We again found a match-trial disadvantage. These experiments suggest that VWM matches do not always attract attention.

Locomotion and Navigation

B11 *240* Combining Moving Targets and Moving Obstacles in a Locomotion Model

Jonathan A. Cohen[1] (jonathan_cohen@brown.edu), Hugo Bruggeman[1], William H. Warren[1]; [1]Brown University

Our dynamical model of locomotor behavior has separate components for (a) steering to a stationary goal, (b) avoiding a stationary obstacle, (c) intercepting a moving target, and (d) avoiding a moving obstacle (Fajen & Warren, 2003; submitted). Recent research has shown that these components can be linearly combined, with fixed parameters, to predict human paths with a moving target and a stationary obstacle (Bruggeman & Warren, VSS, 2005), and vice versa (Cohen, Bruggeman, & Warren, VSS, 2005). Here we test the model in situations where both the target and the obstacles are moving. We attempt to predict the paths participants take when intercepting a moving target while avoiding one moving obstacle (Experiment 1), or avoiding two moving obstacles (Experiment 2). Studies were conducted in the Virtual Environment Navigation Lab, a 12m x 12m ambulatory virtual environment with a head-mounted display (60° H x 40° V) and a hybrid sonic/inertial tracking system (latency 50-70 ms). Participants walked toward a moving target (blue pole) while avoiding moving obstacles (yellow poles). Objects moved on parallel trajectories in the frontal plane. Their speeds were manipulated to create situations in which the model predicts switching between paths ahead of and behind an obstacle. Human paths are close to the model paths and switch from ahead to behind an obstacle near the predicted speeds. The results generalize the steering dynamics model to more complex environments with multiple moving objects. Future work will seek to extend the model to situations with multiple competing goals.

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B12 *241* Is obstacle avoidance controlled by perceived distance or time-to-contact?

Hugo Bruggeman[1] (hugo@brown.edu), Daniel B. Rothman[1], William H, Warren[1]; [1]Dept. of Cognitive & Linguistic Sciences, Brown University

Question: Do steering adjustments depend on the perceived distance or time-to-contact with an obstacle? Our locomotor dynamics model (Fajen & Warren, JEP:HPP, 2003) currently assumes distance as an input variable but could alternatively use time-to-contact, specified by the relative rate of optical expansion. To dissociate these hypotheses we independently vary physical walking speed and the visual gain in a virtual environment. The manipulations produce similar optical speeds but only the physical walking speed affects the inertial properties of the body.

Design: The experiment is performed in an ambulatory virtual environment (10m x10m) with a head-mounted display (60° H x 40° V) and a sonic/inertial tracking system (50-70ms latency). Participants are instructed to walk at three speeds (2/3, 1 or 3/2 of preferred walking speed). These are partially crossed with three visual gains (2/3, 1, 3/2), such that the optical motion in the display is slower, matched, or faster than the actual walking speed. Participants walk to a stationary goal (6m straight ahead) around an obstacle whose position varies across trials (initial distance of 3 or 5m, 3° to the left or right of the straight path).

Results: Using distance as the control variable, the model predicts that the agent will turn later as speed increases, whereas using time-to-contact it predicts the reverse. The dependence of steering behavior on the body's inertial properties can also be assessed. Model predictions are evaluated against the human data to empirically determine whether human obstacle

avoidance is controlled by distance or time-to-contact.

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URL: http://www.cog.brown.edu/~hugo/

B13 *242* Optic flow aids in the formation of cognitive maps

Kasey C. Soska[1] (kasey.soska@nyu.edu), Rick O. Gilmore[2]; [1]New York University, Department of Psychology, New York, NY 10003, [2]The Pennsylvania State University, Department of Psychology, University Park, PA 16802

The presence of optic flow facilitates spatial navigation and place memory (Kirschen et al. 2000). The present study investigated the role that optic flow plays in cognitive mapping. Adult participants (n=42) were shown a video that simulated movement through a maze. The video was edited such that one group viewed fluid optic flow information (32 frames/s) and the other only viewed discontinuous (2 frames/s) optic flow. A recognition task measured the ability to correctly identify aerial views of sections of the maze near target locations (with the location of either the targets or the walls changed to generate two incorrect views in each trial). A recall task measured the ability to draw part of the maze free hand. Recognition accuracy was lower in the discontinuous condition for target position changes (p=.0039), but not for wall location changes (p=.73). There was a marginal effect of flow condition in the recognition task overall (p=0.076). Recall ability was not significantly lower in the discontinuous condition (p=.116), though the effect size was moderate. Discontinuities in optic flow may compromise the perception and subsequent processing of information about orientation and action crucial for forming an allocentric representation of the environment. Connections between the dorsal visual stream and hippocampal areas, among others, are hypothesized to underlie the contribution of optic flow to cognitive mapping.

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B14 *243* Flexible attunement to different optical variables in visually guided action

Gabriel J. Diaz[1] (diazg2@rpi.edu), Brett R. Fajen[1]; [1]Rensselaer Polytechnic Institute

A common approach to the study of visually guided action is to search for optical invariants that reliably guide action across a range of conditions. However, optical invariants are not always available, and the reliability of non-invariants can change with local constraints. So the visual system must be able to flexibly tune to different optical variables. We investigated such flexibility within the context of a simulated braking task. In a previous study, observers braking before a stationary target relied on global optic flow rate (GOFR). When braking behind a moving lead target, GOFR is unreliable because it specifies the observer's absolute speed rather than observer-target relative speed. We predicted that participants could learn to disregard unreliable GOFR cues, but only to the extent that other reliable information is available. Participants used a footbrake to decelerate from a rapid approach and make soft contact with a moving lead target. Observer absolute speed and observer-target relative speed were independently manipulated, and target size was either fixed or variable. A combination of optical angle and expansion rate closely correlates with the required deceleration when target size is fixed, but not when it varies. Participants in the variable-size condition exhibited a weak GOFR bias, but those in the fixed-size condition were unaffected by GOFR, apparently because other reliable information was available that allowed them to ignore GOFR. The results highlight the robust process of flexible attunement, and suggest that the single optical invariant assumption is too rigid to account for successful visually guided action.

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B15 *244* Perceptual learning and the visual guidance of braking

Brett R Fajen[1] (fajenb@rpi.edu); [1]Rensselaer

I investigated the hypothesis that performance on a visually guided action improves with practice (in part) because actors learn to exploit more reliable information in optic flow. Participants performed a simulated braking task, using a joystick to decelerate to a stop before a target. Information is available in optic flow that specifies how hard to decelerate, and is invariant across changes in target size and approach speed. However, observers (especially novices) may rely on a less reliable non-invariant, which would result in biases as target size and approach speed are varied. Participants completed eleven blocks of 25 trials. Target size and approach speed were manipulated within each block. Participants exhibited a weak size bias that quickly disappeared with practice, and a strong speed bias that diminished but did not disappear. In a control condition in which the textured ground plane was absent, the speed bias was greater and did not change with practice. The results suggest that participants quickly became attuned to a size-invariant optical variable, and learned to use more reliable information in optic flow (global optic flow rate of the ground plane) to perform the task across changes in speed. I conclude that actors do not always rely on a single optical invariant, contrary to most existing theories of continuously controlled visually guided actions. The reliability of different optical variables depends on task and environmental constraints. The ability to flexibly tune to different optical variables may underlie actors' ability to adapt to changes in such constraints.

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B16 *245* Learning Virtual Building Layouts: The Effects of Age on the Usefulness of Geometric and Nongeometric Visual Information

Amy Kalia[1] (kali0080@umn.edu), Gordon E. Legge[1], Nicholas A. Giudice[2]; [1]University of Minnesota Twin-Cities, [2]University of California Santa Barbara

This study examines the effect of age on the use of visual information when learning target locations in novel buildings. We define two types of visual information available for indoor navigation: 1) geometric cues conveying information about layout geometry, specifically, the network of corridors, and 2) nongeometric cues that are distinct from geometry, including identifiable objects (e.g. wall posters) and image characteristics (e.g. color, shading). Previous research suggests that although geometric visual cues are usually sufficient for spatial learning, nongeometric information can assist memory for geometrically-similar locations. We propose that age reduces the capacity to remember locations using geometrical features, resulting in greater reliance on nongeometric features. Sixteen younger (ages 17-22) and eight older (ages 53-66) normally-sighted individuals learned novel layouts in a Real building, and two desktop virtual environments, one displaying only geometric information (Sparse VE) and another displaying additional nongeometric features (Realistic VE). Older subjects exhibited greater difficulty learning in the Sparse VE compared to the Realistic VE, as indicated by poor target localization when navigating in the corresponding real building ($p < 0.001$). Younger subjects located targets accurately after learning in either VE. Because many visual impairments are caused by age-related disorders, we also compared performance to eleven visually impaired individuals (ages 18-67). The low-vision participants yielded similar results as their age-matched sighted peers, indicating that age is a factor to consider in evaluating navigation with low vision. These results reveal the importance of nongeometric visual cues for spatial navigation by older adults.

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B17 *246* Collision detection and factors affecting "reality" of a virtual environment

Russell L Woods[1,2] (rwoods@vision.eri.harvard.edu), Lee T Lichtenstein[1], Aaron J Mandel[1], Eli Peli[1,2]; [1]The Schepens Eye Research Institute, Boston, MA, [2]Department of Ophthalmology, Harvard Medical School, Boston, MA

Purpose: Factors expected to improve the immersive experience ('realism') in a virtual environment (e.g. updating the viewpoint using head position) may affect collision detection performance. Methods: Participants stood or walked on a treadmill 75cm from 95-degree-wide screen that displayed a textured representation of a 'shopping mall' corridor. Participants indicated whether they would collide with human-sized obstacles, that appeared for one second, if they continued on the same path. Perceived safe passing distance and decision quality were compared for: (1) locomotion (standing versus walking at fixed and participant-controlled speeds); (2) viewing eyes (monocular or binocular); (3) viewpoint updating (moving the viewpoint with head position) and (4) viewpoint error (30cm left or right). Results: When standing, participants had a slightly smaller perceived safe passing distance ($p=0.07$) and more definite decisions ($p=0.01$) than when walking. Participant-controlled walking speed, viewing eyes and viewpoint updating had no significant effect on the perceived safe passing distance ($p>0.18$) or decision quality ($p>0.38$). Viewpoint error caused subjects to have a non-symmetric perceived safe passing distance (shifted their perceived centerline), with females shifting towards and males shifting away from the incorrect viewpoint ($p=0.02$).Conclusions: Attempts to increase realism (walking, viewpoint updating, using one eye with non-stereo display) did not affect collision detection performance. Temporal lag of our headtracker may have degraded performance in the viewpoint-updating condition. The implications of the gender difference in perceived body position due to viewpoint error is not clear.

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B18 *247* The behavioral dynamics model of locomotor control: Integrating basic behaviors

William H. Warren[1] (Bill_Warren@brown.edu); [1]Brown University, Providence, RI, USA

We have developed a dynamical systems model of visually-guided locomotor behavior in which the directions of goals and obstacles behave like attractors and repellers of the agent's heading (Fajen & Warren, 2003; submitted; Cohen, Bruggeman, & Warren, VSS, 2005). The model has separate components for (a) steering to a stationary goal, (b) avoiding a stationary obstacle, (c) intercepting a moving target, and (d) avoiding a moving obstacle. The present question is whether the model is generative: Can these components be linearly combined (with fixed parameters) to predict human locomotor paths in more complex environments? This talk presents an overview of recent experiments on human walking with combinations of stationary/moving targets and stationary/moving obstacles. The studies were performed in the Virtual Environment Navigation lab, a 12m x 12m ambulatory virtual environment with a head mounted display (60° H x 40° V) and a hybrid sonic/inertial tracking system (latency 50-70 ms). The model closely predicts both the quantitative paths and the qualitative switching points between paths that were observed in human behavior. The model thus appears to scale to increasingly complex dynamic environments with no free parameters. Apparently simpler steering models (Rushton, Wen, & Allison, 2002; Wilkie & Wann, 2003) do not simulate human paths as accurately without additional terms. Research frontiers include modeling complex natural behavior such as football, creating a virtual world in which people interact with model-driven avatars, and agent-based simulations of crowd behavior.

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B19 *248* Wormholes in Virtual Reality and the Geometry of Cognitive Maps

Daniel B. Rothman[1] (Daniel_Rothman@Brown.edu), William H. Warren[1]; [1]Brown University

The underlying geometry of cognitive maps could take different forms. At one extreme, spatial knowledge might have a Euclidean structure that preserves metric distances and angles (Gallistel, 1980). At the other, it might have a topological graph structure that only preserves the connectivity between known places. We investigate this question by introducing two "wormholes" that link remote places in a virtual hedge maze, making it non-Euclidean. A control maze had the same layout with no wormholes. Participants walked in an immersive virtual environment (10m x10m) with a head-mounted display (80deg FOV) and a sonic/inertial tracking system (50-70ms latency). In the learning phase, they explored the environment and were then trained to a criterion of two trials walking directly from a Home location to each of 10 landmark locations. In the test phase, they walked from Home to location A and thence to location B. On probe trials, the possible routes from A to B included a shortcut through a wormhole that required initially walking away from B. If participants learn both environments with comparable numbers of training trials and errors, and take advantage of wormholes during testing, it suggests that they rely on a graph-like structure for navigation. Conversely, if they have more difficulty learning the wormhole environment, or fail to use wormholes and make errors during testing, it suggests that they acquire more metric spatial knowledge. The results will allow us to better understand the geometrical structure underlying human cognitive maps.

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B20 *249* The role of topological boundary relations in active navigation

Huiying Zhong[1] (huiying_zhong@brown.edu), Marianne C. Harrison[1], William H. Warren[1]; [1]Brown University

We have found that humans depend heavily on ordinal spatial knowledge and landmarks, rather than metric spatial knowledge, when navigating in a virtual hedge maze (Harrison et al, VSS, 2001, 2002; Zhong et al, VSS 2005, Psychonomics, 2005). A related form of topological structure is provided by boundaries that carve up space into adjacent neighborhoods. Kuipers et al (2003) found that people tend to choose paths that participate in more boundary relations when navigating in grid-like desktop virtual environments. Here we investigate whether knowledge of boundary relations improves the accuracy of shortcuts when walking in a virtual maze. Participants actively walk in the VENLab, an immersive virtual environment (10m x10m) with a head-mounted display (60 deg H x 40 deg V) and a sonic/inertial tracking system (50-70ms latency). In the learning phase, participants freely explore a hedge maze with primary, secondary, and tertiary paths (the boundaries) and are trained to walk from a Home location to each of 10 places successfully. In the testing phase, they walk to place A, the maze is removed, and they are instructed take a shortcut to place B. On control trials, all features of the maze are removed. On probe trials, either (a) primary, (b) primary and secondary, or (c) all three paths remain visible. If participants utilize knowledge of boundary relations, their shortcut accuracy and precision should improve as more paths remain. The results allow us to determine the role of topological boundary relations in active navigation.

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B21 *250* Intercepting moving targets on foot: Can people learn to anticipate multiple trajectories?

Justin M. Owens[1] (jmo@brown.edu), William H. Warren[1]; [1]Brown University

Previous work (Fajen & Warren, 2004; submitted) modeled human interception of moving targets based on first-order information about the target's bearing (constant bearing strategy). The model has accurately predicted paths to constant velocity and accelerating targets and to targets moving on a curved trajectory. Owens & Warren (VSS 2005) found that with repeated presentation of the same trajectory, most participants learn heuristic strategies to anticipate target motion and take "shortcuts" to accelerating and curving targets, although there was considerable variation. Here we investigate the number and variety of target trajectories that participants can learn to anticipate by varying trajectory characteristics within blocks of trials. Participants walked in the VENLab, a 12m x 12m virtual environment with a head-mounted display (60 deg H x 40 deg V)

and a sonic/inertial tracking system (latency 50-70 ms). One block of 20 trials consisted of two randomized target trajectories that curved in the same direction, but had different radii and speeds. Another block of 20 trials contained two mirror-image trajectories with identical radii and speed. Presentation order of these blocks was counterbalanced. The final block of 40 trials presented four novel trajectories with different radii and speeds. Most participants developed shortcut strategies in all three conditions, although more learned them for the same-side targets than for the mirror-image targets. The trajectories in the last block of trials were the most quickly and consistently learned. A second experiment investigates how the addition of a color cue to target trajectory affects the acquisition of anticipatory strategies.

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B22 *251* Estimating Distance and Duration of Travel: A Possible Shared Mechanism

Ling-Dan Wu[1] (sunhong@mcmaster.ca), Huai-Yong Zhao[1], Qiang Liu[1], Jennifer L. Campos[2], Hong-Jin Sun[2]; [1]Southwest University, China, [2]McMaster University

The perception of spatial extent and time duration may share several common properties. It is well established that a visually specified distance appears to be longer if there are more intervening points within that distance. Similarly, segmenting an interval of time leads to biases in duration judgments. To explore the involvement of temporal mechanisms in distance processing, we conducted a series of studies investigating aspects of traversed distance perception - a skill that typically involves integrating input from both proprioceptive and temporal duration information. In Exp. 1 we first explored the segmentation effect in time perception alone. It was found that if there were more intervening auditory events (identifying odd/even digits) during a temporal duration, subjects'(Ss') estimates of duration were longer. In Exp. 2, Ss traversed a distance and were then required to walk again to, both reproduce the extent of the learned distance and reproduce the duration of travel. Again intervening auditory events served as a means of segmenting the distance/duration. In Exp. 3, Ss traversed two distances and were required to make discrimination judgments related to either, the distance extent or the duration of travel. Different levels of segmentation were achieved by requiring Ss to pause briefly for a predetermined time period during one of the walked distances. For both Exp. 2 and Exp. 3, similar effects of segmentation were observed for distance reproduction and for duration reproduction, suggesting a possible shared mechanism.

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B23 *252* Path Integration Precision is Increased Near Familiar Destinations

John W. Philbeck[1] (philbeck@gwu.edu), Shannon O'Leary[1]; [1]George Washington University

PURPOSE. For many, there is a subjective sense of certainty about one's current location when walking in familiar environments, even without vision. One consequence of this could be that self-location updating via path integration is enhanced in the vicinity of familiar locations. METHOD. To test this idea, we asked 24 observers to walk without vision to 2 previously-viewed targets, seen outdoors in an open field. All paths consisted of 3 straight segments separated by 2 turns, with the first segment being determined by the experimenter (16 trials total). Group 1 always started from the same origin, while Group 2 moved to another origin halfway through testing. In a critical manipulation, for Group 2, the ideal final segment would take them to the previous (i.e., familiar) origin. The starting locations were counterbalanced within and between groups. RESULTS. Straight-line distance errors from the final destination were similar for both groups, averaging 2.1 m for paths totaling 14.10 and 15.58 m long. There was a trend in Group 2 toward more tightly-clustered final stopping locations (within-subjects) for the (familiar) final destination ($p = .057$). The mean dispersions around the within-subject centroids were 1.51 m (Group 1) and 1.16 m (Group 2). CONCLUSION. Navigating via path integration may be facilitated when the destination is a familiar location. Here, the facilitation was primarily in terms of decreased variable error. More extensive familiarization may intensify this effect.

B24 *253* Temporonasal motion induces stronger vection.

Takeharu Seno[1] (seno@l.u-tokyo.ac.jp), Takao Sato[1]; [1]the University of Tokyo

Ohmi & Howard (1986) reported that the magnitude of OKN induced by temporonasal motion input is stronger than that induced by nasotemporal motion. If OKN and vection had some common mechanisms, the magnitude of vection should also show the same tendency. We examined this issue by measuring vection for hemifield / monocular motion stimulations. Experiment 1: We presented temporonasal and nasotemporal (horizontal) motion stimuli that subtended only within a hemifield to the subjects who observed them monocularly. The magnitude of vection was measured by using a magnitude estimation method. The stimuli were sinusoidal vertical gratings (contrast = 10%, SF = 0.07 c/degree). The Stimulus velocity was 36 degree/sec. The stimulus was not projected to the central visual field. The duration was 20 sec. Subjects were 8 naive volunteers. Each eye had 10 trials. Results: Temporonasal motion induced stronger vections than nasotemporal motion. In addition, contralateral input induced stronger vections than ipsilateral input. Experiment 2: A similar experiment was conducted with downward (vertical) motion stimuli. Subjects were 7 naive volunteers. Results: There was no significant difference in the vecttion magnitude between ipsilateral and contralateral stimulations. Discussion: The magnitude of vection and OKN correlated each other well. The effectiveness of contralateral information to vection suggests possibilities that certain subcortical mechanisms are shared between OKN and vection. The results from Experiment 2 suggest that the mechanism subserving vertical and horizontal vection may be at least partially different.

B25 *254* Effects of perspective jitter on vection and visual control of posture are dissociated

Michiteru Kitazaki[1,2] (mich@tutkie.tut.ac.jp), Taku Hashimoto[3]; [1]Research Center for Future Vehicle, Toyohashi University of Technology, 1-1 Hibarigaoka, Tempakucho, Toyohashi, Aichi 4418580, Japan, [2]Intelligent Sensing System Research Center, Toyohashi University of Technology, [3]Department of Knowledge-based Information Engineering, Toyohashi University of Technology

Vection is visually-induced self-motion perception. Palmisano and his colleagues (2000, 2003) reported the adding global-perspective jitter on expanding optical flow improved vection. We aimed to test if different types of jitter simulating viewpoint-change and/or eye-movement, and if the jitter enhanced both vection and postural sway. We simulated a linear forward/backward motion of the viewpoint in a 3-D cloud of dots (2730dots visible) and projected on a large screen (91x75deg). Four types of optical flow were used. (1) No-jitter condition was just a straight motion of viewpoint without jitter. (2) Viewpoint-jitter condition was a simulation of vertical oscillation (0.96Hz, amplitude 2.29deg) of viewpoint (eye position). (3) Eye-movement-jitter condition was a simulation of vertically oscillating eye-movement. (4) Line-of-sight-jitter condition was a simulation of vertical oscillation of line-of-sight (combination of (2) and (3)). Randomized 8 conditions (2 motion directions x 4 jitter conditions) were presented 10 times. Vection latency and postural sway were measured for 10 naive subjects. We found improvement of vection by any type of jitter (latency 1>2=3=4). Thus, the effective jitter is not specific to type of viewpoint/eye-movement, but generic. The jitter effect was more explicit in forward self-motion than backward self-motion. Observers inclined in the opposite direction of simulated self-motion, however, its amplitude was not affected by jitter. Since the jitter effect was specific to vection, it is suggested the processes for vection and visual control of posture are dissociated before the jitter modulates self-motion perception.

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B26 255 Children's use of extended three-dimensional surfaces for reorientation

Sang Ah Lee[1] (lee@wjh.harvard.edu), Elizabeth Spelke[1]; [1]Harvard University

Disoriented humans and nonhuman animals reorient by the overall shape of the environment(1). For example, when subjects see an object being hidden in one corner of a rectangular room and then are disoriented, they restrict their search to the two geometrically correct corners (the correct corner and its diagonal). Geometry-based reorientation occurs only with extended surfaces: for example, 3-year-olds reorient by a rectangular array of wall panels but not by a rectangle drawn on the floor(2). In seven experiments, we asked what defines an extended surface by testing the reorientation of 4-year-old children in a circular enclosure containing a rectangular area defined by taped lines on the floor, by surfaces of various heights, or by extended columns, both separate and connected by borders on or off the ground.Children reoriented by the shape of extended surfaces of all heights, including <1 inch, but not by lines on the floor or unconnected columns. When columns were connected by borders, children's use of geometry was more variable. These findings begin to shed light on the properties of the visual layout that guide navigation. They contribute to the evidence that visual representations of surfaces are crucial for the geometric encoding that underlies reorientation.1 Cheng, K., & Newcombe, N.S. (2005). Is there a geometric module for spatial reorientation? Squaring theory and evidence, Psychonomic Bulletin and Review, 12, 1-23.2 Gouteux, S., & Spelke, E.S. (2001). Children's use of geometry and landmarks to reorient in an open space. Cognition, 81, 119-148.

Perceptual Learning

B27 256 Sound aids perceptual learning

Robyn S Kim[1] (robynkim@ucla.edu), Aaron Seitz[2], Ladan Shams[1]; [1]Department of Psychology, University of California Los Angeles, [2]Department of Psychology, Boston University

Numerous studies have demonstrated that repeated practice can induce substantial improvements in performance on low-level visual perceptual tasks. However, such learning is characteristically difficult and slow, requiring many days of training. The purpose of this study was to investigate whether the addition of sound affects learning of a visual perceptual task. Therefore, we trained one group with an audiovisual coherent motion stimulus (dynamically moving dots of varying coherence in the visual modality, and directional moving sounds masked with varying amounts of white noise, in the auditory), and a second group with a unimodal visual stimulus, and compared visual learning across ten training sessions. The visual stimulus and the number of trials containing visual stimulus was identical in the two groups. As expected, observers in both groups showed improvements of visual sensitivity with training. The audiovisual group also showed auditory sensitivity improvements. A follow-up test confirmed that visual-sensitivity improvements were specific to the trained stimulus directions, and therefore likely due to low-level perceptual learning rather than higher cognitive factors such as task learning. Most importantly, we found (for trials containing only visual signals) a significant benefit of audiovisual training over the visual-alone training. While both groups achieved similar performance by the end of each session, sensitivity improvements were much better retained across sessions for the audiovisual groups. These results suggest that sound can indeed enhance perceptual learning of a visual task.

257 Audio-Visual Statistical Learning

Ladan Shams[1] (ladan@psych.ucla.edu), Aaron Seitz[2], Virginie van Wassenhove[1,3]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Psychology, Boston University, [3]Division of Biology, California Institute of Technology

Statistical learning theories suggest that people implicitly learn arbitrary stimulus-stimulus associations based solely on the statistics of inter-stimulus contingencies (Fiser and Aslin, 2001). Various studies have supported such learning in the visual, auditory and somatosensory modalities. To date, cross-modal statistical learning has not been investigated. Here, we present results of a novel audio-visual statistical learning procedure where participants are passively exposed to arbitrary audio-visual pairings (comprised of artificial/synthetic auditory and visual stimuli). Following this exposure period, participants' degree of familiarity to the experienced audio-visual pairings is evaluated against novel audio-visual combinations drawn from the same stimulus set. The results of this comparison demonstrate the existence of audio-visual statistical learning. Additionally, we investigated whether audio-visual associations with an appropriate "gestalt" were learned more robustly than those with less appropriate relationships. We used a procedure in which visual objects disappeared into a 'visual abyss' and reappeared as new objects (Fiser and Aslin 2002). During each disappearance-to-reappearance interval, an upward or downward frequency-modulated sound was played. The Gestalt+ condition consisted of downward-frequency sweeps paired with disappearances and upward-frequency sweeps paired with appearances. The opposite combinations were assigned to the Gestalt- condition. In this condition, subjects showed greater familiarity for Gestalt+ than Gestalt- audio-visual pairs.Our results suggest that audio-visual statistical learning occur naturally despite the absence of a task or of an explicit attentional engagement, for audio-visual stimuli that are spatio-temporally coincident. More importantly, the degree of learning depends partially on appropriate gestalt relationships between the multisensory events.

B29 258 Face-inversion effects flex with perceptual learning.

Zahra Hussain[1] (hussaiz@mcmaster.ca), Patrick J Bennett[1,2], Allison B Sekuler[1,2]; [1]McMaster University, [2]Centre for Vision Research, York University

Perceptual learning is often highly specific to the trained stimulus. For example, practice effects are abolished for stimuli orthogonal to the trained orientation in tasks such as vernier discrimination (Fahle, 2005). We examined the extent to which such stimulus-specific learning occurs for faces: complex stimuli that are notorious in the literature for their orientation-specific disruptions to identification. On Day 1, observers were trained to identify one of two sets of faces using a 10AFC task; for each set, separate groups were trained with upright or inverted stimuli. On Day 2, all observers performed the task with Same Upright, Different Upright, Same Inverted, and Different Inverted faces at several contrast and external noise levels. Proportion correct was measured on both days. Performance improvements on Day 2 were consistently specific to the trained stimulus set. Practice with upright faces substantially enhanced performance within the same set for the upright orientation, and partially benefited identification in the inverted orientation. Practice with inverted faces also improved performance in the trained orientation for the trained set; however, there was no benefit for upright faces from the same set. Overall, the face-inversion effect for the trained set of faces respectively increased and decreased after practice with upright and inverted faces. A control experiment with phase-scrambled faces showed no transfer of learning across either trained orientation or stimulus set. Thus, the face-inversion effect can be attributed to viewpoint-specific experience with oriented stimulus structure.

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B30 259 Perceptual learning of discriminating features for facial recognition

M.F. Peterson[1] (peterson@psych.ucsb.edu), M.P. Eckstein[1]; [1]UC Santa Barbara

Introduction: Various studies have shown humans preferentially utilize certain facial features in identity discrimination (Schyns et. al, 2002). How-

ever, there has not been thorough investigation into the ability of humans to learn which features are more discriminating. The goal of this study is to measure human perceptual learning in comparison to a learning optimal Bayesian for a face identification task. Methods: We selectively augmented features (nose, eyes, chin and mouth) of simulated faces of four individuals to create four feature sets. For each set a distinct feature maximally discriminated the individuals' faces as confirmed by an ideal observer analysis and a human study. The study comprised 50 sessions, each with 50 learning blocks consisting of four learning trials. Observers were informed about the fact that a feature set was randomly chosen and maintained throughout a learning block. On each trial, a face from the selected feature set was displayed embedded in white Gaussian noise. Observers identified the displayed face. Feedback was provided about the individual's identity, but not as to the discriminating feature. Results: Humans learned to utilize informative features, with face identification percent correct increasing by 7-26%. Relative to the optimal observer certain features (eyes, mouth) were more efficiently used. Human efficiency, in general, remained constant or increased with learning trial. Conclusion: Human observers learn discriminating features as well as or better than the optimal observer or, more likely, humans are suboptimal when integrating information across multiple features.Support: NIH EY 015925

B31 *260* EFFECTS OF PERCEPTUAL LEARNING ON THE TEMPORAL DYNAMICS OF PERCEPTUAL DECISION

Wilson Chu[1] (wilsonch@usc.edu), Zhong-Lin Lu[1], Barbara A. Dosher[2]; [1]Laboratory of Brain Processes (LOBES), University of Southern California, Los Angeles, CA, [2]MAP Laboratory , Department of Cognitive Science, University of California., Irvine, CA 92697

The cued-to respond Speed-Accuracy Tradeoff (SAT) paradigm (1) combined with external noise manipulations was used to evaluate the effects of perceptual learning on the temporal dynamics of perceptual decision. Observers were trained in a 2AFC Gabor (+/- 12°) orientation-discrimination task in eight sessions. An auditory beep occurred at one of 8 delays (SOA = 25ms to 800ms) that cued the subjects to respond. Subject's performance was constrained to 79.1% and 70.7% correct at the longest SOA by a 3-to-1 and a 2-to-1 staircase respectively that adjusted the contrast of the signal stimuli. All subjects showed learning, demonstrated by an average reduction of contrast threshold levels of 23% in high noise and 22% in low noise. An elaborated perceptual template model with a dynamic decision process (2) provided very good fits to the data. The best-fitting model included identical time constant and intercept (t0) across all the training sessions. The result suggests that perceptual learning enhances stimulus (in the zero external noise condition) and excludes external noise (in the high external noise condition) without altering the temporal dynamics of perceptual decision.

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B32 *261* Learning to discount noise

Miguel P. Eckstein[1] (eckstein@psych.ucsb.edu), Binh N. Pham[1], Craig K. Abbey[1], Yani Zhang[1]; [1]Department of Psychology, University of California Santa Barbara

Ability to visually find targets is limited by noise inherent in the brain's sensory processing and random variability in the environment that can make an irrelevant distractor visually confusable with the sought target. In some occasions the variability is purely random and cannot be overcome even by an optimal detector. However, in other instances environments consist of target-like background structures that albeit contain some random components are not entirely unpredictable. Thus, in theory, unlike pure noise, these fortuitous target-like occurrences in the backgrounds could be potentially discounted if humans could learn to recognize and classify them as part of the environment. This learning could drastically increase the ability to find the targets. Here, we measure six observers' performance localizing Gaussian targets of random size and contrast embedded in white noise and a randomly spatially-shifted background composed of a fixed pattern of randomly configured target-like structures. Average human target localization performance was initially very poor (24 %) but then remarkably progressed (80 %) after 600 trials to exceed that of theoretical models that do not have knowledge of the background but are otherwise ideal (e.g, ideal observer in white noise with/without human visual contrast sensitivity). Humans achieved a maximum efficiency of 20 % relative to an ideal observer that uses full knowledge of the background to mitigate its detrimental effects on performance. Our results suggest that background learning can be an important mechanism to quickly adapt to the visual environment and thus maximize the probability of successful target search.

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B33 *262* Hastening Orientation Sensitivity

Nestor Matthews[1] (matthewsn@denison.edu), Kei Kurosawa[1], Kristen Strong[1]; [1]Department of Psychology, Denison University

Previous perceptual learning studies have shown that sensitivity to subtle orientation differences improves with practice at oblique axes, but not with practice at cardinal axes. The cause of this anisotropy in angular resolution is uncertain, and it is not known whether the same anisotropy pertains to temporal resolution -the minimum stimulus duration needed to achieve a specified angular resolution. Here, we investigated the hypothesis that practice effects at cardinal axes had previously not occurred because there had been little or no internal noise in the visual response to cardinal orientations. Accordingly, we exploited the internal noise that occurs naturally when masked stimuli are presented for extremely brief durations. After 110,000 trials were completed over seven daily sessions, temporal resolution improved by 51% at cardinal axes, and by 86% at oblique axes. This hastening of the visual response was accompanied by significant improvements in angular resolution that were specific to the cardinal axis in the cardinal training group, and the oblique axis in the oblique training group. The data demonstrate plasticity in the response to cardinal orientations, and support the hypothesis that sufficient levels of internal noise are necessary for perceptual learning.

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URL: http://personal.denison.edu/~matthewsn/hastening05.html

B34 *263* Perceptual learning of motion leads to faster-flicker perception

Aaron R. Seitz[1] (aseitz@bu.edu), José E. Náñez Sr.[2], Steven R. Holloway[2], Takeo Watanabe[1]; [1]Department of Psychology, Boston University, [2]Department of Psychology, Arizona State University, West

Critical flicker fusion (CFF) describes when quick amplitude modulations of a light source (i.e. flicker) become undetectable as the frequency of the modulation increases. The threshold at which CFF occurs has been shown to remain constant under repeated testing. The current study was designed to test the relationship between CFF and perceptual learning for motion. In experimental groups, subjects were exposed to sub-luminance-contrast-threshold coherent dot motion in which specific directions of motion were paired with characters of a rapid serial visual presentation (RSVP) training task, which has previously been shown to cause perceptual learning for motion (Seitz and Watanabe, 2003). In five-control groups, variations were made to the RSVP-training task or the luminance or coherence of the paired motion stimuli. On each day of training a Macular Pigment Densitometer was used to determine CFFT. Pre-training and post-training sensitivity tests were conducted with different directions of moving dots displayed at varying contrasts, sub-threshold through supra-threshold levels. Here we show that CFF thresholds increase by 30% in subjects who are trained in this procedure. The results of the control tasks demonstrate that changes in CFF thresholds are tightly coupled with improvements in discriminating motion stimuli and only individual sub-

jects showing improvements in contrast-sensitivity showed significant changes in CFF thresholds. In addition, this CFF changes were long lasting and are retained for at least one year after training. We discuss how these results are highly suggestive of CFF plasticity being mediated by plasticity in low-level visual areas.

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B35 *264* Practice-induced improvements for target detection in rapidly presented visual search displays is temporal-context-dependent

Angela Vavassis[1] (vavassis@alcor.concordia.ca), Michael, W. von Grünau[1]; [1]Concordia University, Psychology Department

Purpose: The current study examined perceptual learning of dual target-location associations within the same visual scene at various visual search display durations (ranging from 500msec. to 50msec.). The study assessed whether acquired improvements in target detection accuracy for rapidly presented visual search displays (50msec.) over successive sessions are temporal-context-dependent. **Method:** Participants consisted of 4 Concordia University Psychology students with normal or corrected-to-normal vision. Testing was subdivided into a series of training sessions, spanning two consecutive days, and a testing session on a third consecutive day. During training, rapidly presented stimulus displays (50msec.) were presented randomly amongst all other stimulus display durations (mixed sessions). The testing session consisted of rapidly presented displays only (rapid-only session). **Results:** As a result of perceptual learning, target detection accuracy for 50msec. trials significantly improved between the first mixed session and last mixed session (p=.010). Accuracy for 50msec. trials significantly deteriorated between the last mixed session and the rapid-only session (p=.024). A comparison of 50msec. trials between the first mixed session and the rapid-only session revealed that performance had returned to pre-training accuracy (p=1.000). **Conclusion:** These findings may suggest an incapacity for sustained high-speed perceptual processing even for well-practiced visual search tasks.

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B36 *265* Perceptual learning of contrast detection is color selective

Genevieve M Heckman[1] (gheckman@ucla.edu), Stephen A Engel[1]; [1]UCLA, Department of Psychology

How perceptual learning generalizes can help reveal the specific perceptual mechanisms that training improves. Performance in contrast detection can be explained by the existence of independent cardinal mechanisms sensitive to opposing and combined L and M cone contrast (L-M and L+M, respectively). We tested whether these mechanisms underlie learning in a detection task by training in the color direction preferred by one and testing in the direction preferred by another. Four subjects trained on a two temporal interval forced choice detection task. Stimuli were 5 deg, 5 cpd Gabor patterns that were displayed for 500 msec centered at an eccentricity of 10 deg. Stimulus contrast varied under the control of a staircase procedure, and subjects were given feedback about their performance on each trial. Two subjects were trained using patterns containing L-M cone contrast, and two were trained using patterns containing L+M cone contrast. Subjects participated in over 20 daily 30-minute training sessions. Before and after training, detection thresholds were measured for L-M, L+M, L, and M cone contrast patterns. We found that L-M and L+M training decreased thresholds (and thus increased sensitivity) for the trained color direction by 50% on average. Furthermore, the reductions in L-M thresholds following L-M training were, on average, 2.0 times larger than threshold reductions for untrained directions. L+M training showed less specificity. Our results suggest that training on detection of L-M patterns may cause red-green color opponent neurons to increase their sensitivity.

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B37 *266* Two cases of a requirement of feedback for perceptual learning.

Steven R. Holloway[1] (Holloways@aol.com), Yoshiaki Tsushima[2], José E. Sr. Náñez[1], Takeo Watanabe[2], Aaron Seitz[2]; [1]Arizona State University, [2]Boston University

The role of feedback is an issue of much uncertainty in research of perceptual learning. While it is commonly acknowledged that feedback can aid in perceptual learning (Herzog and Fahle, 1997), there are many examples in which it is not required. For instance, learning without feedback can occur for stimuli that are irrelevant to the subject's task (Seitz and Watanabe 2003). This result together with others suggest that internal reward signals can serve the same role as external reward signals (Herzog & Fahle, 1998; Seitz & Watanabe, 2005). Does this indicate that external feedback is not necessary in any perceptual learning? Here we report results from two different studies in which feedback turned out to be necessary for learning. In the first study subjects were trained for 10 days to report the orientation of bars (of two orthogonal orientations) that were masked by spatial noise. Trials of 8 different SN levels (yielding a psychometric function that ranged from chance to ceiling) were randomly interleaved. In the second study subjects were trained for 1 day to report the direction of motion (of four oblique directions) of a 10 degree patch of 100% coherent, but low-contrast dynamically moving dots. Trials of 10 different contrast levels (yielding a psychometric function that ranged from chance to ceiling) were randomly interleaved. In both studies, subjects who received no feedback failed to show any learning, whereas subjects who were given trial-by-trial feedback showed significant learning across all SN or contrast levels.

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B38 *267* Specificity of Perceptual Learning for Difficult Tasks During Simultaneous Training

Pamela E. Jeter[1] (pjeter@uci.edu), Barbara A. Dosher[1], Zhong-Lin Lu[2]; [1]Cognitive Science Department, University of California, Irvine, [2]Psychology Department, University of Southern California

Perceptual learning studies in vision attribute patterns of specificity to learning in retinotopically-organized areas, with difficult tasks being more likely to show specificity when trained sequentially with a single point of transfer (Ahissar & Hochstein, 1997). Liu and Vaina (1998) developed an assay for testing specificity in which training on a base condition and the transfer condition are interleaved in uneven proportions. For motion direction discrimination tasks with different base directions, they showed substantial task transfer. Using a similar test design, we trained subjects in a 2AFC orientation discrimination task using Gabor patches in noise, where the discrimination was relatively difficult (with conditions +/-58 from a reference angle). Trials were interleaved in uneven proportions using the following schedule, A-A-B-A-A-B... 'A' trials were presented on one diagonal while 'B' trials were presented on the opposite diagonal with opposite reference angles. If learning were independent for the two types of stimuli, performance on the first half of 'A' trials would equal the performance on 'B' trials. If learning transfers between 'A' and 'B' trials, the performance on 'B' trials would be higher than the first half of 'A' trials, but lower than the second half of 'A' trials. Although interleaved designs might encourage transfer, we found that the learning in 'B' trials exactly equated to the learning in the first half of 'A' trials, indicating little transfer, or full specificity of learning in this difficult task. This extends claims about lack of transfer in difficult tasks to interleaved training protocols.

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B39 *268* Motion perceptual learning: only task-relevant stimulus information is learned

Zili Liu[1] (zili@psych.ucla.edu), Hongjing Lu[1], Xuan Huang[2], Yifeng Zhou[2]; [1]Department of Psychology, University of California Los Angeles, USA, [2]School of Life Sciences, University of Science and Technology of China, Hefei, CHINA

Motion perceptual learning had been found with task-irrelevant motion stimuli. We further investigated this phenomenon using two motion tasks. In coherence detection, the precise motion direction of coherent dots was not critical. In direction discrimination, however, coherence detection was necessary to discriminate subtle motion directions. By using these highly similar, supra-threshold stimuli and closely related tasks, we hypothesized that task-irrelevant, direction-discrimination learning had the best chance in the detection task. The discrimination task served as a control because coherence-detection learning was expected in this task.Method: two random-dot motion stimuli were presented, one without coherent dots, the other with a certain proportion of coherent dots moving along one of two possible directions. Pointed along the two's average direction was an uneven cross, serving as the fixation. In detection, participants identified the coherent stimulus. In discrimination, they determined whether the directional difference between the coherent motion and fixation was clockwise. The detection psychometric curve was measured as a function of coherence, with a constant directional difference of ±8°. The discrimination psychometric curve was measured as a function of directional difference, with detection coherence at 95% correct. Participants were trained with either task. For detection training, the coherence was maintained at 80% correct by staircase while the directional difference was at the pre-training, 80% correct threshold; and vice versa for discrimination training. After eight days' training, psychometric curves were re-measured.Participants trained with discrimination improved on both discrimination and detection psychometric measurements; whereas those trained with detection improved only on detection, but not discrimination.

B40 *269* Sleep-dependent perceptual learning with and without distractors.

Sara C. Mednick[1] (smednick@salk.edu), John Serences[1], Geoffrey M. Boynton[1], Edward Awh[2]; [1]Salk Institute for Biological Studies, La Jolla, CA., [2]University of Oregon, Eugene, OR

Does sleep-dependent improvement on a visual search task depend on distractor inhibition or target enhancement? We investigated this question by testing two groups of subjects in three sessions across two days. Group N (Night first) was tested at 9PM on Day 1, and 9AM and 9PM on Day 2. Group D (Day first) was tested at 9AM and 9PM on Day 1, and 9AM on Day 2. Subjects detected targets that appeared alone, or embedded in a field of distractors, followed by a mask. Performance was measured as the exposure duration that led to 80% correct in a staircase procedure. We found that learning was demonstrated only after a night of sleep in both groups. Deterioration in performance occurred only in Group D across the first two daytime sessions, but not in Group N during the last two daytime sessions that followed a night of sleep. In some conditions, sleep-dependent improvement occurred for both the distractor present and distractor absent trials, while some conditions produced distractor-specific learning only. Our results suggest that improvement on these visual search tasks depends on inter-session sleep; that sleep may be a protective factor that prevents post-sleep deterioration; and that depending on the condition, sleep-dependent learning can modulate both target enhancement and distractor inhibition.

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B41 *270* The spatio-temporal window of task-irrelevant perceptual learning

Shigeaki Nishina[1] (nishina@atr.jp), Aaron Seitz[2], Mitsuo Kawato[1], Takeo Watanabe[2]; [1]Department of Cognitive Neuroscience, ATR Computational Neuroscience Laboratories, [2]Department of Psychology, Boston University

Perceptual learning is generally known to be highly location specific in that sensitivity-improvement are greatest at the location of a learned task. Our recent research has found that task-irrelevant visual features can be learned when those features are presented during an attentionally demanding task (Watanabe et al. 2001; Watanabe et al. 2002). This task-irrelevant learning is observed only when the presentation of the learned feature is temporally paired with the targets of training task (Seitz and Watanabe 2003). However, spatial and temporal extent of task-irrelevant learning signals has yet to be clarified. In this study, we presented stationary Gabor patches on a noisy background while subjects performed a rapid serial visual presentation (RSVP) task. We measured the performance of orientation detection for the Gabor patches at two different spatial locations and in four different timing relative to task targets. By comparing the performance before and after seven-day learning, we found significant improvement only for Gabor stimuli that had been presented spatially close to the attended location. The results show that while task-irrelevant perceptual learning is not specific to a task location, the spatial extent is limited. Preliminary results indicate a broad temporal window for learning. These suggest an underlying mechanism for task-irrelevant perceptual learning that has rough spatial-temporal tuning.

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B42 *271* Is Statistical Learning Theory Applicable to the Human Brain?

Monica Padilla[1,2] (monicapa@usc.edu), Norberto M. Grzywacz[1,2,3]; [1]Department of Biomedical Engineering, [2]Center for Vision Science and Technology, [3]Neuroscience Program

Methods of machine learning, especially from Statistical Learning Theory (SLT), yield excellent results. We wondered to what extent these theoretical tools are applicable to human Perceptual Learning (PL). Standard SLT (Vapnik, 2000), allows learning of the optimal decision rule, without learning the input information (data). We show two examples where the human brain can learn without learning the decision rule. First, we trained subjects in a 2AFC homogeneous-versus-non-homogeneous motion task with 34 segments. After extensive training, subjects couldn't perform the task. Hence, they never learned the optimal decision rule. However, training resulted in significant improvement for tasks with two segments. In the second example, subjects trained and learned a homogeneous-versus-non-homogeneous task with varying edge position across stimuli. Improvement in a Vernier task using a similar display was also seen. The two tasks have different optimal decision rules, that if learned should result in improvement of the Vernier task with further training, which is not the case. In conclusion, mechanisms of PL in humans do not follow standard SLT. They involve forms of learning that are not limited to the optimization of the decision rule. Our data suggest that the brain may be learning the statistics of the input information, which allow improved performance in tasks different from the ones trained on. Alternatively, the brain may be tuning its noisy processing stages to deal with the inputs, regardless of the decisions. We have proposed a generalization of SLT that allows for these alternative forms of learning (Grzywacz and Padilla, 2006).

B43 *272* Bayesian Method for Repeated Threshold Estimation

Alexander Petrov[1] (apetrov1969@yahoo.com); [1]University of Colorado, Boulder

We propose a method for estimating perceptual learning curves from longsequences of low-quality 2AFC data. Perceptual learning experiments requirenaive observers and very long schedules. Motivation is low and lapse rates arehigh. The good news is that there are thousands of observations. Our objectiveis to track the threshold of interest with as fine temporal resolution aspossible. The method uses long, overlapping data sequences to obtain a jointposterior distribution of the lapse rate and other "nuisance" parameters of thepsychometric function. With this information,

the threshold can be estimatedreliably from short data segments. A MATLAB routine approximates theBayesian distributions on a 3-dimensional grid, assuming a Weibullpsychometric function. Monte Carlo simulations validate the method andcompare it with standard methods that treat each data block independently.The mode of the posterior threshold distribution is a nearly unbiased estimatorof the true threshold. The posterior mean and median are unbiased too, but haveslightly higher variance than the mode. The posterior threshold distributiontends to underestimate the sampling variance of the true threshold.It is advantageous to include a few high-intensity presentations in each blockto stabilize the estimate of the lapse rate. Concurrent estimation of thepsychometric slope is possible but less reliable than the threshold estimation.The method is applied on behavioral data from a perceptual learning study oforientation discrimination of Gabor patches embedded in visual noise.MATLAB software available at http://alexpetrov.com/softw/

URL: http://www.andrew.cmu.edu/~apetrov/

B44 *273* **The limits of perceptual learning in previously untreated amblyopia: an intensive case study**

Roger W Li[1,2] (orogerli@hotmail.com), Allison Provost[1], Jenny Sung[1], Jennie Nguyen[1], Karen G Young[1], Pia Hoenig[1], Dennis M Levi[1,2]; [1]School of Optometry, University of California-Berkeley, Berkeley, CA 94720, USA, [2]Helen Wills Neuroscience Institute, University of California-Berkeley, Berkeley, CA 94720, USA

Practicing position discrimination improves visual performance in children with amblyopia. In a previous study, we found a 30% improvement in position acuity after 7-10 sessions of practice, in children who previously had completed occlusion therapy before starting our experiment. The present study was aimed at quantifying the limits and time course of perceptual learning in previously *untreated* juvenile amblyopia.

Two children with untreated amblyopia (line-letter acuity: AL $20/100^{-2}$, SG $20/125^{+2}$) practiced a positional acuity task repetitiously. The task was to judge which of three pairs of segments was misaligned. Each segment consisted of eight discrete Gabor patches (carrier SF, 5 cpd). The observer was trained at three or four positional noise levels (including zero). Viewing was monocular. Trial-by-trial feedback was provided. More than 10000 trials were performed over a 6-week period.

After practice, the observers showed substantial improvement in positional discrimination. Positional acuity improved on average by about 67%, both with and without noise. The improvement began to plateau after 20 sessions. In observer SG, the performance in the amblyopic eye following practice was almost comparable with that in the non-amblyopic eye. The improvement could be attributed primarily to increased efficiency (AL 400%, SG 1600%) with a small decrease in equivalent internal noise.

Our findings suggest that the "fresh" (previously untreated) amblyopic brain is remarkably plastic; positional acuity can be substantially improved after 40 hours of training. We speculate that perceptual learning techniques may add an effective new clinical method for the treatment of juvenile amblyopia.

B45 *1120* **Temporal aspects of cue recruitment in visual perception**

Qi Haijiang[1] (haijiang@seas.upenn.edu), Benjamin T. Backus[2]; [1]University of Pennsylvania, Bioengineering Department, [2]University of Pennsylvania, Psychology Department

Using a Pavlovian conditioning procedure, we recently showed that previously irrelevant visual signals can be recruited to act as new cues that control the appearance of bistable stimuli (Haijiang et al., 2005). This learning was positive in sign (unlike most contingent adaptation aftereffects) and long lasting. In group average data, the learning was incremental. However, the average may not faithfully reflect the individual time courses, which could be either truly incremental or step-like with the abrupt changes that occur at different times (Gallistel et.al. 2004). Here we conducted additional experiments to study the time course of cue recruitment in individuals, using the rotating Necker cube stimuli of Haijiang et al. (2005). In training trials the cube's position (top and bottom screen locations) was made contingent on the trusted cues (stereo and occlusion) that forced the direction of perceived rotation, while the test trials contained the new position cue but not stereo or occlusion. After the first block of training, which caused an initial bias in the observer's perception, signal contingency was reversed for the remainder of the session. Data from each individual subject show a gradual transition from the initial bias to its opposite over a 30-40 minute period. There was also a slow oscillating component with a period of approx. 15 min. We conclude that cue recruitment (at least for learning after reversal) is incremental in some cases. This is consistent with a Bayesian probabilistic decision-making framework, and with models of incremental learning such as the Rescorla-Wagner model.

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URL: http://www.psych.upenn.edu/backuslab/cuerecruitment/

Multi-Sensory Processing

B46 *274* **Ambient Sounds Can Enhance Visual Perception and Memory Performance in Virtual Environments**

Elizabeth T. Davis[1] (etdavis6@earthlink.net), Kevin Scott[1], Kenneth W. Hailston[1], Jarrell Pair[1], Larry Hodges[1]; [1]Georgia Institute of Technology

Purposes: Does the addition of audio enhance visual perception and memory performance within a virtual environment (VE)? Can ambient sounds boost subjective 3D quality of the visual display? Can they facilitate a sense of "being there"? Can they enhance recall and recognition of visual objects and their locations?**Method:** To answer these questions 60 students, with normal vision and hearing, were tested within a VE consisting of four rooms. Each room had a different wall color with furnishings that included a bookcase filled with outline pictures of objects from different categories (Snodgrass & Vanderwart, 1980). Subjects either perused each room for 3 minutes in silence or while listening to a unique low- or high-fidelity sound associated with the room (e.g., thunderstorm in yellow room). Afterward, they filled out a questionnaire form, and then recalled the objects seen in each room. Finally, in a forced-choice recognition test they matched each object to a specific room.**Results and Discussion:** Ambient sounds significantly increased the subjective 3D quality of a visual display as well as enhancing the sense of "being there." Adding audio can effectively compensate for low visual fidelity of typical VEs used in psychotherapy and entertainment, with a smaller increment in bandwidth than upgrading the visual display's temporal and spatial resolutions. Moreover, high-fidelity audio resulted in better recall and recognition performance than low-fidelity or no audio conditions. The multimodal display creates a richer perceptual environment to anchor objects to specific locations within the environment, thus enhancing recognition and recall.

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B47 *275* **Temporal ventriloquism: Perceptual shifts in temporal position and improved audiovisual precision predicted by maximum likelihood estimation**

David Alais[1] (alaisd@physiol.usyd.edu.au), Erin Weston[1]; [1]School of Psychology, University of Sydney

AIM: The maximum likelihood estimation (MLE) model accounts for classical (spatial) ventriloquism (Alais & Burr, 2004, Current Biology). Does temporal ventriloquism occur, and does the MLE model explain it? METHODS: Temporal localisation was first measured unimodally (2IFC).

Each interval was defined by auditory white-noise (1000ms) to provide a temporal reference frame. Auditory trials: a brief tone pulse occurred in each interval (jittered around the midpoint). Observers indicated which was perceived earlier in the 1-sec timeframe. Visual trials: brief luminance blobs were shown in each interval. Observers indicated which occurred earlier in the timeframe. Resulting psychometric functions yielded the subjective temporal midpoint and its variance (precision). Audiovisual trials: first interval contained synchronous audiovisual stimuli at the temporal midpoint; the second contained asynchronous stimuli jittered around the midpoint. Subjects again made temporal order judgements. Subjective midpoint and variance were taken from psychometric functions and compared with MLE predictions calculated from unimodal data. RESULTS: In both modalities, subjective temporal midpoints were typically earlier than actual midpoints. Auditory temporal precision was better than visual. Localisation precision depended on stimulus duration (more precise for brief stimuli). In bimodal conditions, data agreed well with MLE predictions, both for temporal localisation and temporal precision. CONCLUSIONS: Temporal mislocalisations of asynchronous stimuli do occur (temporal ventriloquism). These closely matched MLE predictions, being a weighted average of unimodal signals (each weight the inverse of temporal precision). Also consistent with MLE predictions, bimodal temporal discrimination was more precise than unimodal, indicating statistically optimal integration of information.

B48 *276* Audiovisual interactions in signal detection

Tobias S. Andersen[1] (tobias.andersen@univ-paris5.fr), Pascal Mamassian[1]; [1]CNRS & Université Paris 5

A concurrent auditory stimulus can improve luminance change detection. This could partly be due to a cross-modal interaction where an increase in sound intensity causes an increase in perceived brightness (Stein et al., J. Cog. Neurosci., 1996, 8:6, pp. 497-506). In that case, we would also expect that a decrease in sound intensity would decrease perceived brightness and impede detection of a luminance increase. Thus, generally, we would expect that a congruent sound intensity change would improve luminance change detection while an incongruent sound intensity change would impede it. To test this hypothesis, we designed a luminance change detection paradigm. Participants (N=8) were asked to detect which of two rectangles changed in luminance from a baseline of 63 cd/m2. The luminance change magnitude was 1 cd/m2, the duration was 100 ms and the onset varied randomly between 1-3 s after trial onset. Auditory white noise was presented concurrently with the two rectangles. Sound intensity increased from 65 dB(A) to 80 dB(A), decreased from 80 dB(A) to 65 dB(A) or remained constant at 80 dB(A) during the luminance change. We found that a change in sound intensity significantly increased the probability of correctly detecting in which of the two rectangles the luminance change occurred. However, this effect did not depend on the congruence of sound intensity and luminance change. This indicates that auditory enhancement of luminance change detectability is not due to an interaction between sound intensity and perceived brightness for the stimulus configuration employed in our study.

B49 *277* Modulation of Visual Perceptual Learning by Sounds

Anton L. Beer[1] (albeer@bu.edu), Takeo Watanabe[1]; [1]Vision Sciences Laboratory, Boston University, Boston, MA 02215

Repetitive practice of a task leads to enhancement of the performance of the task. Since this so-called perceptual learning is in some cases highly specific for primitive visual features, it may involve low-level visual stages (e.g., Fahle & Poggio, 2001). Another line of research has shown that visual spatial perception is affected at so called 'modality-specific' stages by auditory signals (e.g., Eimer, 2001; McDonald et al., 2003). The present study aimed to investigate whether and how these crossmodal interactions in spatial perception also play a role in perceptual learning. Participants identified the direction of moving dots presented at one of various peripheral locations both prior to and following a crossmodal training. During the crossmodal training, two motion displays were presented to the right and left together with a sound coming from one of the display locations. Participants' task was to detect a target sound at one of the two sound locations. One motion direction co-occurred frequently with the target sound at the relevant side. Another motion direction was more likely tied to the same sound from the irrelevant side. All other directions were equally likely tied to distractor sounds. Performance improvements in the motion direction identification task tended to be larger for the motion direction tied to the target sound at the relevant side as compared to other motion directions. These auditorialy induced perceptual learning effects seemed to be spatially specific. The results suggest that crossmodal interactions not only affect instantaneous perception but also modulate perceptual learning.

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B50 *278* Auditory-visual interactions in the judgment of a ball's speed

Laurie M. Heller[1] (laurie_heller@brown.edu), Suzanne Gilman[1], Karen Sripada[1], Elena Helman[1]; [1]Dept. of Cognitive and Linguistic Sciences, Brown University

Audition and vision both contribute to the perception of an event, and when the auditory stimulus is rich, auditory information can exert a powerful influence on multimodal perception. Previous research (Ecker and Heller, Perception 2005) found that auditory information which indicates rolling surface contact can strongly influence whether or not a visually displayed ball is perceived as rolling. In the experiments to be presented here, a quantitative approach was taken to assess the relative contribution of audition and vision on the perceived speed of a rolling ball. A video of a ball rolling in depth was paired with the sound of a ball rolling. In a 2IFC comparison, observers indicated which ball seemed faster. When the near-threshold visual and auditory speed information was consistent, performance improved as much as would be predicted by a linear model. On the other half of the trials in which the auditory and visual information were inconsistent, performance declined accordingly. Results are compared with a straightforward model of the optimal linear combination of information from independent channels in which we assume that the combination of auditory and visual information is obligatory.

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B51 *279* Effects of concurrent auditory stimulation on human visual cortex

Susanne Watkins[1,2] (swatkins@fil.ion.ucl.ac.uk), Ladan Shams[3], Geraint Rees[1,2]; [1]Institute of Cognitive Neuroscience, University College London, Alexandra House, 17 Queen Square, London WC1N 3AR, UK., [2]Wellcome Department of Imaging Neuroscience, Institute of Neurology, University College London, 12 Queen Square, London WC1N 3BG, UK., [3]Deparment of Psychology, University of California, Los Angeles, Los Angeles, CA, 90095-1563, USA.

There is increasing evidence that visual processing can be modified by sensory stimulation in another modality. Traditionally it has been assumed that such multisensory integration occurs after sensory signals have been extensively processed in unisensory cortical regions. However, recent studies have shown multisensory convergence at early stages of visual processing. An important, but unresolved issue is how such neural interactions might be reflected in conscious visual perception. Here, we investigate the association of V1 activity with conscious perception during a crossmodal illusion. The auditory induced flash illusion shows that conscious visual perception can be modified by concurrent irrelevant auditory stimulation. A single visual flash accompanied by two bleeps is incorrectly perceived as two flashes ('fission'). Similarly, two flashes can be incorrectly perceived as one flash when accompanied by one bleep ('fusion'). Signal detection analysis suggests that this is a perceptual effect rather than response bias. Activity in human V1 is increased in association with the 'fission' illusion suggesting that V1 activity is modulated by sound. How-

ever, it is not clear whether such modulation represents a correlate of altered visual perception or a response to mismatch between the two sensory modalities. Here, we used functional MRI in conjunction with retinotopic mapping to examine the cortical response to both the 'fission' and 'fusion' illusions. We present data from both early visual areas and across the whole brain suggesting that V1 does indeed follow conscious perception rather than the physical stimulus and providing further evidence for the neural mechanisms underlying this crossmodal illusion.

B52 *280* Integration and segregation of visual-tactile-auditory information is Bayes-optimal

David R Wozny[1] (dwozny@ucla.edu), Ladan Shams[1]; [1]Psychology Department,University of California Los Angeles

At any instant, the human brain is bombarded with sensory information originating from disparate sources. While acquiring multiple sensations tremendously enriches our perception of the environment, it also poses the nervous system with the critical problem of estimating which sensory signals have been caused by the same source and should be integrated, and which have been caused by different sources and should be segregated. We investigated how simultaneous signals in tactile, visual and auditory modalities are combined by the human nervous system, by examining when and how they get integrated and by comparing the human observers judgments with a Bayesian ideal observer. Methods: In each trial, participants were presented with variable number of flashes, taps, and beeps and were asked to report the number of flashes, taps, and beeps. Unimodal, bimodal, and trimodal (visual, auditory, and tactile) trials were interleaved. Results: As expected, we were able to produce both the sound-induced flash illusion (Shams et al., 2000), and the touch-induced flash illusion (Violentyev et al., 2005) previously reported. Smaller tactile-auditory illusory effects were also found. We also found three-way interactions among the three modalities when there was an inconsistency between the modalities. Importantly, observers' performance in all conditions was highly consistent with that of the Bayesian ideal observer. Conclusion: These results show that human auditory-visual-tactile perception is Bayes-optimal, and this optimal and general strategy may be the underlying principle for integration as well as segregation of sensory signals across modalities.

B53 *281* Haptic exploration of facemasks recruits left fusiform gyrus

Thomas W. James[1] (thwjames@indiana.edu), Andrea R. Kilgour[2], Philip Servos[3], Ryo Kitada[4], Eunji Huh[1], Susan J. Lederman[5]; [1]Indiana University, USA, [2]Wilfrid Laurier University, Canada, [3]University of Manitoba, Canada, [4]Kyoto University, Japan, [5]Queen's University, Canada

In two experiments, we investigated the neural substrates that underlie difficult haptic discrimination of 3-D within-class object stimuli using fMRI. The stimuli were clay facemasks made from molds of real people's faces. Subjects were trained to haptically identify 18 clay facemasks and 18 control objects in the absence of vision. In Experiment 1, subjects haptically explored and silently named 12 facemasks and 12 control objects in a block-design imaging experiment. A statistical parametric map (SPM) comparing facemasks and control objects found more activation in the left fusiform gyrus with facemasks. In Experiment 2, subjects performed a haptic old/new recognition memory test on 12 trained and 12 untrained facemasks in an event-related design. A SPM comparing familiar and unfamiliar facemasks found more activation in the left fusiform gyrus with familiar facemasks. Finding evidence for left fusiform gyrus activation with haptically explored facemasks was surprising, given the reliability of right fusiform gyrus activation with visually explored face stimuli. As previously documented, haptic exploration of complex stimuli requires greater integration of features over time, whereas visual exploration requires greater integration of features over space. Also previously documented is a general functional lateralization in which left hemisphere functions are more sequential and right hemisphere functions are more spatial. Thus, activation in the fusiform gyrus may reflect this general functional lateralization applied specifically to the integration of object features.

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B54 *282* Orientation Specificity With Vision and Touch: Map Learning, Haptic Updating, and Functional Equivalence

Nicholas A. Giudice[1] (giudice@psych.ucsb.edu), Jack M. Loomis[1]; [1]Department of Psychology, University of California, Santa Barbara

When people visually inspect a map, the map's orientation at learning is known to be privileged in memory (Orientation Specificity). That is, judgments aligned with the map are reliably more accurate than those which are mis-aligned (Alignment Effect). The present studies use an alignment paradigm with visual and haptic map learning to investigate haptic-updating and the development of functionally equivalent spatial representations. In three experiments, subjects learned four-point routes either by seeing or feeling the maps. After map training, Ss were blindfolded and asked to imagine that they were standing at a point along the route and then to turn to face another point. Half of the judgments were aligned with their learning orientation and half were mis-aligned. Results revealed a highly similar pattern of reaction times and absolute angular errors between visual and haptic conditions across all experiments. Experiment 1 replicated the traditional alignment effect with vision and extended the phenomenon to haptic map learning. In Experiment 2, Ss turned in place with and without the map and Experiment 3 had them rotate the map or rotate around the map before making their judgments. Conditions where Ss rotated without the map or rotated around the map showed significant improvement for mis-aligned judgments, indicating that updating after physical movement can modify the preferred learning orientation in memory for both modalities. We conclude from these experiments that visual encoding and haptic encoding lead to functionally equivalent spatial representations and that haptic-updating yields a similar perceptual bias as visual-updating.

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B55 *283* Integration of shape information from vision and touch: Optimal perception and neural correlates

Hannah B Helbig[1] (helbig@tuebingen.mpg.de), Emiliano Ricciardi[2], Pietro Pietrini[2], Marc O Ernst[1]; [1]MPI for Biological Cybernetics, Tübingen, Germany, [2]Laboratory of Clinical Biochemistry and Molecular Biology, University of Pisa, Italy

Recently, Ernst and Banks (2002) showed that visual-haptic size information is integrated in a statistically optimal manner, i.e. visual and haptic size estimates are weighted according to their reliabilities. Here we investigate whether the same is true for visual-haptic shape information. We further explored the neural substrates underlying visual-haptic integration in shape processing using fMRI and examined whether neural activity elicited by multisensory integration correlates with cue weighting. For this we used ridges of elliptical objects. Subjects saw the front of the object and/or they felt the back. The elongation of the elliptical ridges on both sides of the objects could differ. Subjects' task was to decide whether the ellipse was elongated vertically or horizontally. This way we could study the weight of vision and touch during shape discrimination. We varied the weight given to vision by degrading the visual information, using blur. The psychophysical experiments showed that visual and haptic shape information is integrated in a statistical optimal way even when the visual information is displayed via a mirror. That is, we observed a decrease in visual weight when vision was degraded and thus less reliable. Furthermore, we found an increase in discrimination performance when both modalities were presented together. We also determined neural activity with fMRI while individuals were performing the same ellipse discrimination task. When the visual reliability is reduced in the visual-haptic task,

neural responses decreased in the lateral occipital cortex while increased in the anterior intraparietal cortex, a brain region strongly involved in multisensory integration.

B56 *284* Interaction of Visual and Haptic Cues in the Image-based Perception of Depth

Bing Wu[1,2] (bingwu@andrew.cmu.edu), Roberta L. Klatzky[1,3], Damion Shelton[2], George Stetten[2,4]; [1]Department of Psychology, Carnegie Mellon University, [2]Robotics Institute, Carnegie Mellon University, [3]Human-Computer Interaction Institute, Carnegie Mellon University, [4]Department of Biomedical Engineering, University of Pittsburgh

Many medical applications attempt to locate targets by using imaging techniques such as ultrasound. If the target is located in a compressible medium (e.g., human tissue), however, its position in the ultrasound image will shift as the medium is compressed. We investigated whether users can accommodate to such displacements by using visual and haptic cues and accurately judge target depth. Subjects were asked to locate targets underneath a soft rubber surface. Visual cues to the amount of compression were provided by a grid on the surface that deformed under pressure and by the visible displacement of the tip of the ultrasound probe. The first experiment tested whether these visual cues are sufficient for judging surface deformation and compensating so as to accurately locate the target. Subjects acquired ultrasound images of targets at different depths and localized them with a triangulation-by-pointing procedure. Using conventional ultrasound with a remote display, subjects consistently underestimated surface deformation and thus target depth. In a second experiment, haptic feedback was added so that resisting force increased with surface deformation. We found that the stiffer the surface, the less the underestimation of target depth due to compression. A third experiment used a different imaging display, the Sonic Flashlight, an augmented-reality tool that enables users to directly see the target in 3D space. The perception of target location with this device was accurate despite the surface compliance. An ongoing experiment is further examining the learning and transfer of skills to correct the compliance effect.

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B57 *285* Visual bias of perceived tactile location

Ilja Frissen[1] (ilja.frissen@tuebingen.mpg.de), Marc Ernst[1]; [1]Max Planck Institute for Biological Cybernetics, Tuebingen, Germany

The primary source of information to determine where on the body we are being touched is derived from the somatosensory system. However, can visual information influence the perceived location of touch on the body? Ten participants localized a brief air puff (ca. 250ms) applied to the smooth ventral surface of the right forearm somewhere between wrist and elbow. Localization was measured with a 2AFC paradigm in which participants judged the location of the tactile stimulus relative to a visual reference using two opposing 1-up/2-down staircases. Participants' task was to indicate whether the air puff was closer or further from the wrist relative to the reference. In one condition the visual reference was a line drawn on the forearm midway between elbow and wrist (AIR ONLY). In another the air puff was accompanied by a temporally synchronous line of laser light projected onto the reference location (AIR+LASER). We expected the synchronous light to facilitate multimodal integration and therefore affect discrimination performance without introducing a bias. In the AIR ONLY condition the PSE was on average on the reference location. Surprisingly, in the AIR+LASER condition we did not find a change in discriminability relative to the AIR ONLY condition. We found, however, a significant shift of the PSE by 0.9cm towards the elbow. This bias was evident in eight out of the ten participants. This demonstration of a visual effect on tactile localization may indicate that judging the location of a visual reference on the body is not free from biases.

B58 *286* Task-Irrelevant Perceptual Learning of Crossmodal Links in Exogenous Covert Orienting

Melissa A Batson[1,2] (melbats@bu.edu), Anton L Beer[2], Takeo Watanabe[1,2]; [1]Boston University, Program in Neuroscience, [2]Vision Sciences Laboratory, Boston University, Boston, MA 02215

An auditory cue improves performance in discrimination of subsequent visual stimuli that are *spatially aligned* with the cue. This *crossmodal spatial cuing effect* is found for short stimulus onset asynchronies (SOAs) and in some cases reverses at longer SOAs (inhibition of return, IOR). It is commonly thought that the underlying crossmodal links are established early in life. However, based on recent research showing task-irrelevant plasticity in auditory and visual cortical areas, we hypothesized that the links between visual and auditory features can be changed, even in adults, without focused attention on stimulus features. During eight training sessions, participants performed a shape detection task. Each shape was presented together with a task-irrelevant Gabor and sound stimulus. Gabors were equally likely to appear at one of two sound locations or at one of four non-adjacent locations. However, target shapes were presented more frequently with sounds paired with a Gabor at a non-adjacent location. Crossmodal cuing effects were measured before and after training at ten different peripheral locations with a two-alternative forced-choice visual orientation discrimination task. All auditory cues originated either from the left or right, independent of the location of the visual stimuli. Pilot study results show that after training crossmodal cuing effect and IOR at the non-adjacent locations that were paired with the target shape during training were strengthened, whereas the cuing effect at the locations aligned with the sound was weakened. These findings suggest that crossmodal spatial links can be modified even late in life and without focused attention.

B59 *287* The role of visual background orientation on the perceptual upright during microgravity

Richard T Dyde[1] (richard_dyde@hotmail.com), Michael R Jenkin[2], Heather L Jenkin[1], Jim E Zacher[1], Laurence R Harris[1,3]; [1]Centre for Vision Research, York University, Toronto, Ontario, M3J 1P3, Canada, [2]Departments of Computer Science and Engineering , York University, Toronto, Ontario, M3J 1P3, Canada, [3]Psychology, York University, Toronto, Ontario, M3J 1P3, Canada

The perceptual upright (PU) -- the orientation in which an object is most easily and naturally recognized -- is determined by a combination of the orientation of the body, the visual background, and gravity. PU can be assessed by identifying a character the identity of which depends on its orientation (the Oriented Character Recognition Test: OCHART, Dyde et al. VSS 2004. J. Vision, 4(8), 385a). Using OCHART we measured the influence of the orientation of the visual background on the PU in the fronto-parallel plane under conditions where gravity was irrelevant (when the character was presented orthogonal to gravity, with the subject lying supine); or not present (during exposure to microgravity created during parabolic flight). When supine in 1g the influence of the background on the PU was reliably greater than when the observer was upright in 1g. In microgravity the influence of the background on PU was reliably less than in the equivalent 1g state; curiously a similar reduction relative to the 1g condition was also found during the hyper-gravity phase of parabolic flight. These perceptual changes are consistent with an increase in the use of the body as a reference frame when gravity is changed. The effects of microgravity in the fronto-parallel plane cannot be simulated by simply arranging gravity to be orthogonal to that plane by lying supine.

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B60 *288* **Behavioral assessment of unisensory and multisensory integration**

Guy Gingras[1] (ggingras@wfubmc.edu), Benjamin A. Rowland[1], Barry E. Stein[1]; [1]Dept. of Neurobiol. and Anat., Wake Forest Univ. Sch. of Med.

Although there is a rich history of speculations about how stimuli in one sense affect perception and behavior in another, one of its most fundamental issues remains unexplored: whether the neural computations underlying the synthesis of information from different senses (multisensory integration) differ from those underlying the integration of information within a given sense (unisensory integration). Examining this issue experimentally was the motivation for the present research project. Cats were trained to detect and then approach either a visual or an auditory stimulus that could appear at any of 7 possible locations (0°, ± 15°, ± 30°, ± 45°), or maintain fixation in response to a "catch" (no stimulus) trial. During the testing phase, the cats were required to detect and then move toward a variety of stimulus combinations (visual alone, auditory alone, coincident visual-visual, coincident auditory-auditory, coincident visual-auditory, or catch trials). The data obtained strongly suggest that the probability of correct responses is significantly enhanced by stimulus combinations, but far more for the cross-modal stimulus combinations than for the within-modal stimulus combinations. The present data indicate that the underlying computations render multisensory integration substantially more effective than unisensory integration in facilitating performance at the behavioral level, which parallels data from single neurons in a midbrain structure (i.e., the superior colliculus) known to be involved in orientation behavior. These results support the contention that there are fundamental differences between multisensory and unisensory integration. Supported by NIH grants NS22543 and NS36916.

B61 *289* **Does the levitation illusion depend on the view seen or the scene viewed?**

Heather L Jenkin[1] (hjenkin@yorku.ca), James E Zacher[1], Laurence R Harris[1, 2]; [1]Centre for Vision Research, York University, Toronto, Ontario, M3P 1J3, Canada, [2]Department of Psychology, York University, Toronto, Ontario, M3P 1J3, Canada

The levitation illusion is an example of a visual reorientation illusion (VRI) in which observers continue to feel upright while slowly tilted onto their backs in a room that tilts with them, remaining aligned with their body axis (Howard & Hu 2001, Perception 30: 583). Objects such as a ball hanging in the room appear to levitate. Similar VRIs are very significant in unusual environments such as microgravity.

We assessed the effectiveness of different fields of view (FOV) on creating the levitation illusion in York University's Tumbling Room. We varied FOV from unrestricted to approximately 15°x15° in a counterbalanced design. The content of the visual scene was controlled by viewing at twice the distance with half the FOV. Free viewing was compared to head fixed. Responses were categorized as 'full', 'confused' or 'no effect'.

The majority of supine observers experienced the levitation illusion with unrestricted viewing. The effectiveness reduced systematically with reduction of FOV. Doubling the viewing distance revealed that this was not an effect of FOV per se but rather of the visibility of polarized visual features. A field of e.g. 30°x60° was equally effective at inducing a VRI as a 15°x30° field viewed from twice the distance. The incidence of VRIs was enhanced when subjects were allowed to move the head indicating that the features do not have to be visible all at once.

We conclude that VRIs, such as the levitation illusion depend critically on what can be seen but are not critically affected by the FOV.

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B62 *290* **Monkeys match sequentially presented sets with simultaneously presented arrays based on numerosity**

Kerry E. Jordan[1] (kej8@duke.edu), Evan L. MacLean[1], Elizabeth M. Brannon[1]; [1]Duke University

Recent studies demonstrate profound similarities between the nonverbal number representations of humans and nonhuman primates. For instance, monkeys' accuracy and reaction time in making numerical judgments are modulated by ratio (e.g., Cantlon & Brannon, in press; Jordan and Brannon, submitted). Monkeys also detect numerical correspondences between sets presented in different formats or sensory modalities (e.g., Hauser et al., 2003; Jordan et al., 2005); however, these studies have tested untrained animals in tasks that assess spontaneous looking or orienting to stimuli. It remains unknown whether monkeys can make explicit matches based on numerical correspondences across different stimulus formats or modalities. As a first step toward answering this question, we trained two rhesus monkeys to numerically match visual stimuli presented in different formats on a touch-sensitive monitor in a match-to-sample task. Samples were sequences of sequentially presented visual elements, whereas the two choice stimuli were arrays of simultaneously presented elements. The choices were presented after the last element in the sample array, and correct responses were rewarded with juice. Results indicate that choices were based on number regardless of other varying parameters such as total sample sequence duration, rate, individual sample element duration, inter-element interval, cumulative surface area, and perimeter. Accuracy was also modulated by the ratio between the sample and the distracter numerosities. Results thus show that monkeys can explicitly match number across presentation format in the visual modality. Future studies will assess monkeys' abilities to explicitly match number across sensory modalities.

B63 *291* **Effects of attention on face and voice processing.**

Marianne Latinus[1] (marianne.latinus@cerco.ups-tlse.fr), Margot J. Taylor[2]; [1]Centre de recherche Cerveau et Cognition, CNRS - Université Paul Sabatier , Toulouse, France, [2]Diagnostic Imaginig, Hospital for sick children, University of Toronto, Toronto, Canada

Multimodal perception has been previously investigated using simple stimuli such as pure tones and geometric forms or light flashes. It is generally found that presentation of bimodal stimuli improves behavioural performance, whether in detection, localisation or identification tasks. However, little is known about the multimodal integration of biologically relevant stimuli such as faces and voices. The purpose of this study was to determine the time-course of face and voice perception, depending on the attended modality. Nineteen subjects performed a gender categorisation on congruent or incongruent bimodal stimuli with attention directed to one or the other modality, i.e. to the faces or to the voices. ERPs were recorded concurrently. Behavioural data showed that gender categorisation was faster for faces than voices. Incongruent information in the unattended modality decreased accuracy and prolonged RTs compared to the congruent condition. ERPs were dominated by the response to the faces. Brain topography analyses showed a larger activity when attention was directed to faces around 100 ms after stimulus onset, equivalent to the P1 latency. However, the face-specific ERP component, N170, was not sensitive to the direction of attention. These data showed that directing attention to a particular sensory modality modulates early processing of visuo-auditory information, but not the N170. Further analyses will clarify the way in which attention affects the processing of bimodal stimuli. It is currently debated whether the N170 is sensitive to top-down effects or not. Based on these results, we suggest that neural mechanisms underlying the N170 are automatically recruited by faces.

B64 *292* **Relative weights of static and dynamic visual cues in the perception of body roll**

Paul R MacNeilage[1] (pogen@berkeley.edu), Carmel A Levitan[1], Martin S Banks[1]; [1]UC Berkeley

Visual and non-visual cues, both static and dynamic, affect perception of body orientation relative to gravity. Prior research has investigated the relative influence of static orientation and dynamic rotation vestibular signals (from the otoliths and canals, respectively) on perceived body roll. We used a cue-conflict paradigm to directly compare the influence of static orientation and dynamic rotation visual cues. Vestibular stimulation was provided by rolling the subject. Visual stimulation was provided by a stereo display attached to the rolling device. Subjects set a visible rod to earth-vertical after being rolled to the target angle. In static conditions, the visual scene appeared only when the target angle was reached. In dynamic conditions, a rotating scene was visible throughout. The speed of the visual rotation was varied relative to the speed of the body rotation. Four visual scenes were used: 1) dynamic room scene; 2) static room; 3) static cube; 4) dynamic random-dot cloud. Subjects' settings were always a compromise between the visual and vestibular stimuli. The weights given to the visual stimulus varied systematically with the type of scene. The most weight was given to the dynamic room scene and the least to the dynamic random-dot cloud. Static orientation and dynamic rotation information both contribute to body orientation judgments, but static orientation information is weighted more highly. Alternative models for the combination of static and dynamic visual and non-visual cues are considered.

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B65 *293* What Does the Illusory-Flash Look Like?

David McCormick[1,2] (david.mccormick@univ-paris5.fr), Pascal Mamassian[1,2]; [1]Université Paris 5, [2]CNRS

In the illusory-flash effect (Shams et al. 2000, Nature, 408, 788), one flash presented with two tones has a tendency to be perceived as two flashes. The origin of this illusory-flash is uncertain; to date, the literature surrounding this phenomenon has focused primarily on the strength of the illusion and its underlying brain mechanisms. We address the following issue – what are the perceptual attributes of the illusory-flash? A white flash of 24ms was presented prior to a flashed Pac-Man of the same radius and duration at the same location. The Pac-Man had one of twelve low contrasts above or below mean background luminance. Half of the visual stimuli were presented in silence; the other half in conjunction with two beeps. The Pac-Man could have one of two possible orientations and observers responded to their perceived orientation. We predict better orientation discrimination if the illusory-flash has the same polarity as the real flash, and poorer performance if it has the opposite polarity. We first confirmed that our stimuli produced a strong illusory-flash effect. We then compared the psychometric functions for orientation discrimination, where concomitant beeps were present or absent. Initial results show a relative shift of the psychometric functions consitent with a same-polarity illusory-flash. We discuss other situations in which our method may elucidate further properties of the illusory-flash.

B66 *294* Visual aftereffects of proprioceptive stimulation not due to proprioceptive adaptation

Tatjana Seizova-Cajic[1] (tanjas@psych.usyd.edu.au), Ben W. L. Sachtler[2]; [1]University of Sydney, [2]University of New South Wales

Illusory motion of a visual target can be elicited by vibratory stimulation of the neck muscles; after vibration stops, motion in the opposite direction is perceived (Biguer et al, 1988, Brain, 111, 1405-1424). This motion aftereffect could be due to adaptation exclusively at the proprioceptive level, or at a stage where visual and proprioceptive information are combined. To distinguish between these two possibilities, we applied vibratory stimulation to dorsolateral neck muscles for 15-sec periods alternating with 15-sec periods without vibration. Observers (N=26) used a hand-held tracker to indicate perceived motion of the target (an LED). In the critical condition, observers were in complete darkness during vibration, and the LED was only turned on in post-vibration periods. If adaptation was purely proprioceptive, illusory LED motion should have occurred in this condition, but it did not. In a follow-up experiment (N=9), we used a similar method to determine if there was a position aftereffect. The LED was presented intermittently during the test period (for 150 msec, with 1.35 sec of dark periods in between), such that its displacement, rather than motion, could readily be perceived. No aftereffect occurred. Both experiments show that there has to be a visual stimulus during the adaptation period for the aftereffect to occur, at least for the relatively brief adaptation periods used. Proprioceptive mechanisms did not adapt, and visual motion mechanisms were mainly responsible for the illusion. We conclude that they adapt more quickly than the proprioceptive mechanisms from which they receive input.

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Spatial Vision: Mechanisms and Texture

B67 *295* Bars & Edges: a multi-scale Gaussian derivative model for feature coding in human vision

Mark A Georgeson[1] (m.a.georgeson@aston.ac.uk); [1]School of Life & Health Sciences, Aston University, Birmingham B4 7ET, UK

How do early spatial filters in human vision serve to encode elementary features, such as bars and edges? Since visible features often correspond to peaks of luminance, gradient, or curvature in the smoothed intensity profile, Gaussian derivative (GD) filters up to order 3, denoted G0 to G3, at multiple scales, are a natural framework. Previous models have used even and odd filters, including GDs, either separately or in nonlinear combination, but none provides an adequate account of perceived features. I describe a scale-space model that extends our model of edge and blur coding (VSS 2001,2003) to encompass bars and edges. Candidate edges (of +ve or -ve polarity) are peaks in a pair of nonlinear G3 scale-space response maps (E+,E-) while candidate bars are peaks in a pair of G2 maps (B+,B-). Both filtering schemes are derived from general scale-space principles (Lindeberg, IJCV,1998). Crucially, features are output only if they are peaks in a composite response map: max[E+,E-, B+,B-]. Position, scale and intensity are returned for each feature. With only two free parameters, this model accounts well for edge and bar features seen on a wide variety of sharp or blurred 1-D luminance profiles, correctly predicts Mach Bands on ramp edges and sine-wave edges and correctly predicts no Mach Bands on Gaussian-blurred edges that are otherwise similar to the sine edge. It also correctly predicts a new phenomenon: 'Mach Edges', seen when the gradient profile (rather than the luminance profile) is a Mach ramp.

B68 *296* Extending Observer Models for More Difficult Identification and Discrimination

Seong-Taek Jeon[1] (seongtaj@usc.edu), Zhong-Lin Lu[1], Barbara M. Dosher[2]; [1]Laboratory of Brain Processes (LOBES), University of Southern California, Los Angeles, CA 90089, [2]Memory, Attention & Perception Laboratory (MAP), University of California, Irvine, CA 92697

Discrimination or identification task performance level is a joint function of many factors, including signal contrast, external noise contrast, template overlap (similarity of target stimuli), as well as the state of the observer. The many observer models, including the Linear Amplifier model, the Perceptual Template model (*PTM*), and the Eckstein-Ahumada-Watson model, were constructed for cases where any single stimulus plausibly activates only one perceptual template (e.g., Gabors of orientation ±45°). In this research, we developed and evaluated an extended *PTM* to handle cases in which close to-be-discriminated stimuli activate overlapping perceptual templates (e.g., Gabors of ±3°). Threshold versus external noise contrast (*TvC*) functions were measured in an orientation identification task at fovea for four orientation differences (±3°,±6°,±15°, and ±45° from the vertical) across a range of external noises using the newly developed *qTvC* procedure (Lesmes, Jeon, Lu & Dosher, 2004) for three observers. The *qTvC* procedure was used to obtain *TvC* functions at multiple performance levels with about 500 trials per orientation separation. The extended *PTM*

provided excellent fits to the data in all conditions with changes of a single parameter that characterized the overlap between perceptual templates in different stimulus conditions. In other words, the gain of the perceptual template, the internal noises, and the non-linear transducer remain the same across different orientation conditions. The extended *PTM* provides a general functional description of identification task performance in different signal contrast, external noise contrast, as well template overlap conditions. It also supports the estimation of feature thresholds.

URL: http://lobes.usc.edu

B69 *297* Signal detection analyses of an uncertainty discrimination paradigm.

Lynn A. Olzak[1] (olzakla@muohio.edu), Jordan R. Wagge[1], Robin D. Thomas[1]; [1]Department of Psychology, Miami University of Ohio

An uncertainty discrimination paradigm (Thomas & Olzak, 1996) can be used to assess the independent or non-independent processing of two components in a compound stimulus. In certainty conditions, the observer knows in which component the cue to discrimination will appear. In the uncertainty condition, it can appear in either. If the components are processed by independent mechanisms, performance will be lower in the uncertainty case due to there being two sources of noise in monitored channels, as opposed to a single source in the certainty case. Thomas and Olzak (1996) presented a signal detection decision model that predicted a performance ratio between the uncertainty and the certainty conditions of $2^{-0.5}$, or 0.71, if the components are processed independently. Here, we explore the optimality of that model relative to plausible alternatives, and we further determine how to compute d' in a statistically correct way under each model. Finally, we explore the implications under each model for making inference about neural channel interactions.

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B70 *298* The pedestal effect is caused by off-frequency looking, not nonlinear transduction or contrast gain-control

Felix A Wichmann[1] (felix@tuebingen.mpg.de), G Bruce Henning[2]; [1]Max Planck Institute for Biological Cybernetics, Spemannstr. 38, 72076 Tuebingen, Germany, [2]Department of Experimental Psychology, South Parks Road, Oxford OX1 3UD, United Kingdom

The pedestal or dipper effect is the large improvement in the detectabilty of a sinusoidal grating observed when the signal is added to a pedestal or masking grating having the signal's spatial frequency, orientation, and phase. The effect is largest with pedestal contrasts just above the 'threshold' in the absence of a pedestal.We measured the pedestal effect in both broadband and notched masking noise---noise from which a 1.5- octave band centered on the signal and pedestal frequency had been removed. The pedestal effect persists in broadband noise, but almost disappears with notched noise. The spatial-frequency components of the notched noise that lie above and below the spatial frequency of the signal and pedestal prevent the use of information about changes in contrast carried in channels tuned to spatial frequencies that are very much different from that of the signal and pedestal. We conclude that the pedestal effect in the absence of notched noise results principally from the use of information derived from channels with peak sensitivities at spatial frequencies that are different from that of the signal and pedestal. Thus the pedestal or dipper effect is not a characteristic of individual spatial-frequency tuned channels.

B71 *299* Orientation discrimination threshold-as-a-function-of-size curves shift more dramatically with increased stimulus contrast at 0 than 10 degrees in the temporal visual field

Sharon L. Sally[1] (ssally@vax2.concordia.ca), Rick Gurnsey[1]; [1]Department of Psychology, Concordia Univeristy, Montreal, Canada

PURPOSE. Performance on many tasks can often be made equal across the visual field by appropriate scaling (F) of stimuli at all eccentricities according to [F=1+E/E2], where E2 indicates the eccentricity at which the size of the stimulus must be doubled, relative to the foveal standard, to achieve equivalent performance. Sally and Gurnsey (2004, Vision Research) have noted that E2s are larger at near-detection-threshold levels of stimulus contrast. This situation would arise if there was a relatively greater change in orientation thresholds as a function of stimulus contrast at the fovea than in the periphery, perhaps owing contrast-dependent changes in receptive field structure. METHODS. Stimuli were broadband line patterns of 2 different aspect ratios (width 2.75 and 11 percent of height) presented at a range of sizes (0.2 to 36 deg.) at 0 and 10 degrees in the temporal periphery. Orientation discrimination thresholds were obtained for all stimuli at 3 levels of Michelson contrast (3, 12 and 48%). RESULTS. For each aspect ratio, E2s increased from about 2.5 deg. at 48% contrast to 6 deg. at 3% contrast. The critical line sizes marking the transition to asymptotic orientation thresholds at large stimulus sizes changed to a greater extent (factor of 1.3 to 2.3) with increasing stimulus contrast at the fovea than in the periphery.CONCLUSIONS. Less spatial scaling is required to equate foveal and peripheral performance at low contrast; this is related to a greater overall change in orientation thresholds as a function of contrast at the fovea.

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B72 *300* Orientation Tuning Channels in Old and Young Observers

Stanley W. Govenlock[1,2] (govenlock@mcmaster.ca), Christopher P. Taylor[1], Allison B. Sekuler[1,2,3,4], Patrick J. Bennett[1,2,3,4]; [1]Dept. of Psychology, Neuroscience, and Behaviour, McMaster University, [2]CIHR Training Program in Communication and Social Interaction in Healthy Aging, [3]CIHR Group in Sensory and Cognitive Aging, [4]Center for Vision Research, York University, Toronto

Human visual function generally declines with age. Although some decline is caused by changes in the eye, changes in the brain also play a role (e.g., Bennett et al., 1999). Despite the importance of these age-related changes, fundamental questions about how neural changes affect processing in older brains remain unanswered. For example, although Leventhal et al. (2003) recently demonstrated decreased selectivity for visual stimuli orientation in V1 neurons in older macaques, researchers have never asked how aging affects orientation channels in older humans. Here, we used a notched-noise masking technique (Patterson, 1976) to address this question. A 2-IFC task (stimulus duration = 200ms; isi = 500ms) was used to measure detection thresholds for a horizontal Gabor target (sf=2.5 cpd) embedded in noise. The noise was broadband in terms of frequency and contained all orientations except for those within ± 0, 7.5, 15, 22.5, 30, 45, 60, 75, and 80 deg of horizontal. Detection thresholds decreased as notch width increased. Older observers (mean age = 69) yielded slightly higher thresholds at all noise-notch widths than did younger observers (mean age = 22). However, the shape of the masking functions did not differ across age groups, suggesting that the underlying orientation channels remain constant as a function of age. Currently, we are examining the effects of luminance on the tuning of orientation channels, and exploring whether tuning for other dimensions of visual patterns (e.g., spatial frequency) change as a function of age.

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B73 *301* Curvature perception in aging

Isabelle Legault[1] (zabellegault@hotmail.com), Remy Allard[1], Jocelyn Faubert[1]; [1]Université de Montréal

It has been argued that curvature discrimination requires receptive fields sensitive to different orientations. Furthermore, aging monkeys are less efficient for orientation discrimination when compared to their younger

counterparts. One purpose of the present study was to determine if curvature shape influences curvature perception. Another was to assess whether normal aging affects curvature perception given that curvature is believed to involve the integration of different oriented filters. Stimuli consisted of curvatures with three different shapes. The three shapes differed in that one was bell shaped, the second looked like a regular arc and the third appeared as a compressed arc. Ten young and ten older healthy observers participated in this study. Individual contrast thresholds were obtained to adjust for stimuli visibility. A 2AFC paradigm where the observers had to indicate in which interval the curvature was presented versus a straight line was used. The dependent variable observed was curvature amplitude. Results show that different amplitudes are necessary to detect curvatures of different shapes. Both aging and young observers obtained differences in sensitivity for the different shapes. The older observers showed higher thresholds for the arc and compressed arc shapes, while they were similar to the younger observers for the bell-shaped function. Those data suggest that alternate processes are required for different shapes. Possible explanations presently considered are that different orientation receptor pooling is necessary for the individual shapes or that they solicit different energy levels, both of which could be affected by normal aging.

B74 *302* Crowding Counting

Jake Baron[1,2] (jakebaron@prodigy.net), Denis G. Pelli[1]; [1]NYU, Psychology and Neural Science, [2]Stuyvesant High School

Counting a few objects in one glimpse is easy. The ability to count (estimate number) is perfect in the "subitizing" domain of up to about 4 objects, but beyond that, error increases linearly with the number of target objects (Jevons, 1871; Kaufman et al., 1949). This is usually explained by supposing that a second, independent process provides estimates of many objects. We wondered whether crowding might affect one process more than the other, and thus help to distinguish them. Five observers performed several dot counting tasks. Visual conditions included surrounding the target dots, in a box, by distracter dots outside the box, using peripheral as opposed to central dot presentation, or both. We expected crowding only when the dots were peripheral and surrounded by distracters. Indeed, we find that this condition increases the standard deviation of the observers' counts by about 2 at every number of dots presented. This is trivial at large numbers, but dramatic at small numbers since the standard deviation is normally zero in the subitizing domain. Even so, the consistent increase of SD by +2 at all dot numbers seems difficult to reconcile with the popular two-process model of counting ability.

B75 *303* Collinearity and Surround Size Effects on Spatial Discrimination Tasks

Michael L. Kramer[1] (kramerml@muohio.edu), Lynn A. Olzak[1]; [1]Department of Psychology, Miami University, OH 45056

Previous research has shown both collinear facilitation in contrast detection tasks (Solomon & Morgan, Vis. Res., 2000) and a lack of any collinear effects in apparent contrast tasks (Cannon & Fullenkamp, Vis. Res., 1991). The present study was performed to better understand the effect of spatial characteristics of surrounds on suprathreshold spatial discrimination tasks. The tasks used were hyperacuity orientation (centered around vertical) and spatial frequency (centered around 4 cpd) discriminations between 40-minarc, circular center patches of sinusoidal grating. Surrounds were vertical sinusoidal grating rings at exactly 4 cpd, with a ring width of 40-minarc. Surround size and location was modulated using BOW-TIE style stimuli (Cannon & Fullenkamp, Vis. Res., 1991) in order to specifically test how collinearity (or its lack) affects fine spatial discriminations. Discriminability was measured using d' values (obtained from a 6 point response scale). Our preliminary results suggest that collinear surrounds have a stronger inhibitory effect on these discrimination tasks when compared to non-collinear side-flanks of equal size. Our results also suggest that for most people, increasing surround size increases this inhibitory effect.

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B76 *304* Cross-orientation suppression is proportional to the square-root of speed for flickering Gabor stimuli

Tim S Meese[1] (t.s.meese@aston.ac.uk), David J Holmes[1]

A property of many striate cells is cross-orientation suppression (XOS): the response to an optimal grating is suppressed by an orthogonal and superimposed mask. Models of this nonlinear phenomenon have been motivated by physiological constraints (pre-synaptic depression), engineering solutions for components with poor dynamic range (contrast normalization) and fundamental coding strategies for natural images (redundancy reduction). These accounts often make tacit assumptions about the scale invariance of XOS, but this has not been investigated. We addressed this by measuring psychophysical masking functions for flickering horizontal Gabor stimuli (full-width at half-height of 1.67 cycles) over wide ranges of spatio-temporal frequency (SF=0.5–8c/deg; TF=0.5-15Hz) and mask contrast (0-45%). Gabor masks were identical to the target, but with orthogonal orientation. We found substantial levels of XOS (~12dB) that predominated at fast speeds (where speed=TF/SF) and small levels (~3dB) of cross-orientation facilitation (XOF) that predominated at slow speeds. Little or no XOS or XOF were found at slow and fast speeds respectively. The data were normalized by detection threshold, and well fit by a functional model of contrast gain control. In this model, the suppressive weight of XOS (w) was a free parameter for each of 15 masking functions, and the modulatory weight of XOF was constant (=16 DF for 90 points). A power function (exponent=0.48) accounted for 89% of the variance in a plot of w against speed. These results (i) provide new constraints for general models of suppression and (ii) suggest that the process underpinning XOF is widespread, but often hidden by suppression.

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B77 *305* EVIDENCE FOR PLAID-GRABBERS

Charles Chubb[1] (cfchubb@uci.edu), Joshua A. Solomon[2], Michael J. Morgan[2]; [1]Department of Cognitive Sciences, UC Irvine, Irvine, CA 92697-5100, [2]Optometry Dept., City University, London EC1V 0HB

We wondered whether plaids activate preattentive mechanisms distinct from those activated by their component gratings. Observers searched for a target plaid--the sum of two perpendicular components in a circular window (radius = 0.65 deg). The target was present on half the trials. On target-present trials, approximately half of the three or seven distractors were one component (frequency f1), the rest were the other component (frequency f2). Target and distractors were evenly arrayed on a circle (radius 2.36 deg) around fixation. Target and distractor contrasts were randomly perturbed. When f1 = 2 c/d and f2 = 5.25 c/d, reaction times increased with the number of distractors (15.75 ms/item). When f1 = f2 = 5.25 c/d, the set-size effect was much smaller (2.35 ms/item). When f1 = f2 = 2.00 c/d, reaction times did not increase with the number of distractors. These results suggest the existence of "plaid-grabbers": preattentive, plaid sensitive mechanisms with bandlimited input that do not respond to individual plaid components.

B78 *306* THE NEURAL CORRELATES OF HUMAN SURROUND SUPPRESSION

Suzanne P. McKee[1] (suzanne@ski.org), Alex R. Wade[1], Yury Petrov[1], Anthony M. Norcia[1]; [1]Smith-Kettlewell Eye Research Institute, San Francisco, CA

The perceived contrast of a target is reduced by a higher contrast annular surround that shares the orientation and spatial frequency of the central target. In the fovea, perceived target contrast is somewhat suppressed by a surround, but, in the periphery, suppression of perceived contrast is much stronger. Like perceived contrast, contrast detection is also impaired by high contrast surrounds. However, there are important differences between the two measures. The surround only affects contrast thresholds for peripheral, not foveal, targets, and threshold suppression is more tightly tuned for orientation than is suppression of perceived contrast. To explore the neural origin of these suppression effects, we made high den-

sity EEG recordings. Observers passively viewed temporally modulated Gabor targets presented at 0 and 12 deg eccentricity, either alone or surrounded by higher contrast collinear or orthogonal gratings of the same spatial frequency; target and surround had different temporal frequencies. We used the minimum norm distributed inverse to measure current density signals in fMRI-defined visual areas V1, V2, V3, V3a, V4 and hMT+. Within V1, both foveal and peripheral target responses were suppressed by surrounds, with the periphery showing more suppression and stronger orientation tuning. The pattern of results was more similar to surround effects on perceived contrast than on contrast detection. Both perceived contrast and EEG potentials probably depend on massed output of a heterogeneous neural population, while thresholds may depend on a select subset of active neurons.

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B79 *307* Lateral interaction mechanisms in texture segregation can be studied with a two-frequency VEP method

Thomas Meigen[1] (t.meigen@augenklinik.uni-wuerzburg.de), Patrick Hottenroth[1]; [1]Department of Ophthalmology, University of Wuerzburg, D-97080 Wuerzburg, Germany

Purpose. We present a two-frequency method to isolate a lateral interaction component in the human visual evoked potential to texture stimuli (liVEP) and to compare this liVEP to a texture segregation specific VEP component (tsVEP, Bach & Meigen 1992).**Methods.** 20 visually normal subjects participated in the study. Vertical bars with either horizontal or vertical dominant orientation were generated by superposition of Gabor patches with random amplitude. For liVEP isolation the dominant orientations of neighboring vertical bars were modulated with different temporal frequencies f1=3.3Hz and f2=2.2 Hz. The Fourier component at the intermodulation frequency f1+f2=5.5Hz indicates a nonlinear interaction and was used to define the liVEPs. tsVEPs were isolated by linear combination of VEP responses to steady-state stimuli (f=5.5Hz) where the same changes in dominant orientation resulted in an onset or offset of the vertical bars. The significance of the binocularly recorded liVEPs and tsVEPs (criterion p<5%) was quantified by the signal-to-noise ratio in the Fourier domain.**Results.** (1) The percentage of significant responses was 85% for liVEPs and 95% for tsVEPs. (2) This difference in percentage was not significant (p>0.25, Cochran-test). (3) The regression analysis showed a highly significant correlation (r=0.90, p<0.0001) between liVEP and tsVEP magnitudes.**Conclusions.** The close correlation of liVEP and tsVEP data suggests that liVEPs offer a new method to study lateral interaction mechanisms in texture segregation. liVEPs can be isolated in a single recording and do not require a linear combination of different VEP responses. Thus liVEPs may help to facilitate the electrophysiological investigation of texture segregation.

B80 *308* Changes in VEP indices of cortical lateral interactions with epilepsy treatment

Mary M. Conte[1] (mmconte@med.cornell.edu), Anastasiya Ashurova[1], Laura J. Ponticello[1], Erik J. Kobylarz[1], Douglas R. Labar[1], Jonathan D. Victor[1]; [1]Weill Medical College of Cornell University, NY, NY

The steady-state VEP elicited by appropriately-designed stimuli, such as the radial windmill-dartboard, can be parsed to isolate components generated by lateral interactions among cortical neurons. The purpose of this study was to determine whether such indices of lateral interactions are affected by treatments for refractory epilepsy. Steady-state VEPs were recorded in 31 epileptic patients receiving standard anti-epileptic drug (AED) treatment (N=24); or long-term (3.5–10 yrs) vagus nerve stimulation (VNS) therapy (N=7). To determine the acute effects of neurostimulation on the VEP, VNS patients were tested twice on the same day, with the stimulator turned on (STIM-ON) and off (STIM-OFF). Twenty-one age-matched normals served as controls. Stimuli consisted of the radial windmill-dartboard pattern and conventional checkerboards (contrast: 0.3; modulation rate: 4.19 Hz). VEP responses were averaged and Fourier analyzed. First- and second-harmonic response components were used to calculate indices reflecting facilitatory (FI) and inhibitory (SI) cortical interactions, along with confidence limits on these indices. Compared to normals, both patient groups showed no difference in the facilitation index, but significantly ($p < .05$) less lateral suppression. For the VNS patients, there was no difference (paired t-test) between responses obtained in the STIM-ON and STIM-OFF conditions. VEP responses to the radial windmill/dartboard pattern can be used to measure lateral interactions in normal subjects and epileptic patients, including during administration of VNS. This technique identifies an alteration of cortical interactions associated with VNS and gabapentin treatment. We speculate that these changes are related to the mechanisms of action of these treatments.

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B81 *309* Isodiscrimination contours in a three-parameter texture space

Jonathan D. Victor[1] (jdvicto@med.cornell.edu), Ana Ashurova[1], Charles Chubb[2], Mary M. Conte[1]; [1]Department of Neurology and Neuroscience, Weill Medical College of Cornell University, New York, NY, [2]Department of Cognitive Sciences, University of California at Irvine, Irvine, CA

We recently (VSS 2005) described a framework for study of visual textures that incorporates histogram statistics and spatial correlations, based on maximum-entropy extension (Zhu et al., 1998) of statistics defined on small blocks. When applied to statistics on 2x2 blocks, this approach yields a three-dimensional space of binary textures, in which mean luminance ("gamma"), third-order spatial correlations ("theta"), and fourth-order spatial correlations ("alpha") can be independently manipulated, and second-order correlations are absent. For the ideal observer, isodiscrimination contours at the origin are spherical. Subjects (N=2) segregated textures with specified correlation structure from a random (coinflip) texture in a 4-AFC paradigm. Twelve directions were studied in both the gamma-theta and theta-alpha planes. Weibull functions (exponent 2) fit the data well along each ray. Sensitivities along the gamma, theta, and alpha coordinates are approximately in ratio 1:0.2:0.25. In the gamma-theta plane, isodiscrimination contours were tilted, with their long axis directed into the quadrants in which gamma and theta have opposite sign. In the theta-alpha plane, isodiscrimination contours were elongated into the quadrant in which both coordinates were negative.Unlike the simple behavior in the gamma-alpha plane in which isodiscrimination contours were oriented along the cardinal axes (VSS 2003), isodiscrimination contours reveal interactions in the other cardinal planes. The tilt in the gamma-theta plane is consistent with combination of first- and third- order statistics by the "blackshot" mechanism (Chubb et al. 2005), but the distortion in the theta-alpha plane is not readily explained on this basis.

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URL: http://www-users.med.cornell.edu/~jdvicto/jdvpubsi.html

B82 *310* MULTI-LEVEL ISOTRIGON TEXTURES

Ted Maddess[1] (ted.maddess@anu.edu.au), Yoshinori Nagai[2], Jonathan D Victor[3]; [1]ARC Centre of Excellence in Vision Science, ANU, Canberra, [2]Centre for Information Science, Kokushikan University, Tokyo, [3]Weill Medical College of Cornell University, New York

To date only a small palette of isotrigon textures have been available to study how the brain uses higher-order spatial correlation information. We introduce several hundred new isotrigon textures. Previous isotrigon textures were binary (black and white) but the new versions have 3 or more levels or colours. Some of these textures have properties that allow simple means for temporal modulation of their higher order statistical properties. These modulation properties can be used in evoked potential or fMRI studies to extract neural responses to higher order spatial correlations. We also examine the issues of how many textures make an adequate training set, and how representative individual examples are of their texture class,

depending upon the size of the examples. This is done through examining the convergence rates of the mean second and third order correlation functions, and by consideration of the so called mini-texture spectrum. Human discrimination of 90 of these patterns from uniformly distributed ternary noise was also quantified in a series of 2AFC trials. Discrimination was examined for 3 texture sizes: 8, 16 and 32 pixels squared. When presented the textures were surrounded by uniformly distributed ternary noise. The stimuli and background were presented for 200 ms and 16 repeats were obtained at each size. Simple models were constructed that can closely mimic human discrimination performance providing at least a fourth-order classifier is used. The modelling study indicates however that more than one discrimination mechanism is required, to capture human performance over the textures examined.

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B83 *311* Processing time of second-order contour formation.

Kazushi Maruya[1,2] (maruyan@l.u-tokyo.ac.jp), Yutaka Nakajima[3], Takao Sato[3]; [1]The Jikei University, [2]Intelligent modeling laboratory, University of Tokyo, [3]Department of psychology, Univesity of Tokyo

In this study, we measured the processing time of luminance-, texture-, and motion-defined contours (LDC, TDC, MDC) with a SAT(Speed-Accuracy Trade-off) task (cf. Sutter & Graham, 1995). The stimulus consisted of 200 line segments(length: 27.4 min; LDC, TDC) or 300 dots (MDC) scattered randomly within a stimulus field (4.4 x 4.4 deg). The stimulus field was divided into two parts (horizontal/vertical) by modulating luminance, orientation, or motion direction for elements within a target area. A stimulus duration was fixed to 100 ms. After measuring the orientation discrimination threshold for LDC, TDC and MDC while varying S/N ratio for each subject, we measured the SAT latency for the three types of contours at equalized visibilities. Subjects were asked to discriminate contour orientation with a 2AFC method within 300 ms after the fixation point enlarged and signaled them to response. An interval between the stimulus offset and the response cue (cue lag) was varied in 10 steps from 50 to 1500 ms. As a result, the average correct rates for MDC and TDC increased more moderately, and exceeded 75 % at cue lags around 150 ms. These results indicate that a speed of contour processing varies among contours defined by different properties and suggest multiple contour mechanisms operate in our visual system.

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B84 *312* EFFECTS OF VARIABILITY AND SIZE ON TEXTURE DISCRIMINATION ASYMMETRY

Francois Xavier Sezikeye[1] (fxsezik@vax2.concordia.ca), Rick Gurnsey[1]; [1]Concordia University, Montreal QC

Purpose: Gurnsey and Browse (1987) showed that the textures comprising randomly rotated Ls, embedded in a background of randomly rotated Xs are more easily detected than Xs among Ls. Using a backward masking paradigm Rubenstein and Sagi (1990) showed that this effect is attenuated when the Ls and Xs are not randomly rotated. The initial purpose of this study was to assess whether discrimination asymmetries were indeed variability dependent.Methods: Textures comprised micropatterns on a continuum from perfect Ls to perfect Xs allowing measurement of threshold differences in micropattern properties without a backward mask. Subjects were asked to detect L-type textures in X-type textures (and vice versa). In one condition the micropatterns were randomly oriented, and in another they were uniformly oriented. Texture scale was also manipulated.Results. In contrast to the results of Rubenstein and Sagi (1990) discrimination asymmetries were found in all conditions tested. Surprisingly, the standard asymmetry was found when micropatterns were small but the asymmetry reversed when the micropatterns were large.Conclusions: In contrast to the arguments of Rubenstein and Sagi (1990), orientation variability is not a necessary condition for texture discrimination asymmetries. Line terminators can also influence discrimination as noticed Rubenstein and Sagi (1996) and Julesz (1981). Furthermore, the scale of the textures appears to change the representation upon which discrimination depends

B85 *313* Visual cortex responses to different texture-defined boundaries: An fMRI study

Curtis L Baker[1] (curtis.baker@mcgill.ca), Catherine L Mortin[1], Nicolaas Prins[2], Frederick A A Kingdom[1], Serge O Dumoulin[3]; [1]McGill Vision Research, Dept Ophthalmology, Montreal, Quebec, Canada, [2]Dept Psychology, University of Mississippi, Oxford, MS, USA, [3]Dept Psychology, Stanford University, Stanford, CA, USA

Variations of luminance and of texture have distinct causes in natural scenes, and several kinds of evidence indicate that the mammalian visual system employs distinct mechanisms for processing them. Human brain imaging studies have suggested that some visual cortical areas are differentially responsive to the two kinds of stimulus. However it is unclear whether different kinds of texture variation are processed in the same way, and whether they are represented uniformly across cortical areas. To address this issue we employed human fMRI to compare responses to four kinds of texture boundaries, using stimuli with equated global properties but varying in local luminance, contrast, spatial frequency, and orientation. Overall stimulus strength and attentional load were equated by psychophysical methods. Both stereotaxic and volume-of-interest analyses were performed. Percent BOLD signal change elicited by each stimulus type was determined in retinotopically mapped visual areas (V1 to V4) as well as data-driven VOIs. The early retinotopic areas responded to all four kinds of stimulus to a comparable extent. However higher-order visual occipito-parietal and -temporal regions typically responded more to texture than to luminance-defined boundaries. Modulations of contrast and of spatial frequency produced highly similar patterns of activation, which were markedly distinct from those to orientation variations. These findings suggest that different kinds of texture modulation might be processed, and perhaps utilized, in a distinct manner.

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B86 *314* How important is spatial phase in texture segmentation and contour integration?

Robert F Hess[1] (robert.hess@mcgill.ca), Bruce C Hansen[1]; [1]McGill Vision Research, Dept. Ophthalmology, McGill University, Canada

In a recent study by Huang, Kingdom, and Hess, (VSS 2005) it was suggested that the visual system has only two phase mechanisms, namely +cosine and –cosine. This suggests rather limited access to the rich distribution of receptive field phase that neurophysiologists tell us are represented in the different response profiles of striate simple cells. While that study has suggested that striate receptive field phase is not directly available to perception for the detection/discrimination of localized stimuli, here we investigate whether such information might be utilized in more integrative texture segmentation and contour integration tasks. Specifically, given that simple cells have different local absolute phase response profiles, we ask whether a network of simple cells with similar phase preferences can interact in such a way as to extract textures and/or contours on the basis of phase alone. Accordingly, we designed two novel 4AFC texture segmentation experiments and one 2AFC contour integration experiment both using random-phase fields of log-Gabors with embedded sub-regions of same-phase elements with the intention of providing an answer to the question of how useful is local absolute spatial phase for texture segmentation and contour integration. The results add further support to the proposition that, at the perceptual level, only two phase mechanisms (±cosine) are available, be it for the detection/discrimination of an isolated feature or the segmentation/integration of globally distributed features.

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Poster Session C

Saturday, May 6, 2006

Attention: Selection and Modulation (315-329), Color (330-356), Surfaces and Shape (357-375), Face Perception (376-390), Visual Development (391-400)

Poster Session: 12:00 - 3:00 pm ***Municipal Auditorium***
Author presents: 1:00 - 2:00 pm

Attention: Selection and Modulation

C1 *315* Characterizing Surprise in Humans and Monkeys

David J Berg[1] (dberg@usc.edu), Susan Boehnke[2], Robert Marino[2], Pierre Baldi[3], Doug Munoz[2], Laurent Itti[4]; [1]Neuroscience Graduate Program, University of Southern California, Los Angeles, California 90089-2520, USA, [2]Centre for Neuroscience Studies and Department of Physiology, Queen's University, Kingston, ON K7L 3N6, Canada, [3]Department of Computer Science, University of California, Irvine, Irvine, California 92697-3425, USA, [4]Departments of Computer Science, Psychology and Neuroscience Graduate Program, University of Southern California, Los Angeles, California 90089-2520, USA

We investigate the role of visual surprise in guiding eye movements in humans and rhesus monkeys under free viewing conditions, for a variety of natural stimuli. Surprise differs from other models of bottom-up visual attention in that it quantifies how data affects an observer, by measuring the difference between posterior and prior beliefs of the observer. We recorded eye movements from naive observers, 4 humans and 3 monkeys, while they watched 115 video clips (47,903 frames, 27 minutes) resulting in 6,775 saccades for humans and 10,406 for monkeys. Clips ranged in semantic content, including video of natural, non-natural, building-city, indoor, and sporting-outdoor scenes both with and without main actors. A surprise model of bottom-up visual attention then predicted in real-time how surprising every location was in the display. The distribution of surprise at the endpoint (target) locations of human or monkey saccadic eye movements was then compared to the distribution of surprise at random locations using a standard information theoretic technique, Kullback-Leibler distance. Considering all clips together 59% and 56% of gaze shifts were directed towards locations more surprising than average for humans and monkeys, however, agreement with the model varied greatly across clip type (ranging from 35-77%). Humans and monkeys showed a similar pattern of agreement with the model across image type, with a significant difference only in sporting-outdoor clips. This data suggests that under free viewing humans and monkeys are employing similar bottom-up attentional mechanisms.

C2 *316* Salience effects on bilateral cuing

Anne L Brauer[1] (gtg475y@mail.gatech.edu), James L Dannemiller[2]; [1]Georgia Institute of Technology, [2]Rice University

The sudden onset of an object in the visual field reflexively draws attention. What happens when two objects appear simultaneously? Kean and Lambert (2003) showed using saccadic responses that the brighter of two bilateral cues can draw attention within approximately 50 msec, which is quite short with respect to retino-cortical neural transmission. Would these results also be observed with a response measure not as closely tied to visual attention? Ten participants manually responded to the location of a target appearing 0, 50, 100, or 150 msec after the onset of unequally bright bilateral cues. The target appeared on the side with the brighter cue on half of all trials. Results showed that when the target appeared 50 msec or more after the cues, observers responded significantly faster if it was presented near the location of the brighter cue. The reaction time advantage at 150 msec was even larger than the advantage observed by Kean and Lambert using saccadic latency. We conclude that within approximately 50 msec of the simultaneous onset of nearly identical competing stimuli in the visual field, attention is allocated to the more salient of the two stimuli. We are currently a) extending the SOA's to determine whether inhibition-of-return also operates with differentially salient bilateral cues, and b) planning to determine thresholds for the brightness difference necessary to produce the cued advantage. These results have important implications for theories of visual attention in which competition plays a prominent role (Duncan & Humphreys, 1989).

C3 *317* Priming and Masking Interactions Shape the Transient Component of Focal Attention

Bruno Breitmeyer[1,3] (brunob@uh.edu), Alpay Koç[2], Haluk Öğmen[2,3]; [1]Department of Psychology, University of Houston, [2]Department of Electrical & Computer Engineering, University of Houston, [3]Center for Neuroengineering and Cogntive Science, University of Houston

Purpose. In conjunctive feature search, peripheral cuing improves performance rapidly as the cue lead time (CLT) is increased. After reaching a peak performance at around CLT=50 to100 ms, performance gradually decays to a plateau. This non-monotonic performance curve has been interpreted to support a two-component model for the deployment of attention: An automatic, transient and a voluntary, sustained component. In this study, we investigate the contributions of attention, masking, and priming in shaping the non-monotonic performance curve. Methods. In a conjunctive search paradigm, stimuli were presented at 12 locations uniformly distributed on a circular array at an eccentricity of 2.5 deg. A cue indicating the possible location of the target appeared at CLTs ranging from 0 to 500 ms. A post-stimulus mask appeared following the offset of search items. Three types of cue and two types of post-stimulus masks were used to control systematically their masking effectiveness. Data were also analyzed in terms of cue-target feature congruency. Results. Our results show that a specific combination of cue-type and post-stimulus mask is required to produce the non-monotonic performance curve. Furthermore, the transient enhancement of performance at CLTs of ca. 50-100 ms depends strongly on the feature-based congruency between the cue and the search items. Conclusion. Taken together, our results suggest that the deployment of attention is mainly a monotonic process and that the transient enhancement of performance around CLTs of ca. 50-100 ms reflects a feature-based priming effect by the cue on the search item.

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C4 *318* Negative priming in pure perceptual-based sequence learning

Soo-Jung Min[1] (ming@yonsei.ac.kr), Min-Shik Kim[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, Korea, [2]Department of Psychology, Yonsei University, Korea

Negative priming refers to the slowed response time (RT) to an item that has been previously ignored. This study investigated whether negative priming can be observed in a sequence learning that is purely perceptual-based. A modified version of the Serial Response Time (SRT) task was employed to dissociate the pure perceptual component from the motor component. Four red and four green circles were equally spaced and alternately located along the circumflex of an imaginary circle. According to a prearranged sequence, one red circle and one green circle simultaneously changed to open circles. Participants were asked to determine the location of the gap of the open circle of one color while ignoring the other color circles. After the training, all participants were instructed to attend to the set of circles either attended or ignored during the previous sequence learning phase. Additionally, two novel sequences were used to measure the learning effects: One for the attended sequence and the other for the ignored sequence. Faster RTs were observed in the previously attended sequence condition than in the novel sequence condition, indicating that pure perceptual-based sequence learning occurred. In contrast, slower RTs were observed in the previously ignored sequence condition than in the novel sequence condition, indicating that negative priming in pure perceptual-based sequence learning occurred. These results suggest that negative priming can occur for the temporal regularity of a set of ignored items.

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C5 *319* Attention strikes back: Counteracting the effects of adaptation with attention

Hilda M. Fehd[1] (hilda.m.fehd@vanderbilt.edu), Adriane E. Seiffert[1]; [1]VVRC, Vanderbilt University

Adaptation to visual motion diminishes the ability to see motion in the adapted direction. Attention enhances the processing of a motion stimulus after adaptation. We investigated effects of direction adaptation and attention on a motion discrimination task to determine if an interaction could occur. Participants maintained central fixation while two patches of 80 moving dots (one standard, one test) were briefly presented to the left and right of fixation. The standard always had 50% motion coherence, while the test varied from 10%-90% in steps of 10% coherence. Subjects reported the direction of movement (up or down) of the more coherent patch. To manipulate adaptation, a 100% coherent motion stimulus was shown for 3 secs before the discrimination stimuli and moved in either the same or opposite direction as the following patch. Large dots serving as un-informative exogenous cues were shown for 50 msecs before the discrimination task at fixation, next to the test, or the standard patch. The interaction between attention and adaptation resulted in a diminished effect of adaptation when attention was allocated to the test stimulus. The difference between no adaptation and same direction adaptation was smaller when the test was cued than when a neutral cue was shown. These findings provide evidence that attention during the test period can weaken the effects of adaptation.

C6 *320* DOES ATTENTION MODULATE CHROMATIC VEP RESPONSES?

Jennifer R. Highsmith[1] (highsmit@unr.nevada.edu), David Stoebling[1], Peter Gulla[1], Michael A. Crognale[1]; [1]University of Nevada, Reno

Introduction: Attention has been shown to modulate visual tasks. For example, divided attention causes decrements in performance on psychophysical tasks. Electrophysiological measures (i.e. steady-state and multifocal VEPs) show a decrease in waveform amplitude and an increase in latency with divided attention. In many of these studies VEP stimuli and distracter stimuli are presented to separate eyes with binocular rivalry as a possible consequence. It has been shown that electrophysiological responses for the non-dominant (unattended) stimulus are compromised during binocular rivalry. This study was done to determine if decrements in responses to chromatic stimuli could be found when conditions leading to binocular rivalry are eliminated. Chromatic pattern on-set VEPs were recorded under conditions of divided attention with stimuli presented to both eyes simultaneously.Methods: VEP Stimuli were l cycle/degree horizontal sine wave patterns (on-set mode 100ms on/400ms off). Distracter stimuli were letters superimposed over the VEP stimuli. Subjects attended to either the letters or the gratings and pressed a button when a predetermined stimulus appeared. Attention was assessed by task accuracy. Results: Subjects' responses for the baseline, attended, and unattended conditions showed no significant differences in amplitude and latency for the large negative component of the chromatic onset waveform.Conclusions: Under conditions that preclude binocular rivalry, the chromatic pattern on-set VEP does not change with attentional modulation.

C7 *321* Cueing of the stimulus location in polarity correspondence effect

Akio Nishimura[1] (akio@L.u-tokyo.ac.jp), Kazuhiko Yokosawa[1]; [1]The University of Tokyo

With vertical stimulus and horizontal response arrangement, performance is better with above-right/below-left mapping. The polarity correspondence hypothesis attributes this orthogonal stimulus-response compatibility (SRC) effect to the structural correspondence of positive (above, right) and negative (below, left) polarity in each dimension (Proctor & Cho, in press). Although many studies have shown that manipulation of response polarity affected the orthogonal SRC effect, there is no evidence for the effect of stimulus polarity change on orthogonal SRC effect. We tested whether the modulation of polarity in stimulus dimension affect the orthogonal SRC to test the polarity correspondence hypothesis. To manipulate the stimulus feature in vertical dimension while avoiding the responses from being affected directly by that manipulation, we used the orthogonal Simon paradigm in which the stimulus position is task irrelevant (Nishimura & Yokosawa, in press). Participants responded with right or left key-press to the color of the stimulus presented above or below the fixation. We manipulated the polarity in vertical dimension by cueing stimulus position with high predictability between blocks (Experiment 1) or within blocks (Experiment 2). In both experiments, significant orthogonal Simon effects were obtained when above position was cued, but the orthogonal Simon effects disappeared when below position was cued. Results indicate that the manipulation of positive and negative polarity in stimulus dimension, as well as in response dimension, affects the orthogonal SRC effect, supporting the polarity correspondence hypothesis. We discuss the findings in terms of the polarity coding based on multiple frames of reference.

C8 *322* Measuring accommodation of visual attention: Titchener's "attention-wave" reconsidered?

Ekaterina Pechenkova[1] (e_v_pech@mtu-net.ru); [1]Perception Laboratory, Lomonosov Moscow State University, Russia

It takes less time to focus one's attention on an event if one prepares to pay attention to this event. Such preparation or "accommodation" was first described among the properties of attention by Titchener (1912). In his terms, accommodation of attention towards an event results in faster rising of an impression onto the crest of the "attention-wave". Accommodation takes time (1500 ms, according to Titchener's data). Decreased performance at shorter preparation intervals is nowadays discussed in terms of preparation costs (e.g., Ariga, Yokosawa, 2005).We developed a method to investigate both time-course and individual differences in the accommodation of attention. It is based upon the fact that focused attention diminishes the pattern-masking effect. Thus,under the same masking conditions, the better the accommodation, the better the performance. We instructed

55 subjects to read a series of 60 common 6-letter Russian nouns presented for near-threshold durations (25-75 ms). Successive words were separated by a series of non-letter strings. These strings acted as forward and backward masks, and were presented for 200 ms each, alternating to fill the 600-1600 ms accommodation intervals between words. The results were wave-like accuracy patterns 91% of which demonstrated a single peak of performance accuracy within the interval range of 1000-1600 ms with a mode of 1200 ms (45%).The substantial performance decrement at 1400-1600 ms suggests that attentional accommodation is more than mere preparation costs. Our method also provides a way to manipulate the probability of successful attention focusing for a particular individual.

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C9 *323* Learning-induced sensitization for motion directions is modulated by attention

Chia-huei Tseng[1] (CH_Tseng@alumni.uci.edu), Thomas Papathomas[1,2], Zoltan Vidnyanszky[3]; [1]Lab of Vision Research, RuCCS, Rutgers University, Piscataway, NJ 08854, [2]Department of Biomedical Engineering, Rutgers University, Piscataway, NJ 08854 , [3]Neurobiology Research Group, Hungarian Academy of Sciences - Semmelweis University, Budapest, Hungary

Goals: We investigated how practicing a task that requires attentional selection of one component in bivectorial transparent dot motion affects observers sensitivity for different motion directions. Methods: We measured observers 75%-correct coherence threshold for motion detection in eight major directions pre- and post- learning. During the learning phase, observers underwent 6 hourly sessions of speed discrimination involving two transparently moving families of dots moving either in opposite or orthogonal directions. Observers' task is to attend to dots in the target direction and indicate the speed change (faster or slower) in the middle of the trial, while ignoring the other (distracter) direction. In the control condition, observers discriminate speed change with a single motion direction. Results: In the case of opposite motion, although practice led to an increased sensitivity for both the attended and the neglected motion direction, the sensitivity enhancement was significantly larger for the attended motion direction. Practicing with an orthogonal transparent motion display, however, resulted in an enhanced sensitivity for the attended direction and the direction between the attended and neglected motions, but not for the neglected direction. In the control condition - single motion direction during practice - we found a Mexican-hat shaped modulation of the sensitivity, with the strongest sensitivity enhancement at the practiced motion direction.Conclusions: Our results provide evidence that learning-induced changes in sensitivity for different motion directions - present during practice - are strongly affected by attentional selection and reveal the direction tuning of such attentional modulation.

C10 *324* Exogenous attention distorts visual space and speeds up processing: Effects on apparent size

Michael von Grünau[1] (vgrunau@vax2.concordia.ca), Cesar Galera[2], Afroditi Panagopoulos[1], Mikael Cavallet[2]; [1]Department of Psychology & CSLP, Concordia University, Montreal, Que, Canada, [2]FFCLRP-DPE, University of São Paulo at Ribeirão Preto, Brazil

Purpose: Exogenous selective attention can be employed to a restricted region in space by using a brief peripheral cue. Subsequently presented stimuli in this region are processed in ways that give them a competitive advantage (e.g. discriminability and contrast sensitivity are increased, response time is decreased, apparent contrast is increased). We used two kinds of cues to assess how apparent size is altered by attention. **Methods**: Peripheral cues were a briefly flashed small spot or an outline circle, always with central fixation. Test lines or squares were flashed at the cue location and at a symmetrical position. Size equivalence was determined by a 2AFC method. Temporal order (TO) and response time (RT) were also determined in the same situations. **Results**: Apparent size at the cued location was judged to be larger with the spot cue, but smaller with the circle cue, as compared to the uncued position. When both cues were used, the two opposite effects on apparent size were canceled when the two cues were simultaneous, but otherwise were in accordance with the effect of the last cue displayed. TO and RT measures indicated that the cued stimulus was processed faster and appeared ahead temporally for both cue types. In all cases, the effects were largest for short cue-test intervals. **Conclusion**: Exogenous cues distort space for brief periods in such a way that stimulus edges are repelled from the cue center. Temporal effects, however, are uniform and independent of cue type.

Acknowledgment: NSERC, FQRSC (MvG), CNPq, Fapesp (CG)

C11 *325* Morphed Objects Do Not Capture the Eyes

Jason H. Wong[1] (wongjasonh@gmail.com), Anne P. Hillstrom[2], Matthew S. Peterson[1]; [1]George Mason University, [2]University of Portsmouth

Abrupt onsets of objects involuntarily draw attention (Jonides & Yantis, 1988) and the eyes (Theeuwes et al, 1998) even when they are irrelevant to the task at hand. Luminance changes or other low-level transients do not fully explain why onsets capture attention. Instead, the new-object hypothesis proposes that it is the appearance of new structural or semantic information in the display that captures attention rather than the perceptual transient (Yantis & Hillstrom, 1994). In the present task, we investigated whether structural and semantic changes are sufficient to capture attention and the eyes. Observers moved their eyes to an object defined as the target by the shape of a frame around it, and concurrently another object in the search display smoothly and quickly morphed, thereby changing its structural and semantic information. Morphing an object also had the added advantage of minimizing the number of confounding low-level transients. If a strong version of the new-object hypothesis is correct, this "new" object should capture the eyes. A control condition used abrupt onsets rather than morphs in the periphery to compare capture rates. The morphed objects did not capture the eyes; however, the abrupt onsets did. These findings indicate that new structural or semantic information is not sufficient to capture the eyes. Instead, capture appears to require the onset of a new object to be accompanied by a sudden transient (Boot, Kramer, & Peterson, 2005).

C12 *326* Attentional Filtering of Dot Intensities in Centroid Estimations

Stefanie A Wong-Drew[1] (wongsa@uci.edu), Charles F Chubb[1], George Sperling[1]; [1]Department of Cognitive Science, University of California, Irvine, CA 92717, U.S.A.

Substantial evidence suggests that observers can accurately estimate the centroid of a spatially extended target. We investigated whether these mechanisms could be brought under top-down attentional control. Specifically, we asked observers to estimate (with mouse-clicks) the centroids of briefly flashed, sparse clouds comprising either 8 or 16 dots of various intensities under three different attentional instructions: give equal weight (i) to just those dots brighter than the background, (ii) to just those dots darker than the background, and (iii) to all dots. Under all conditions participants did well at achieving the required attentional filter although filter tuning was somewhat compromised in conditions (i) and (ii) for the 16- versus the 8-dot clouds, with intensities near the background receiving less weight than more extreme intensities. In condition (iii), the 8- and 16-dot trials yielded equally variable responses. By contrast, conditions (i) and (ii) showed larger variability on the 16-dot trials compared to the 8-dot trials, suggesting that in these conditions the cost per dot of imposing the required attentional filter is higher than in condition (iii). Summary: In estimating centroids, participants can selectively attend either to the brighter dots or to the darker dots alone; however, they are more accurate when attentional filtering is not required.

C13 *327* Transient attention and selective adaptation to high and low spatial frequencies.

Yaffa Yeshurun[1] (yeshurun@research.haifa.ac.il); [1]University of Haifa, Israel

Several studies have demonstrated that sustained attention –the voluntary component of spatial attention– can modulate effects of adaptation. Typically, attending to the adaptation stimulus increases adaptation effects. In comparison to sustained attention, our knowledge regarding adaptation and transient attention –the involuntary component of spatial attention– is scarce at best. This study explores the effects of transient attention on adaptation to low and high spatial frequency: Can transient attention affect adaptation? If so, does it affect differently the adaptation to stimuli of different spatial frequencies?To answer these questions, four Gabor patches, of high (8-cpd) or low (0.25-cpd) spatial frequency, are simultaneously presented throughout the adaptation phase. Additionally, a peripheral cue, known to automatically attract transient attention, indicates one of the four possible locations. Two locations may be indicated by the cue, and the rest are never indicated by the cue. In the test phase, observers detect the presence of a single Gabor patch appearing in one of the four locations, whose frequency is identical to that of the adaptation phase, but with either identical or orthogonal orientation. Adaptation effects were found for both high- and low-frequency conditions, but they were differentially modulated by transient attention: High-frequency adaptation was more pronounced at the cued than the non-cued locations, as was found with sustained attention. However, no such amplification was found for the low-frequency adaptation, and it even reversed in some cases. These findings will be discussed in relation to the hypothesis that transient attention favors parvocellular over magnocellular activity.

C14 *328* TRANSIENT COVERT ATTENTIONINCREASES THE PERCEIVED RATE OF FLICKER

Barbara Montagna[1] (barbara.montagna@nyu.edu), Marisa Carrasco[2]; [1]Psychology, New York University, New York, NY, [2]Psychology & Neural Science, New York University, New York, NY

Background: Transient (exogenous) covert attention affects basic dimensions of vision such as contrast sensitivity, spatial resolution, and temporal resolution. Two recent studies relate such evidence to corresponding phenomenological changes, showing that the observed increase in contrast sensitivity and spatial resolution is associated with an increase in the apparent contrast and spatial frequency of the attended stimulus (Carrasco, Ling, & Read, 2004; Gobell & Carrasco, 2005). Here we explored the possibility of a phenomenological correlate of attention for temporal aspects of our visual experience. Specifically, we asked whether and how transient attention affects the perceived flicker rate of temporally modulated visual stimuli.

Methods: We employed a psychophysical method recently developed to directly assess changes in appearance with transient attention, manipulated attention via uninformative spatial cues, and used suprathreshold Gabor stimuli that were counterphase modulated at various temporal frequencies (3.75 - 12 Hz). In each trial, two Gabors, appearing briefly (317 ms) to the left and right of fixation (1.5ï eccentricity), were modulated at either the same or different rates. To assess appearance, observers were asked to perform an orientation discrimination task contingent on perceived flicker rate. "What was the orientation of the Gabor that flickered faster?"

Results: The transient precue increased the perceived flicker rate of the temporally modulated stimuli at the cued location. A control experiment, in which observers reported the orientation of the Gabor that flickered slower, ruled out the possibility that such a result was determined by a cue bias. We conclude that transient attention increases perceived flicker rate.

C15 *329* Apparent contrast differs across the vertical meridian of the visual field: visual and attentional factors.

Ruby Zoe Rodriguez[1] (rzr201@nyu.edu), Joetta Gobell[1], Stuart Fuller[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, New York, NY, [2]Center of Neural Science, New York University, New York, NY

Background: Performance across the visual field differs at isoeccentric locations. Accuracy is better on the horizontal than the vertical meridian, and in the lower than the upper region of the vertical meridian (Carrasco, Talgar & Cameron, 2001). Recently, it has been shown that attention increases the apparent contrast of a stimulus (Carrasco, Ling & Read, 2004). Here we investigate whether attention affects appearance differentially as a function of spatial location.Methods: Two Gabor stimuli were presented North and South of fixation at 4ï eccentricity along the vertical meridian. Observers were asked to report the orientation of the Gabor that appeared higher in contrast. By assessing which stimulus observers perceived as higher in contrast, we obtained appearance psychometric functions and their concomitant points of subjective equality (PSE). These functions were measured both when attention was deployed via an uninformative peripheral cue and when a neutral cue was presented in the middle of the display. Observers were told that the cues were uninformative as to the stimulus contrast or its orientation.Results: Consistent with previous findings, we found that attention increases apparent contrast. Furthermore, attention's effect on appearance is asymmetric along the vertical meridian. These results differ from prior work on accuracy, which found symmetric attentional performance gains in both North and South locations.

Color

C16 *330* Measuring the Impact of Laser Eye Protection on Color Vision

Thomas Kuyk[1] (thomas.kuyk@brooks.af.mil), Paul Garcia[1], William Brockmeier[1], Robert Gorsche[2], Gary Martinsen[2]; [1]Northrop Grumman Corporation, [2]Air Force Research Laboratory

Laser eye protection is used to prevent eye injuries in laboratory and military settings. Protecting against lasers requires filtering of light at the wavelengths where these systems operate. If that filtering includes wavelengths in the visible range, significant changes in color detection and perception may occur. The purpose of this study was to determine the effects on color vision of filtering at different locations in the visible band and how well those effects were predicted by a model based on color processing in CIE color space. Ten filters were tested and these varied in the width of the filtered wavelength band, but were similar in depth (optical density). The filters were designed to protect against lasers operating in different regions of the visible spectrum. Color vision was assessed with the Farnsworth-Munsell 100 Hue Test (FM100) and a color naming test that had subjects identify the hue of colored symbols presented on a dark background. Twelve observers with normal vision participated. The baseline error scores (ES) on the FM100 ranged from 0 to 32. ES changes with filters ranged from 4 to 112 points. Color naming errors, like the ES, varied depending on the filter bandwidth. Color naming performance for many hues declined to nearly 100 percent mis-identifications and this was well predicted by the model. There was also evidence that blocking light in some spectral regions had a greater effect on color discrimination than blocking it in others.

C17 *331* Utilization of the Crawford Transformation in Evaluation of Spectral Background Efficiency of Solid State Light Sources

Harry Zwick[1] (harry.zwick@brooks.af.mil), Peter Edsall[2], Louis Hare[3], James Ness[3]; [1]USAMRD Walter Reed Army Institute of Research, Brooks City Base, San Antonio Tx, [2]Northrup Grumman Inc, Brooks City Base, San Antonio Tx, [3]US ARMY Military Academy, West Point N.Y.

Visual sensitivity is governed by target and background lighting conditions. The Crawford transformation provides a link between the test target threshold function of dark adaptation and the background increment threshold intensity function obtained by incrementing background energy and redetermining threshold. The equivalent background is assessed as a function of time in the dark, providing assessment of increment back-

ground intensity, as the visual system returns to a dark adapted state (Blakemore and Rushton, 1965). Spectral dark adaptation functions obtained from four LED visible light sources were merged with four equivalent background threshold functions for measurement of equivalent background energy as functions of time in the dark for two LED background sources; the first had a single peak transmission at 630 nm; the second had a bimodal transmission at 440 and at 540 nm. Equivalent background measurements for the first LED background source showed minimal variation in dark adaptation equivalent background functions with test LED sources 441, 501, and 562 nm. The 525 nm test LED remained a log unit higher in threshold over test period. The second LED background source with peaks at 440 and 540 nm showed maximum early sensitivity for the 525nm LED source. After 7 min of dark adaptation, both the 525 and 501 LED sensitivities were equal. Equivalent background thresholds remained higher at 562 and 441 nm. Utilization of the Crawford transformation to evaluate solid state spectral light sources with varying spectral content supports its utility for evaluation of cone sensitivity associated with emerging LED light sources.

C18 *332* Characteristic variations in the color statistics of natural scenes

Yoko Mizokami[1] (yoko@unr.edu), Shernaaz M. Webster[1], Michael A. Webster[1]; [1]Department of Psychology, University of Nevada, Reno

Models of visual coding based on natural scene statistics depend on identifying regularities in the environment. However, the colors characteristic of natural scenes can vary widely both across different environments and within the same environment over time because of seasonal changes. We compared these seasonal variations in two very different outdoor environments: alpine forest and meadows in the northern Sierras and tropical forest and grasslands in the Western Ghats of India. Images were acquired with a digital camera calibrated by correcting the rgb values for the known values of a color palette included in a corner of each image. The palette and scene illuminant were measured with a spectroradiometer. Vegetation changes between monsoon and winter seasons in India shift the average chromaticity of scenes from green to yellow and rotate the principal axes of the color distributions from roughly an S-cone varying axis to a blue-yellow axis. Seasonal variations in the Sierra images were weaker but followed a similar pattern. In both cases the mean color shifts are largely along an LvsM axis, suggesting that this axis captures the general lushness of scenes. Rotations in the color distributions provide a further correlate of lushness, but imply that in many contexts the color distributions are not well described by independent variations along the S and LM axes. While natural color distributions and consequently models derived from them are context dependent, the fact that the variations themselves show characteristic properties suggests important regularities in the color environment that might shape color coding.

C19 *333* Flank Facilitation for Isoluminant Chromatic Stimuli

Pi-Chun Huang[1] (pi-chun.huang@mail.mcgill.ca), Kathy T. Mullen[1], Robert F. Hess[1]; [1]McGill Vision Research Unit, Department of Ophthalmology, McGill University, Montreal, Quebec, Canada

It is well established that the detection of a luminance-defined Gabor is improved if measured in the presence of two high contrast aligned flanking Gabors (Polat and Sagi, Vis. Res., 1993) and this is termed flank facilitation. Here we investigate whether this facilitation occurs for isoluminant chromatic stimuli. We measured the effect of flank facilitation for achromatic and chromatic Gabors, (0.75 cpd, 1 octave bandwidth). Stimuli isolated either the S-cone opponent mechanism, the L/M cone opponent mechanism, or the achromatic mechanism. We used a 2AFC paradigm with a double staircase to measure, in a blocked design, the detection threshold of a central Gabor target presented alone and in the presence of two flanking Gabors. Three conditions were investigated: 1) target and flanks all of the same color and spatial phase, 2) target and flanks of the same color but different phase (180 degrees), 3) target and flanks of different colors. Results were collected for 3 different target-flank distances (2, 3, 6 ë) in three subjects. A facilitation effect occurred when the target and flanks were the same color and same phase and its magnitude decreased as the target-flank distance increased., There was no facilitation in the out of phase conditions for achromatic or chromatic stimuli. A weaker and inconsistent facilitation effect was found in crossed (i.e. achromatic/chromatic) conditions. A comparable degree of flank facilitation occurs in both achromatic and chromatic mechanisms that exhibits phase dependence. There is no consistent cross interaction between color and luminance mechanisms.

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C20 *334* Loss of position perception and size constancy for equiluminant counterphase flickering color stimuli

Seiichiro Naito[1] (snaito@keyaki.cc.u-tokai.ac.jp), Yoshihiro Hirano[1], Satoshi Kikuchi[1]; [1]Tokai University

The subjects observed two overlapping concentric equiluminant red and green circles. Their colors alternate at 10 Hz. The circles subtended at 15 and 7 degree visual angles on a black background. Over the inner circle, a white fixation point moves slowly back and forth. Subjects would perceive the displacing motion of the stationary inner circle. It migrates back and forth sometimes following the fixation point, and at other times evading the point. The apparent motion is generally unstable and inconsistent. Nevertheless, the magnitude of the illusion could be measured. Subjects could produce an equivalent motion impression on a neighboring screen with similar non-flickering circles. The typical apparent displacement distance is approximately 10% of the inner circle radius. The luminance range over which subjects observed the illusory motion suggests that it has mangnocellular properties. While the moving fixation point helps the illusion, it is not essential to the condition. Subjects could observe indefinite motions with slow voluntary eye movements over the inner circle. The geometry of the stimuli does not necessarily have to be a circle. Two rectangles produce similar results. Additionally, the subjects observed that the size constancy is not applicable for the inner circle. They changed the observing distance back and forth by approximately a foot in a few seconds. Significant size changes of the inner circle could be observed. When he/she was going away from the screen, the inner circle would extend its size, and vice versa.

C21 *335* The "chromatic tilt" effect: hue changes induced by a chromatic surround

Thomas Wachtler[1] (thomas.wachtler@physik.uni-marburg.de), Susanne Klauke[1]; [1]Neurophysics Group, Department of Physics, University of Marburg

It is well known that a chromatic surround influences the perceived color of a stimulus. But little is known quantitatively about how perceived hue depends on the hue of the surround. In cone-opponent color space, chromaticities can be expressed in terms of spherical coordinates, and hue corresponds to polar angle. We measured changes in hue angle induced by a chromatic background, using asymmetric matching of 2-degree chromatic patches across different isoluminant backgrounds. One background was neutral gray, the other had a chromaticity corresponding to one of eight hue angles with fixed cone contrast with respect to the gray background. Subjects adjusted the hue angle of the match patch on the neutral background to match it to the test patch on the chromatic background. When plotted as a function of hue angle difference between test patch and background, induced hue angle changes showed a maximum around 41 ± 4 degrees, with maximal induced changes of 24 ± 3 degrees. The curves for different backgrounds were qualitatively similar, but the amount of induced hue change depended on the hue angle of the background, indicating that induction is weaker along the S-cone axis than along the M-L axis. The dependence on angular difference between stimulus and background is qualitatively similar to the well-known tilt effect, where changes in perceived angle of oriented stimuli are induced by surrounding orienta-

tions. This suggests similar mechanisms of contextual processing for quite different visual features such as orientation and color.

C22 *336* Cone weights for the cone opponent detection mechanisms in human peripheral vision

Masato Sakurai[1] (masato.sakurai@mcgill.ca), Kathy T. Mullen[1]; [1]McGill Vision Research, Dept. of Ophthalmology, McGill University, Montreal, Canada

Aims: To determine whether there are any changes between foveal and peripheral vision in the L, M and S-cone weights for the two cone opponent chromatic mechanisms (red-green and blue-yellow).**Methods:** We measured detection threshold contours in three different planes in 3-d cone contrast space, chosen to best reveal the cone weights to the two chromatic mechanisms: the L/M plane, the (L+M)/S plane, and the isoluminant plane (L-*x*M)/S. Thresholds were measured for foveal and peripheral stimuli (15 or 20 degs in the nasal field). Stimuli were spatio-temporal Gaussian "blobs" on a gray background (49.7 cd/m^2) with a spatial sigma fixed in the horizontal meridian (0.5 deg), and variable in the vertical meridian (0.5-1.8 deg, scaled by the cortical magnification factor). To suppress the increased contribution of the luminance mechanism relative to the chromatic mechanisms in peripheral vision, achromatic masking noise (2-d, dynamic) was added to the test stimulus when measuring in the L/M and L+M/S planes in the periphery. Detection thresholds were measured using a 2AFC staircase procedure in three normal subjects.**Results:** Detection thresholds were fitted by ellipses in each plane at each eccentricity. Comparisons of the orientations of the ellipses between fovea and periphery show no consistent changes with eccentricity across subjects.**Conclusions:** Cone weights for the foveal mechanisms support those of previous studies (Sankeralli and Mullen, *JOSA A*, 1996). Our results indicate that cone weights for the red-green and blue-yellow chromatic mechanisms are invariant up to 20 deg in the nasal visual field.

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C23 *337* Are color-selective neurons representing structure?

Ruixia Xu[1] (ruixiaxu@usc.edu), Ione Fine[1]; [1]Department of Ophthalmology ,Keck School of Medicine, University of Southern California, USA

We previously developed a Bayesian model that estimated whether two pixels within an image fall on the same surface, given the chromatic and luminance differences between them (Fine et al., 2003). Here we extended this model to estimate the amount of structure in an image patch. The model convolves image patches with a bank of luminance, red-green or blue-yellow Gabor filters varying in spatial frequency, orientation and phase. The probability that a given patch has structure is calculated using a Bayesian algorithm based on the energy output across the filters. Estimates of structure by the model are consistent with human perception; model estimates of the probability of structure in 6000 patches correlate with observers' ratings of the patches as having "no", "some" or "clear" structure.

Estimates of structure by the model are also consistent with V1 neurophysiological responses. Using data from 22 V1 cells (measured by Horwitz et al., 2005), we found a correlation between the number of spikes elicited by any given chromatic noise patch and the model's estimate of structure for that patch. The model predicts V1 spikes as well as traditional linear and non-linear receptive fields constructed using spike-triggered averaging and covariance techniques. Our results suggest that both the amount of perceived structure within an image patch, and responses within V1 cells, are associated with chromatic and luminance contrast energy within an image patch. Color-selective neurons in V1 may therefore be representing the amount of structure in stimuli, rather than their chromatic content.

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C24 *338* Comparison between figure segregation and color discrimination thresholds for multi-colored texture stimuli

Takehiro Nagai[1] (nagai@u.ip.titech.ac.jp), Keiji Uchikawa[1]; [1]Department of Information Processing, Tokyo Institute of Technology

The visual system has an ability to segregate a figure in a multi-colored texture by grouping similar colors. Chromatic properties of this figure segregation, however, have not been fully investigated as compared with the luminance-based figure segregation.The present study aims to reveal chromatic mechanisms underling chromatic figure segregation.We used a multi-colored texture as a stimulus. It was divided into two regions, test and background regions, having different color distributions. The DKL opponent color space was utilized to define the stimulus. The stimulus color distribution was obtained on an isoluminant azimuth line from the origin of the DKL space. We measured the threshold of angle between the test and the background azimuth lines to segregate the test figure from the background. We also measured the thresholds in color discrimination between the test and the background color distributions.It was found that the mean threshold in figure segregation was about three times as high as that in color discrimination, which means that chromatic figure segregation could not be achieved by small color difference even above color discrimination threshold. The thresholds in the figure segregation and in the color discrimination differently depended on the azimuth line of the background distribution in the DKL space. These results suggest that the chromatic mechanism responsible for figure segregation would not be the same as that for color discrimination, and the chromatic figure segregation might be characterized in the opponent-color mechanism.

C25 *339* Misreading Patterns of Ishihara Plates by Normal Trichromats

Eriko Miyahara[1] (emiyahara@fullerton.edu), Patrick C. Hwang[1]; [1]Department of Psychology, California State University, Fullerton, Fullerton, CA.

Ishihara Pseudoisochromatic Plates have been known to be one of the best screening tools for red-green color vision deficiencies. Although majority of the normal trichromats read all the plates correctly, it has been known that some normal trichromats make mistakes in reading the plates. The purpose of this study was to obtain reading results of Ishihara plates by normal trichromats and analyze the misreading patterns to seek potential explanations.

Methods. Reading data on Ishihara plates (abbreviated version, 2001) and the anomaloscope setting were obtained from 249 normal trichromats as part of color vision screening procedure for psychophysical experiments. The spectral reflectance of each color of dots in the Ishihara plates was measured by GretagMacbeth Spectrolino Spectrophotometer and plotted in the DKL cone-excitation space. Each plate was scanned into a digital image file and colored dots were put into separate layers to simulate various combinations of reading patterns.

Results. Out of 249 normal trichromats, 111 individuals (45%) misread at least one plate. The common misreading patterns generally followed the reading behavior of color vision defectives. Otherwise, the misreading patterns appear to originate in the cognitive aspect. For instance, the plate number 13 that should read "73" was misread as none (response by color defectives), 7, 13, 18, 23, 28, or 78. These misreading patterns cannot be predicted by chromaticity coordinates of the colored dots. Rather, the interpretation of "7" (can be read as 1 or 2 due to the unique Ishihara style) or "3" seem to induce various misreading patterns.

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C26 *340* Variability in symmetric and asymmetric colour matching

Eli Brenner[1] (e.brenner@erasmusmc.nl), Jeroen J M Granzier[1], Jeroen B J Smeets[1]; [1]ErasmusMC, Rotterdam, The Netherlands

When we match two surfaces' colours, are we primarily matching the light coming from those surfaces or are we primarily matching the colour contrast with the background? To find out, we asked eight subjects to set the

colour and luminance of a 2 deg diameter test disk on a computer monitor to match a 2 deg diameter grey, reddish or greenish reference disk. Moving the computer mouse to the left or right decreased or increased the extent to which light from the test disk stimulated l-cones, and pushing it away or bringing it nearer increased or decreased m-cone stimulation. The disks were presented on various backgrounds. We assume that the variability in performance is proportional to the amplitude of the underlying signal. Thus, if subjects primarily match the colour contrast then they should be most accurate when the target and background are the same colour. This was indeed so (ignoring errors in luminance). If subjects had primarily matched the light from the targets themselves they would probably always have been most accurate for grey surfaces (smallest colour opponent signals) irrespective of the background colour. In fact, subjects were equally accurate for greenish or reddish disks on a grey background as for grey disks on a greenish or reddish background. However, similar matches with more complex backgrounds and with different colours near the two disks show that subjects do not just match the colour contrast at the borders between the disks and the background.

C27 *341* Temporal luminance artifacts in chromatic motion are specific to L/M cone systems

Magda L Michna[1] (magda.michna@mcgill.ca), Kathy T Mullen[1], Tatsuya Yoshizawa[2]; [1]McGill Vision Research, Dept of Ophthalmology, McGill University, Montreal, Canada, [2]Motto Laboratories for Human Information Systems, Kanazawa Institute of Technology, Ishikawa, Japan

Purpose: We have previously demonstrated that motion discrimination for red-green chromatic stimuli is based on luminance signals under certain conditions, specifically those of linear motion (Yoshizawa et al., Vis.Res. 2000), signed apparent motion (Yoshizawa et al., Vis.Res. 2003), and grating motion (Mullen et al. Vis Res. 2003). Here we test whether the motion of blue-yellow chromatic stimuli is similarly contaminated by luminance signals or is genuinely mediated by chromatic mechanisms.

Methods: Stimuli were gabor patches (spatial frequency = 1.5cpd, ó = 0.66 degrees) calibrated to isolate either the S-cone or L/M cone opponent pathways. We investigated the masking effects of superimposed luminance noise (1-dimensional, temporally dynamic) on contrast thresholds for stimulus detection and direction discrimination using a temporal 2AFC staircase method. Thresholds were measured for stimulus drift rates of 0.75 - 6.0 Hz. Individual isoluminant points were determined using a minimum motion technique.

Results: We find that for S-cone opponent stimuli neither detection nor direction discrimination thresholds were masked by luminance noise, and a large gap was maintained between detection and direction discrimination thresholds. For L/M cone opponent stimuli, detection thresholds were not affected by luminance noise but direction discrimination was masked by increasing luminance noise contrast.

Conclusions: Unlike their L/M counter parts, direction discrimination thresholds of S-cone opponent gabors are not based on luminance signals, and appear to be genuinely chromatic. Hence we conclude that temporal luminance artifacts, previously termed 'temporal chromatic aberration', are specific to L/M cone systems.

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URL: http://www.mvr.mcgill.ca/Kathy/kmullen_home.html

C28 *342* Distortion Products in Chromatic Induction: Nulling of Induced Temporal Frequencies Not Present in the Stimulus

Anthony D. D'Antona[1] (adantona@uchicago.edu), Steven K. Shevell[1,2]; [1]Department of Psychology, University of Chicago, [2]Department of Ophthalmology and Visual Science, University of Chicago

PURPOSE: Chromatic induction is the color change of an object caused by its chromatic surround. The magnitude of time-varying chromatic induction from a time-varying surround is strongly attenuated above ~3 Hz. Surround temporal frequencies >3 Hz, however, can cause time-varying induction when two frequencies are presented in the surround simultaneously. The induced temporal variation is at the difference frequency of the two frequency components in the surround. Here, we show a neural response is present at the difference frequency by canceling it with added out-of-phase light. METHODS: A steady equal energy white (EEW) annular test was embedded within a larger circular surround. The surround was temporally modulated along either the l or s chromatic direction of MacLeod-Boynton color space. Pairs of temporal frequencies were presented in the surround simultaneously. The observer adjusted the amplitude, DC level, and phase (0 or 180 deg) of a sine-wave stimulus added to the test annulus; the frequency was the difference of the two temporal frequencies in the surround. The observer's task was to make the test annulus appear steady and achromatic. RESULTS & CONCLUSIONS: For both chromatic axes, observers nulled the induced temporal variation with a consistent non-zero nulling amplitude, confirming that chromatic induction from high temporal frequency surrounds depends on a distortion product of a nonlinear neural process. The nonlinearity causes high frequency surrounds, previously thought to be ineffective for induction, to induce low frequency variation, which may be useful for segmenting an object from its temporally varying background.

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C29 *343* Illusory color mixing upon perceptual filling-in does not result in 'forbidden colors' and reveals cortical processing

Po-Jang Hsieh[1] (po-jang.hsieh@dartmouth.edu), Peter U. Tse[1]; [1]Dept. of Psychological and Brain Sciences, Dartmouth College

Crane and Piantanida (1983) reported that when presenting stabilized bipartite colored fields in which no clear cues about the foreground and background exist, some observers see novel 'forbidden' mixtures of the two colors. The perceived colors were deemed to be 'forbidden' because they seemed to violate Hering's laws of color opponency, resulting in reddish greens and yellowish blues. Surprisingly, this radical claim has never been empirically tested. To test this, we took advantage of the fact that a retinally stabilized object readily undergoes perceptual fading. It is commonly believed that the color of the apparently vanished object is filled in with the color of the background because the features of the filled-in area are determined by features located outside the stabilized boundary. Here we use visual stimuli composed of spatially alternating stripes of two different colors to investigate the characteristics of color mixing during perceptual filling-in, and to determine whether 'forbidden colors' really occur. Our results show that (1) the filled-in color is not solely determined by the background color, but can be the mixture of the background and the foreground color; (2) apparent color mixing can occur even when the two colors are presented to different eyes, implying that color mixing during filling-in is in part a cortical phenomenon; (3) Our data also show that the 'forbidden colors' reported by Crane and Piantanida (1983) do not exist. Our results show that perceived colors during perceptual filling-in are not 'forbidden colors', but rather intermediate colors.

C30 *344* Partial colour matching: a new method to measure unique hues

alexander d logvinenko[1] (a.logvinenko@gcal.ac.uk); [1]Department of Vision Sciences, Glasgow Caledonian University

After Hering, colour is described in terms of six unique hues (white, black, red, green, yellow, and blue). Yet, there is no objective psychophysical procedure for establishing the nomenclature of unique hues. It is still unclear whether, say, purple is unique or not. A new method has been developed to ascertain the set of unique hues. The procedure was as follows. Trichromatic human observers were presented with pairs from a set of 21 Munsell chips with an instruction to evaluate whether they share any hue (partial colour match). Sets of chips that have identical partial colour match (matching classes), and largest sets of chips all of which partially match

each other (chromaticity classes), were derived from the matrix of responses.A chromaticity class is proved to consist of all chips which contain a particular hue (referred to as component hue). Thus, the number of chromaticity classes shows how many component hues an observer employed in their decision making. A matching class is proved to contain all the chips with identical component hues. We found four matching classes which contained only one component hue. Moreover, these classes consisted of just one chip. We concluded that these four Munsell chips (5Y, 10B, 5R, 10G) represented four unique hues.While our results are in line with the previous studies of unique hues, the partial colour matching technique has an advantage that it is based on the data of type A, in terms of Brindley's classification.

C31 *345* Classical definitions of chromatic induction are inadequate for induction with S-cone patterned backgrounds

Patrick Monnier[1] (pmonnier@colostate.edu), Lucy, J. Troup[1]; [1]Colorado State University, CO, 80523, USA

BACKGROUND/PURPOSE: Inducing patterns composed of circles selectively stimulating the S cones can induce large color shifts. These shifts were previously accounted for by chromatic assimilation to nearby inducing light and simultaneous contrast from distal light (Monnier & Shevell, 2004). Classically, assimilation and contrast are defined as shifts "toward" and "away" from the inducing chromaticity, respectively. In this study, we show that these classical definitions of induction are inadequate to describe shifts observed with S-cone patterns.METHODS: Chromatic induction was measured with asymmetric matching. Shifts were measured for test ring chromaticities that produced: (1) intermediate levels of S-cone stimulation compared to the inducing circles; (2) either lower or higher levels of S-cone stimulation than the inducing circles. According to the classical definitions of chromatic induction, shifts for test chromaticities outside the inducing chromaticities should be much reduced, as assimilation and contrast should tend to cancel.RESULTS: As previously, the appearance of a test ring of intermediate S-cone stimulation shifted toward the nearby, and away from, distal inducing light. Surprisingly, the direction and the magnitude of the color shifts were relatively constant even when the test ring chromaticity was outside the range of inducing chromaticities. The measurements suggest the classical definitions of chromatic induction are inadequate here as the shifts were not always 'toward' and 'away' from the nearby and distal light.CONCLUSIONS: Color shifts with S-cone patterns were relatively independent of the test ring chromaticity. This runs counter to an interpretation based on classical definitions of induction.

C32 *346* Chromatic induction of moving dots in a motion-defined layer

Keiji Uchikawa[1] (uchikawa@ip.titech.ac.jp), Takemi Kawahara[1], Kaori Segawa[1]; [1] Department of Information Processing, Tokyo Institute of Technology, Japan

When a yellow patch is surrounded either by red or by green dots we perceive chromatic induction on the yellow patch. But both red and green dots surround the yellow patch the chromatic induction is canceled. Here, we report a new phenomenon of chromatic induction. When red and green dots moved at different speeds chromatic induction occurred on the yellow patch that moved at the same speed as either red or green dots whereas chromatic induction disappeared when both red and green dots remained stationary. In the present study we quantitatively investigated this phenomenon. Two yellow squares (1 x 1deg, 20cd/m2), separated by 6-deg distance, were presented one in the top and the other in the bottom half-field of the CRT screen. Red and green dots (0.25deg diameter, 1.1 dot/deg2 for each color) surrounded the yellow squares in both fields. The background was dark (0.1cd/m2). A fixation cross was presented at the center between two squares. The red and the green dots moved at 4.77 and 2.38deg/sec, respectively, in the same direction in one half-field. In the other half-field the red and the green dots moved at the opposite speeds. The yellow squares moved with the higher-speed dots in both half-fields. Most observers perceived chromatic induction (assimilation), stronger than those in the static conditions, in the yellow squares although the magnitude of the effect was different among observers. The results may suggest that chromatic interaction exists within the motion module of the same speed in the visual system.

C33 *347* Hue scaling without hue naming

Lesley L Beattie[1] (lesley.beattie@gcal.ac.uk), Alexander Logvinenko[1]; [1]Department of Vision Sciences, Glasgow Caledonian University, UK

Hue scaling techniques aim to describe colour in terms of the relative amounts of unique hues, which are usually defined verbally rather than perceptually. We have developed a hue scaling technique which neither involves hue naming, nor requires observers to estimate the amount of unique hues in compound colours.

It is based on the partial colour matching method (Logvinenko, VSS 2006) which implies judging whether two colours have a common component hue. As proved elsewhere (Logvinenko, VSS 2006), the largest sets of colours which partially match each other - chromaticity classes - are in one-to-one correspondence with component hues. Specifically, each chromaticity class comprises all colours having the same component hue.

Using 325 chips from the boundary of the Munsell tree, we have evaluated chromaticity classes for normal trichromats. The results are in line with the classical six unique hues. Observers were asked to order the chips within each chromaticity class in terms of the strength of the component hue constituting the class (observers found this task much easier than evaluating the relative amount of unique hues in percentage). From this an ordinal scale was constructed for each chromaticity class. The chips which have the same hue scale value make up what we call isochromes. The isochromes for each chromaticity class were plotted in the SML cone space (for equi-energy illumination). As a result we have a geometrical representation of the Munsell colours used that is based on both physiological and psychological grounds.

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C34 *348* The Colored Flashing Spots Illusion

M. Boi[1] (marcoboi@tiscali.it), B. Pinna[2]; [1]University of Cagliari Dept of Psychology, [2]University of Sassary Dept of Science of Languages

An array of black discs surrounded by a set of coloured annuli forming a ramp, whose luminance increases outward, is perceived scintillating of complementary colours when moving the gaze from an element to another. We call this illusion Coloured Flashing Spots (CFS).It differs from simple colour contrast in being vivid, self luminous and lustrous, in not being a property of the inducing surface and occurring in peripheral rather than in foveal vision. It is phenomenally related to the Flashing Anomalous Colour Contrast (FACC) (Pinna, Spillmann, Werner 2004) from which differs in not depending on the radial lines for its flashing and in that the chromatic annuli form a ramp profile instead of a square decrement. Additionally, while the FACC is stronger when the inner disc has the same luminance as the surrounding annulus, here the flashing drops if the disc has a minimal brightness contrast compared to the mean annulus brightness, becoming a simple simultaneous colour contrast. Conversely, replacing the grey disc in the FACC with a white or black one, we obtain an enhanced white or black respectively.The CFS can be partially explained by mechanisms subtending simultaneous colour contrast and brightness-darkness induction as in the Hermann Grid illusion. Further mechanisms accounting for the role of the ramp profile are needed to explain how the reversing of the annulus ramp luminance and the use of a white disc in place of a black one, induces a flashing exhibiting very similar vividness, saturation and lightness to the previous condition.

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C35 *349* Reflectance identification of real colored objects across real illuminants

Marques Bostic[1] (mbostic@sunyopt.edu), Rocco Robilotto[1], Qasim Zaidi[1]; [1]SUNY College of Optometry, USA

To discover what heuristics observers use in identifying materials across illuminants, we placed randomly crumpled 3-D objects with precisely controlled spectral-reflectances, inside two adjacent compartments with a yellowish (Sun) illuminant on one compartment and a bluish (Sky) illuminant on the other. The compartments were lined with similar multicolored patterns. Three of the objects (Standards) were made from the same paper, while the fourth (Test) varied from the Standard along different color lines. On each trial, the observer was instructed to identify the object with the odd material. Along each color line, the threshold for discrimination within illuminants was obtained from the frequencies of correctly picking the Test compartment. The threshold for reflectance identification across illuminants was obtained from the frequencies of correctly picking the Test object. For almost all Tests, whenever the Test was reliably discriminated from the Standard, it was also reliably identified as the odd material. However, for certain Tests, the Standard in the Test's compartment was reliably misidentified as the odd reflectance. In the Macleod-Boynton chromaticity diagram, these Tests plot near the line that passes through the Standard under the other illuminant and is approximately parallel to the line joining the means of the backgrounds across the illuminants. It seems that in separating reflectance changes from illuminant changes, observers use the heuristic that the color of a material should shift across illuminants along a line parallel to the color change for the backgrounds. This heuristic is an approximation to, but systematically different from, the generic physical change.

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C36 *350* The role of mutual illumination in gradient formation

Marina Bloj[1] (m.bloj@brad.ac.uk), Alexa I. Ruppertsberg[1]; [1]Department of Optometry, University of Bradford, Bradford, BD7 1DP, UK

Psychophysical (Bloj et al., Nature, 402; Gilchrist & Jacobsen, Perception, 13) and computational (Funt & Drew, IEEE PAMI, 15; Nayar et al., Int. J Comp Vis, 6) studies have postulated that mutual illumination (indirect illumination due to light reflected by surfaces in a scene) provides cues for colour and shape perception. We have previously shown that RADIANCE can be used to accurately simulate the chromaticity and luminance of scenes (Ruppertsberg & Bloj, JOSA-A, in press). Here, we use this rendering package to study and analyse how mutual illumination varies as a function of light and surface position, in an effort to understand what potential cues are available to the visual system for the recovery of scene layout and colour. Study scenes included corners made from two cards with various hinge angles and different illumination angles as well as a cylinders and other objects. For the corners the scatter plot of the chromaticity profile for a given illumination angle forms a straight line in the CIE chromaticity plane, which shifts systematically toward the "whiter" region of the plane as the illumination angle increases. The slopes of the luminance profiles become steeper and the overall luminance level increases. For the cylinder scene the resulting chromaticity profile is close to a straight line in the chromaticity plane and the luminance profile is non-linear. In summary we find that the colours of the involved objects and lights determine chromaticity profiles of colour gradients, and the luminance profiles convey information about geometry, including illumination angle and/or object shape.

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C37 *351* Color constancy of chromatically textured surfaces

Anya C Hurlbert[1] (anya.hurlbert@ncl.ac.uk), Yazhu Ling[1]; [1]Psychology and Institute of Neuroscience, University of Newcastle upon Tyne, UK

Computational models of color constancy demonstrate (implicitly or explicitly) that the estimation of the illumination spectral power distribution necessarily improves as the number of distinct surface reflectance samples increases. Although the underlying assumption of such models is that each distinct surface is uniform in reflectance, we observe that a single surface with intrinsic chromatic texture may provide a large number of reflectance samples on its own. But chromatic texture within a surface also blocks simultaneous chromatic contrast between the surface and its background, most powerfully when the background is uniform (Hurlbert & Wolf, Prog. Brain Res. , 2003). Thus, the contribution of local between-surface contrast to color constancy for chromatically textured surfaces is weak at best, unlike the empirical results for artificial, homogeneous surfaces (e.g. Kraft & Brainard, Proc. Nat. Sci. Acad., 1999). The contribution of within-surface chromatic contrast, though, may be strong, depending on the spatial scale and luminance statistics of the texture. Here we record and analyze the chromatic texture of representative natural objects and model its effect on color constancy, by estimating limits on the contributions from (1) within-surface chromatic contrast (2) between-surface chromatic contrast (for homogeneous backgrounds) and (3) illumination estimation based on within-surface reflectance sampling. We predict that surface color constancy may be better for objects with natural chromatic texture than for the homogeneous surfaces typically used in laboratory measurements of constancy.

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C38 *352* The saliency of luminance and color (diagnostic and anti-diagnostic) in images

Thomas V. Papathomas[1,2] (papathom@rci.rutgers.edu), Xiaotao Su[1], Anshul Jain[1,2], Henry Uzochukwu[1]; [1]Laboratory of Vision Research, Rutgers University, [2]Department of Biomedical Engineering, Rutgers University

Objective: Examine saliency of luminance/color, and test diagnostic/anti-diagnostic colors.

Methods: Used two sets of 8 512x512 images: diagnostic colors (example: red cherry); anti-diagnostic colors (yellow strawberry). Images contained 3x3 arrays of fruits/vegetables. Procedure within each set:

For each image, k=1-8, obtain (from HSV coordinates) the luminance image Lk (set H=S=0), and the color image Ck (set V to fixed value).

Form low- (l) and high-pass (h) versions (sigmas 38 and 10 pixels, respectively), resulting in 9 variants for each Fk: original Fk, Lk, Ck, and filtered versions, Flk, Fhk, Llk, Lhk, Clk, Chk.

Consider all possible pairs of images k and m, and form all composites Ikm with the color component of one variant and the luminance component of the other (2x9 such images for each pair).

Observers reported whether composite image Ikm resembled more Fk or Fm for all 684 ((9x8/2)x18) composites. We report on averages of 7 observers, who obtained very consistent patterns.

Results: 1) Lk dominated Cm, Clm and Chm at rates above 62%, 97%, and 95%. 2) Llk was dominated by Cm, Clm or Chm at rates above 90%. 3) Lhk dominated Clm and Chm at rates above 80%, but lost to Cm at above 62%. There were no major differences between diagnostic- and anti-diagnostic-color sets.

Conclusions: Generally, luminance is more salient than color. High-frequency components are dominant for both. Diagnostic colors were not advantageous over anti-diagnostic colors in our experimental design; experiments with single-item images and additional sigma values are in progress.

C39 *353* Can semantic information prime surface color judgments?

Holly E. Gerhard[1] (holly.gerhard@nyu.edu), Laurence T. Maloney[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Recent studies of object color perception suggest that semantic information affects color appearance (Hurlbert & Ling, VSS2005; Gegenfurtner & Walter, ECVP2004). We examine whether semantic primes presented 300 msec before a test square alter the square's color appearance. We separated prime and test square in time to insure that any effect would be semantic and not due to the shape or spatial frequency content of the primes. **Preliminary:** Each observer first completed tasks that allowed us to construct an equiluminant red-green scale (passing through neutral) specific to the observer. **Task:** On each trial, observers saw a briefly-presented prime followed after 300 msec by a briefly-presented test square whose chromaticity fell on the red-green scale. The task was to judge whether the test square was "reddish" or "greenish." Chromaticity was adjusted in a staircase procedure along the scale to converge on the point of subjective achromaticity (PSA). There were four prime conditions, each with separate staircases: red- and green-associated words and red- and green-associated images. Psychometric functions were fitted to estimate the PSA for each condition. Five naïve observers participated. **Results:** For four observers, PSAs for the red and green *word*-primed conditions did not differ significantly. For three observers, PSAs for the red and green *picture*-primed conditions did not differ. The remaining significant differences were opposite in direction to the predictions of semantic priming (i.e. PSAs for red primed conditions were greenish). **Conclusion:** The only effect of achromatic semantic primes was to push surface color judgments away from the primed color.

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C40 *354* An extended model for color preference

Yazhu Ling[1] (yazhu.ling@ncl.ac.uk), Anya C Hurlbert[1]; [1]Psychology and Institute of Neuroscience, University of Newcastle upon Tyne

Attempts to develop a universal color preference model have thus far failed to explain individual differences or incorporate physiological factors. In our recent experiments investigating the biological and cultural determinants of color preference (e.g. Ling et al., ECVP 2004), we have shown that the S cone contrast value accounts for the greatest variance in hue preference, with the L-M cone contrast value second. We have therefore proposed a model for hue preference in which each observer's hue preference curve may be predicted by a weighted sum of the S and L-M cone-contrast components of the stimuli. Here, we extend the hue preference model into the lightness domain. We hypothesize that for color stimuli varying in both hue and lightness, the individual preference curves may be predicted by the weighted sum of three components: the achromatic lightness channel (L+M+S contrast), and the 2 cone-contrast channels above. To test this hypothesis, we carry out a new set of experiments in which observers perform a paired comparison task for color stimuli systematically varied in hue and lightness. The results confirm the hypothesis: for each subject, the color preference curve is better predicted by the weighted sum of 3 channels than the weighted sum of 2 cone-opponent channels. Moreover, a positive weight for the lightness component indicates that the observer prefers brighter colors, and vice versa. By reducing the description of each individual's color preferences to a set of 3 weights, this model readily accounts for individual differences and is extensible across populations.

C41 *355* The association of colours with emotions: A systematic approach

David R. Simmons[1] (david@psy.gla.ac.uk); [1]Department of Psychology, University of Glasgow

There is a plethora of data concerning the relationship between colours and emotions, but little of this has been systematically collected. One view is that all such relationships are labile and determined by a combination of cultural and experiential influences. As such, data on colour-emotion relationships should be highly variable both between individuals and between cultures. Another view is that there is a physiological basis to these relationships which is likely to be universal. We have approached this issue systematically by running a series of experiments in which participants were presented with an array of three coloured patches, chosen from a limited set, on a neutral gray background. Colours were specified using CIE coordinates. Participants were asked to choose which of the three evoked the largest emotional response on a given affective dimension. By exhaustively testing all possible three-colour combinations from the set, a hierarchy could be established for the colour-emotion relationships under test. So far two affective dimensions have been examined: pleasant-unpleasant and arousing-calming. The most pleasant colours were found to be saturated blues and purples. The most unpleasant were greenish and yellowish browns. The most arousing ("mood-lifting") were saturated reds and yellows, whereas the most calming were pale (whitish) blues and purples. Whilst the participants were culturally homogeneous there was nevertheless a remarkable level of agreement between them, suggesting either that colour-emotion associations are stereotyped within a given culture, possibly due to media influences, or that there is a strong physiological component to them.

C42 *356* Color Name Evolution in the World Color Survey: a K-Means Analysis

Delwin T. Lindsey[1] (lindsey.43@osu.edu), Angela M. Brown[1]; [1]Ohio State University

Berlin and Kay (1969) proposed that the naming of color within all languages evolves in a hierarchically constrained way toward an end-state resembling English. We evaluated this proposal by examining the color naming data in Kay's World Color Survey (WCS; http://www.icsi.berkeley.edu/wcs/data.html). We used a k-means classifier to partition the 14336 distinct chromatic color naming patterns in the WCS, each obtained when an informant assigned a single color name to a set of WCS color chips. Classification was based on similarities in pair-wise Pearson correlation between binary representations of the color naming patterns. In our first analysis, we varied the number of categories, K, into which our classifier partitioned the naming patterns. When we varied K between 2 and 10, we found: 1) average color names for all values of K glossed to single or composite English names; 2) the structures of the k-means partitions unfolded in a way reminiscent of Berlin and Kay's hierarchical sequence of color category evolution (the two-color solution gave WARM and COOL; the three-color solution gave RED-or-PINK, YELLOW-or-ORANGE, and COOL; etc.). Gap statistical analysis (Hastie & Walther, 2001) revealed K=8 statistically significantly distinct partitions in the WCS data set: RED, GREEN, YELLOW-or-ORANGE, BLUE, PURPLE, BROWN, PINK, and GRUE. The "early" color names, WARM and COOL for instance, were no longer distinct color naming categories when K=8. This variation in the color naming category structure as K varies may help explain why different scholars have come to different conclusions regarding the existence of evolutionary processes in color naming.

Surfaces and Shape

C43 *357* Cortical Activation for 3D Shapes Constructed from Different Depth Cues

Kuei-Po Chen[1] (r93227110@ntu.edu.tw), Chien-Chung Chen[1]; [1]National Taiwan University

We investigated cortical responses to 3D shapes constructed from motion parallax, binocular disparity, and perspective cues with fMRI.The 3D global shapes were horizontal sinewaves (0.1875 cyc/deg) modulated in depth. The local elements were elongated Gaussian bars (space constant

0.7'x20'). The motion cue had the bar elements moving horizontally with a velocity defined by a sinusoid function (maximum velocity: +/- 0.5 deg/s). The disparity cue had the disparities (maximum disparity +/- 0.15 deg) between corresponding bars in the left and the right eye images determined by a sinusoid function. The perspective cue had the bar elements with different orientation defined by a perspective algorithm. We used a block design to measure differential BOLD activations between stimuli with either one or two depth cues and a control with no depth cue. For an attention control, the observer was instructed to respond when the color of the fixation point changed. The EPI image (TR=3000ms, TE=40ms, flip angle=90°) were acquired on a Bruker 3T scanner.The middle occipital gyrus (MOG) and the right intraparietal sulcus (IPS) were activated by 3D shapes defined by any depth cues. The ventral occipital cortex was only activated for monocular depth cues. The MOG activation was expanded toward more anterior and dorsal regions when there were more one depth cue available. Our result implies that the stereopsis is mainly a function of the dorsal stream while processing monocular depth cues requires both ventral and dorsal streams.Support by NSC-94-2413-H-002-021

C44 *358* Primate IPS areas involved in visual 3D shape processing

Jean-Baptiste Durand[1] (JeanBaptiste.Durand@med.kuleuven.be), Koen Nelissen[1], Wim Vanduffel[1,2], James T Todd[3], J Farley Norman[4], Guy A Orban[1]; [1]Lab. voor Neuro & Psychofysiologie, KU Leuven - Medical school, Leuven B-3000, BELGIUM, [2]Massachusetts General Hospital/MIT/Harvard Medical School Athinoula A. Martino's Center for Biomedical Imaging, Charlestown, MA 02129, USA, [3]Psychology Department, 216 Lazenby Hall, 1827 Neil Avenue, Columbus, OH 43210 USA, [4]Psychology Department, Western Kentucky University, Bowling Green, KY 42101-1030, USA

Action-oriented representations of the environment are built in the intraparietal sulcus (IPS) by integrating information from multiple sensory modalities. Among these modalities, vision is of prime importance since it provides most of our knowledge about the 3D structure of the world (crucial for navigation and for recognition and grasping of objects). Using fMRI techniques with awake monkey (Vanduffel et al., 2001), we studied the neural network involved in 3D shape extraction from stereo focusing on the IPS. Stimuli were random lines resembling images of unfolded paper clips (Orban et al., 1999). A set of IPS regions was more activated by stereo-defined 3D shapes compared to their 2D (flat) counterparts presented in different depth planes. On the lateral bank, AIP, LIP and pIPS were significantly more 3D than 2D shape sensitive. For LIP, 3D sensitivity was observed in the anterior part while the intermediate part preferred shapes presented in different depth planes rather than in the fixation plane. On the medial bank, posterior VIP, MIP and PIP also showed 3D shape sensitivity. Overall, this IPS network is highly similar to the network activated by 2D greyscale images and drawings of objects (Denys et al. 2004), showing a shape processing oriented toward object manipulation in the IPS. Moreover, because it was shown previously that the IPS is only weakly involved in 3D extraction from motion in monkeys (Vanduffel et al. 2002), the present results highlight the importance of stereo relative to motion in 3D shape processing in the IPS.

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C45 *359* 3D Surface Representations Derived From Texture Gradients: Filtering, Grouping and Filling-In

Levin Kuhlmann[1] (levink@cns.bu.edu), Stephen Grossberg[1], Ennio Mingolla[1]; [1]Department of Cognitive and Neural Systems, Boston University

A neural model is presented of how cortical areas V1, V2, and V4 interact to convert a textured 2D image into a representation of curved 3D shape. Two basic problems are solved to achieve this: (1) Patterns of spatially discrete 2D texture elements are grouped into a spatially smooth surface representation of 3D shape. (2) Changes in the statistical properties of texture elements across space induce the perceived 3D shape of this surface representation. This is achieved in the model through multiple-scale filtering of a 2D image, followed by a cooperative-competitive feedback loop that coherently groups texture elements into boundary webs at the appropriate depths using a scale-to-depth map and a subsequent depth competition stage. These boundary webs then gate filling-in of surface lightness signals in order to form a 3D surface percept. The model quantitatively simulates a large set of psychophysical data pertaining to perception of prolate ellipsoids (Todd and Akerstrom. 1987, *J. Exp. Psych.*, 13, 242). In particular, the model represents a high degree of 3D curvature for a certain class of images, all of whose texture elements have the same degree of optical compression, in accordance with percepts of human observers. To demonstrate the more general capabilities of the model, simulations of 3D percepts of an elliptical cylinder, a slanted plane, and a photo of a golf ball are presented.

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C46 *360* 3D curvature aftereffects from illusory orientation flows

Andrea Li[1] (andrea_li@qc.edu), Belinda Tzen[1], Alevtina Yadgarova[1], Qasim Zaidi[2]; [1]Queens College, CUNY, [2]SUNY College of Optometry

In perspectival images of textured surfaces, veridical 3D curvatures are conveyed by specific patterns of orientation flows (Li & Zaidi, 2004, 2001, 2000). In Kitaoka's illusion Zabuton, 3D shapes are conveyed by illusory orientation flows: straight horizontal and vertical edges of a checkerboard pattern appear curved because of high contrast interstices. We used concave and convex Zabutons (2 sec) in an adaptation paradigm to establish whether 3D aftereffects can be explained by adaptation of local luminance mechanisms, independent or laterally-interactive orientation selective mechanisms, or 3D-curvature selective neural mechanisms. After adaptation, observers judged shape aftereffects as concave or convex for three types of flat checkerboard tests (200 msec): in-phase with the adapting checkerboard, opposite-phase, or phase-shifted by half-cycles in both dimensions. Local luminance gain controls predict that the aftereffect should be opposite to the adapting curvature for the in-phase test, same as adapting curvature for the opposite-phase test, and flat for the phase-shifted test. Adaptation of independent local orientation mechanisms predicts flat percepts for all of the test stimuli because the adapting orientations are physically horizontal and vertical. Adaptation of laterally-interactive orientation selective mechanisms influenced by the effects of the interstices predicts opposite curvature aftereffects for the in-phase and opposite-phase tests, but flat percepts for the phase-shifted tests. Adaptation of 3D-curvature selective mechanisms predicts opposite curvature aftereffects regardless of the test phase. Preliminary results are consistent with the adaptation of 3D-curvature selective mechanisms that that are invariant to exact placement of contours in the receptive field.

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C47 *361* Perceived depth from linear perspective as a function of image size

Jeffrey A Saunders[1] (saunder2@psych.upenn.edu), Benjamin T Backus[1]; [1]Department of Psychology, University of Pennsylvania

We investigated the ability to use linear perspective to perceive depth from monocular images. Specifically, we focused on the information provided by convergence of parallel lines in an image due to perspective projection. Our stimuli were trapezoid-shaped projected contours, which appear as rectangles slanted in depth. If converging edges of a contour are

assumed to be parallel edges of a 3D object, then it is possible in principle to recover its 3D orientation and relative dimensions. This interpretation depends on projected size, so if an image contour were scaled, accurate use of perspective predicts changes in perceived slant and shape. We tested this prediction, and measured the accuracy and precision with which observers can judge depth from perspective alone. Observers viewed monocular images of slanted rectangles, and judged whether the rectangles appeared longer or wider than a square. The projected contours had varying widths (7°, 14°, 21°), and side angles (7° or 25°), and heights were varied by a staircase procedure to compute a PSE and JND for each condition. Observers were able to reliably judge aspect ratios using only the monocular images: Weber fractions were 6-9% for the largest rectangles, increasing to as high as 17% for small rectangles with high simulated slant. Overall, the contours judged to be squares were taller than the projections of actual squares, consistent with perceptual underestimation of depth. Judgments were modulated by image size in the direction expected from perspective geometry, but the effect of size was smaller than predicted (20-40%).

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C48 *362* The role of texture amplitude in shape from shading

Andrew J Schofield[1] (a.j.schofield@bham.ac.uk), Paul B Rock[1], Gillian Hesse[1], Mark A Georgeson[2], Timothy A Yates[2]; [1]School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK., [2]School of Life and Health Sciences, Aston University, Aston Triangle, Birmingham, B4 7ET, UK.

The pattern of illumination on an undulating surface can be used to infer its 3-D form (shape from shading). But the recovered shape would be invalid if the luminance pattern actually arose from reflectance variation. When the surface has a reflectance texture, variation in local mean luminance (LM) due to shading is accompanied by similar modulation in texture amplitude (AM) in-phase with the LM. This does not hold for reflectance variation, nor for roughly textured surfaces. We presented LM+AM and LM-AM cues in a plaid configuration co-registered with a haptic surface, using a ReachIn workstation. In experiment 1 observers adjusted the position of the haptic surface until its peak in depth aligned with the visually perceived one. Haptic settings varied with plaid orientation and were consistent with a lighting-from-above prior. In experiment 2, AM modulation depths were 0.1, 0.2 or 0.4 and the haptic surface amplitude was adjusted to match the visual one. Observers chose relatively large amplitude settings when the haptic surface was aligned with the LM+AM cue, independently of modulation depth. When the haptic surface was aligned with the LM-AM cue, haptic amplitude settings decreased as modulation depth increased. The weakest stimuli were close to the detection threshold for AM but well above the threshold for LM. We conclude that when a visible AM signal is out-of-phase with its LM partner this is a cue to reflectance variation, which is seen as flat. An experiment using visual depth probes was consistent with the haptic results.

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C49 *363* Perception of illuminance flow in the case of anisotropic rough surfaces

Andrea J van Doorn[1,2] (a.j.koenderink-vandoorn@io.tudelft.nl), Jan J Koenderink[1], Sylvia C Pont[1]; [1]Universiteit Utrecht, [2]Delft University of Technology

Human observers are able to arrive at rather precise estimates of the illumination direction of shaded rough surfaces. When surfaces are rough, the illumination generates "visible texture" due to differential shading at the level of the roughness, whereas shading at the level of significant global surface curvature leads to the more familiar "shading". Shading and texture are related because due to the same direction of illumination. The shading is used in the so-called "Shape From Shading" (SFS) algorithms. Formal analysis reveals that much more powerful SFS algorithms are possible if the texture is taken into account. Since conventional SFS ignores the illumination texture cue, human observers are perhaps more likely to apply different methods.When the roughness is not isotropic one expects systematic errors in the visual detection of illumination direction, conceivably giving rise to erroneous shape estimates. Although it is possible to construct (complicated) algorithms to deal with this, it is unknown whether human observers are able to deal with anisotropy. It seems a priori likely that observers will use simple, robust methods that work well for the majority of cases (isotropic roughness).We address this issue through systematic psychophysics on illumination direction detection as a function of the roughness anisotropy. We find that the observers indeed commit systematic errors that are quantitatively predicted by the theory. The results are precise enough that they allow the inference that illumination direction detection is based on the second order statistics of edge detector (rather than line detector) activity.

C50 *364* A new twist to the "Shading Cue"

Jan J Koenderink[1] (j.j.koenderink@phys.uu.nl), Sylvia C Pont[1], Andrea J van Doorn[1]; [1]Universiteit Utrecht

The "shading cue" is conventionally placed in the context of smooth Lambertian surfaces of uniform (unit) albedo, illuminated by a collimated, uniform beam. Under these assumptions the illuminance varies because of Lambert's cosine Law, that is with the component of the "light vector" that is normal to the surface. The illuminance pattern, or "shading", thus contains shape information: hence "shading cue". Formal analysis reveals that the SFS ("Shape From Shading") problem is very ill posed. Only global solutions exist, and these are subject to an extensive group of ambiguities. Some of these ambiguities have become well known in human psychophysics.In realistic situations the surface will be rough, rather than smooth. This induces an illumination dependent texture. We show that this texture reveals the component of the light vector along the surface, which may be called "illuminance flow". This changes the SFS problem significantly. Local estimates of surface shape become possible, and the group of ambiguities becomes smaller. We have shown psychophysically that observers are able to detect this illuminance flow.Since local mechanisms are much more biologically viable than global ones (solutions of partial differential equations with boundary conditions) we reconsider a number of classical illusions involving the shading cue, but this time in the presence of surface roughness. There exist simple variations on the convex/concave illusion that are disambiguated by the illuminance flow. Informal observation reveals that human observers fail to disambiguate such cases, thus giving rise to a novel set of illusions.

C51 *365* Polo Mint Shading

Peggy Gerardin[1] (Peggy.Gerardin@univ-paris5.fr), Marie de Montalembert[1], Pascal Mamassian[1]; [1]CNRS & Université Paris 5

The visual system exploits prior knowledge on the world to infer shape from shading, in particular the fact that light comes from above rather than from below. Recent studies have suggested that the assumption on the light source position was further biased on the left of the vertical (Sun and Perona, 1998, Nature Neuroscience, 1, 183-184; Mamassian and Goutcher, 2001, Cognition, 81, B1-B9). We investigated the generality of this result with a different stimulus and a novel task. The stimulus was shaped like a polo mint candy divided in eight equal sectors. All but one sectors had the same curvature, namely convex or concave. Upon a brief presentation of a stimulus, observers had to report the side (left or right) that contained the odd curved sector. Stimuli were generated using one of four possible light source positions and were then blurred using one of ten low-pass filters. Results show a strong asymmetry in accuracy in favour of stimuli lit from the left rather than the right. This asymmetry was found both for naïve and experienced observers. There was also an advantage to detect a concave sector amongst convex ones. However, various amounts of blur did not produce any systematic differences. Our results therefore replicate previous studies that found a consistent leftward bias for the assumed light source position. The possible origins of such a preference are discussed.

C52 *366* The effect of viewpoint on visually perceived surface roughness in binocularly viewed scenes

Yun-Xian Ho[1] (yunxian.ho@nyu.edu), Laurence T. Maloney[1,2], Michael S. Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

We investigate how observers assess surface roughness visually. In the past, we have found systematic failures of roughness constancy across changes in scene illumination – more glancing illuminants make surfaces appear rougher (Ho, Landy & Maloney, VSS 2005). Here, we examine roughness constancy across changes in viewpoint in scenes with constant illumination. Methods: The stimuli were 3D surfaces resembling coarse sandpaper composed of small triangular facets. Roughness was defined as the variance of the random facet heights. Stimuli were rendered for binocular viewing both frontoparallel (0ï) and from three viewpoints to the right and left (±20, 40 and 60ï). A punctate illuminant was located at a fixed position relative to the surface (30ï to the left). We used a staircase procedure (two-interval, forced-choice) to estimate the points of subjective equality of perceived roughness for surfaces with various levels of physical roughness across each pair of viewpoints. Results: Across viewpoints on the right-hand side (opposite the illuminant), perceived roughness for a given surface changed little as viewpoint was varied. That is, observers were nearly roughness constant. However, for all other tested comparisons, observers exhibited large, systematic failures of roughness constancy. We found that these failures were well predicted by the changes across viewpoint of (1) proportion of cast shadow, (2) mean luminance and (3) facet shading variance. Our results suggest that, in assessing visual roughness, the visual system mistakenly makes use of "pseudo-cues" to roughness that are not invariant under changes in viewpoint.

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C53 *367* Local 3D shape and reflectance statistics of natural surfaces

Richard F. Murray[1] (rfm@yorku.ca); [1]Center for Vision Research, York University

Shape from shading is an under-constrained problem, so in order to perceive 3D object shape from image shading, observers must make assumptions about what surface shape and reflectance patterns are likely or unlikely. We examined some statistical properties of natural surfaces. METHOD. We measured selected statistical properties of 3D digital scans of fifty-five randomly selected objects. The data was provided by Arius3D, Inc. The scans included naturally occurring objects and man-made objects. We viewed each virtual object through a 256 x 256 pixel virtual camera. The objects were rotated to a random orientation, and scaled so that they spanned the image matrix. Because these were virtual objects, it was possible to determine the orientation and reflectance of the 3D surface patch that corresponded to each pixel, and thus to examine how 3D surface properties changed from pixel to pixel of the 2D image. RESULTS. (a) Changes in surface orientation from pixel to pixel followed a well-defined distribution, with peaks at 0º and 5º, and a smaller peak at 90º. (b) Changes in surface reflectance from pixel to pixel also followed a well-defined distribution, with a sharp peak at zero change, and a rapid falloff at higher changes. (c) Changes in orientation were more likely than corresponding changes in reflectance, which may explain why we generally perceive flat images as renderings of 3D scenes. (d) Changes in orientation and reflectance were moderately correlated. It is unknown whether the human visual system exploits this fact when reconstructing 3D shapes from 2D images.

URL: http://www.yorku.ca/rfm

C54 *368* How viewing distance and object size affect judgments of shape in pictures

Dhanraj Vishwanath[1] (dxvgss@rit.edu), Martin S Banks[2, 3]; [1]Department of Psychology, Rochester Institute of Technology, [2]Vision Science Program, University of California, Berkeley, [3]Helen Wills Neuroscience Institute, University of California, Berkeley

When viewing a picture from different distances, changes in the shape and orientation of depicted objects are often not perceived despite corresponding changes in the retinal image. For example, a slanted rectangular plane should appear to have a higher aspect ratio and a correspondingly higher slant when viewed at greater distances. We examined how perceptual judgments of shape varied with viewing distance. Observers judged the aspect ratio of a slanted rectangular plane in a depicted 3D scene while viewing the picture from different distances along its surface normal. An adaptive staircase procedure was used to determine the aspect ratio of the slanted plane that appeared square. We tested different plane sizes, and also varied the amount of information for viewing distance (binocular viewing and monocular viewing through an aperture). Perceived shape was invariant only for stimulus planes that subtended the smaller visual angles. Judgments were not invariant with larger planes under monocular or binocular viewing. The larger planes appeared to have a higher aspect ratio at greater viewing distances consistent with changes predicted by the retinal image. The failure of invariance with large planes is inconsistent with the pictorial-compensation hypothesis, which states that geometric information in the picture's content is used to recover the depicted scene layout when the picture is viewed from the wrong distance

C55 *369* Selection of specific subjective states via contextual disambiguation in structure-from-motion.

Elliot D Freeman[1] (elliot.freeman@ucl.ac.uk), Jon Driver[1]; [1]Institute of Cognitive Neuroscience, University College London.

We demonstrate how specific subjective rotational states can be switched at arbitrary intervals by reversing the objective rotation of a physically disambiguated context stimulus.We used random-dot kinematograms (RDK's) to simulate 3D objects rotating in depth. In the absence of additional depth cues to specify the relative ordering of surfaces, such objects appear to switch direction of rotation spontaneously.This ambiguity may be resolved, however, by introducing a physically-biased Context stimulus to the display. We compared two methods of physically biasing the Context, by introducing either luminance differences, or binocular disparity differences between dots on different surfaces so that one surface would consistently appear in front. In both cases the subjective state of an unbiased co-axial Test stimulus becomes closely synchronized with the objective state of the Context.This disambiguating context effect is long-range, reaching across a sizable visual chasm between non-contiguous surfaces of Test and Context stimuli. This extends the findings of Fang & He (2004, Curr. Biol. 14, 247-251), but rules out a mechanism based on propagation of local disparity codes. The context is most effective when rendered unambiguous by disparity. This weighs against a recent model (e.g. Grossmann & Dobbins, 2003, Vision Res. 43, 359-369) that predicts it should fail, as it does with extreme luminance modulations. This phenomenon provides a method for remotely controlling subjective states without changing the local stimulus, and helps to further characterize the mechanisms of contextual disambiguation.

C56 *370* Partial Invariance for 3d Layout in Pictures

Martin S Banks[1,2,3] (martybanks@berkeley.edu), Ahna R Girshick[1]; [1]Vision Science Program, UC Berkeley, [2]Psychology, UC Berkeley, [3]Wills Neuroscience, UC Berkeley

In pictures, outwardly directed objects (e.g., the pointing arm in the Army recruitment poster), seem to "follow" the viewer. Fronto-parallel objects (the shoulders in the poster), do not seem to follow the viewer. If objects slanted at ~90 deg in the picture seem to follow the viewer and those at ~0 deg do not, the perceived slant between pictured objects should change

with viewing location, suggesting a failure of perceptual invariance. To investigate this, we used pictures of vertical hinges in an "open book" configuration. Observers viewed them from various azimuths and indicated the perceived angle between the sides relative to 90 deg. We varied the information for estimating picture-surface slant and geometric information in the picture background. We considered three hypotheses. 1) Retinal: Failure to take viewing location into account. 2) Perceptual-invariance: Perceiving the same 3d structure from all locations. 3) Weighted-average: Combination of slant estimates from the depicted scene and picture surface (this hypothesis is only partially consistent with invariance). With minimal picture-surface slant information (monocular viewing through aperture), the results were similar to the retinal hypothesis (no invariance). With rich surface slant information (binocular viewing, picture frame cue), they were similar to the weighted-average hypothesis (partial invariance). Varying the geometric information had no effect. The perceived layout of pictured scenes changes with viewing position, but much less so when information about the picture-surface slant is available.

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C57 *371* CANONICAL REPRESENTATION: AN EXAMINATION OF PREFERENCES FOR VIEWING AND DEPICTING 3-DIMENSIONAL OBJECTS

Suzanne Khalil[1] (suzanne.khalil@gmail.com), Michael McBeath[1]; [1]Arizona State University

This study examines angular vantages of canonical views of three-dimensional objects, and finds that angular variance is consistent with principles of information optimization. We tested if canonical views systematically vary across (1)Domain: Photography versus line-depictions, and (2)Action: Choosing a preferred view versus generating it. The principal statistical hypothesis is that canonical views remain consistent, independent of action in the photographic domain, but vary with action in the drawing domain. The secondary hypothesis is that canonical views vary with object elongation. 144 adults specified best views of objects in a 2(DOMAIN:photographic,line-depiction) by 2(ACTION:choose,generate) by 3(TYPE:geometric, automotive,animal) by 3(ELONGATION:short,medium,long) factorial design. The expected three main-effects (Action, Domain, and Elongation) and the interaction of the three significantly varied as predicted. In the photographic domain, the mean preferred-view was relatively constant across action, while in the linear-depiction domain, the preferred-view angled more toward a profile when drawn than when chosen. There was also a systematic decrease in preferred angle with object elongation. Findings are consistent with the idea that people prefer skewed vantages that optimally provide more overall information regarding both front and side features. The increased information also makes these vantages potentially more difficult to draw; so people prefer such views when allowed to choose or take a photograph, but not when required to draw. In summary, canonical preferences systematically vary depending on domain of representation, action-task, and object feature of elongation, and are consistent with an information optimizing strategy.

C58 *372* Is viewer-centered representation necessary for 3D shape perception?

Yunfeng Li[1] (li135@purdue.edu), Zygmunt Pizlo[1]; [1]Department of Psychology, Purdue University

Purpose: According to Marr (1982), perception of a 3D shape is preceded by forming a 2.5D sketch - a viewer-centered representation involving 3D orientations of surfaces relative to the viewer. The present study examines the relation between *perceived 3D* shape and a *3D shape reconstructed from perceived orientations of the object's surfaces*. Furthermore, it tests a new theory of shape reconstruction based on a 3D *sphericality* (compactness) constraint. **Method:** A set of polyhedral objects was used. The polyhedra were characterized by three independent vertices, which refer to the number of degrees of freedom in the problem of reconstructing the shape from a single image (Sugihara, 1986). Subjects were tested in two tasks: (i) reconstructing shapes of three visible faces, and (ii) reconstructing 3D orientations of the faces. If perceived 3D shape is derived from perceived 3D orientation, shape reconstructed in task (i) should match the shape reconstructed in (ii). **Results:** First, there is a large and systematic difference between shapes reconstructed in tasks (i) and (ii). Second, the perceived 3D shape agrees with the reconstructions produced by a new model, in which a linear combination of sphericality and symmetry of an object is maximized. Sphericality of an object is defined as the ratio of the volume squared to surface area cubed. **Conclusion:** Reliable percept of the shape of a 3D object is NOT derived from the percept of the object's surfaces.

C59 *373* Classification objects

William A. Simpson[1] (wsimpson@utsc.utoronto.ca), Uma Shahani[2], Velitchko Manahilov[2]; [1]Department of Life Sciences, University of Toronto at Scarborough, [2]Department of Vision Sciences, Glasgow Caledonian University

There are many ways in which humans can judge depth and shape: stereo, shading, motion, etc. Presumably the outputs of the different depth mechanisms are used by the brain to create a true 3D representation. We modified the classification image technique and were able to visualise the observer's 3D representation by means of the "classification object". The method was the same as for a classification image, except that we used the z-coordinate instead of luminance at each x,y location in the computation. The observers' task was to discriminate a human face (shown by 2500 random points on its surface) from a version that was stretched along the z-axis. On each trial, the observer judged whether the face or the z-stretched version rotated about a vertical axis. The resulting classification object has a peak coinciding with the tip of the nose, and troughs at the corner of the eye and at the juncture of the lips. In a second experiment, we constructed a classification object for a sinewave depth grating. The troughs and peaks of the classification object coincide with those of the grating. We conclude that humans use a true 3D template when making judgements about 3D object structure.

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C60 *374* Stereoscopic structure seen in flat patterns

Hiroyuki Mitsudo[1] (hmitsudo@atr.jp); [1]ATR Human Information Science Laboratories

One of the ecological requirements imposed on human vision is the recovery of correct three-dimensional (3D) structure invariant across the directions of gaze. This structural invariance is never questioned because we rarely see incorrect 3D structure in ordinal situations. Here I present counterexamples to the belief by showing that binocularly fixated flat patterns produce illusory 3D structure, depending on the direction of vertical eccentric gaze. Stimuli were comprised of curved lines and were presented on a flat monitor almost perpendicular to the lines of sight. Observers were required to fixate the flat patterns at various angles of the vertical gaze direction, and to report their perceived depth. Experiment 1 revealed that (a) the flat patterns appeared three-dimensionally on a downward or upward eccentric gaze, and (b) the perceived 3D structure was reversed depending on whether the stimuli were viewed on a downward or upward gaze. The results are consistent with the idea that the illusory structure arises from a horizontal mismatch of the cyclodisparity induced by torsional binocular misalignment. Experiment 2 showed that the magnitude of the illusory depth rose steeply when gaze direction exceeded a particular angle (on downward gaze, approximately 40 deg). The illusions therefore suggest that ocular torsion is optimized for stereo vision in a wide but limited range of gaze direction.

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C61 *375* Failures of stereoscopic depth constancy: Fact or artefact?

Brian J Rogers[1] (bjr@psy.ox.ac.uk); [1]Department of Experimental Psychology,

University of Oxford, South Parks Road, Oxford, OX1 3UD, UK.

Compensation for a change in distance in the amount of perceived depth (depth constancy) has been found to be substantially smaller (35-40%) than compensation for the flatness of the frontal plane (~100%) (Rogers and Bradshaw, *Perception*, 1994; Bradshaw *et al*. *Vision Research*, 1995). We attributed this to the fact that an explicit estimate of distance is not required for frontal plane scaling because local visual information (e.g. HSR = VSR^2) could be used to solve the task (see also Gärding *et al*, 1994). However, this cannot be the whole story because manipulating vergence angle (which provides only distance information) also has a significantly greater effect on frontal plane scaling. There is an alternative possibility - poor depth constancy may be an artefact of the shape/depth tasks typically used. To investigate this possibility, observers were presented with large field (70deg x 50deg) stereoscopic images at 57 *or* 172 cm distances. Vergence and differential perspective cues were manipulated to depict surfaces in front of or behind the display screens. In a frontal plane task, observers adjusted the pattern of horizontal disparities until the surface appeared flat. As well as measuring depth and shape constancy using traditional methods, observers adjusted the slants of (i) a 3-D pyramid or (ii) a series of intersecting horizontal strips with alternating disparity gradients until they appeared to meet/intersect at 90deg. Constancy was close to 100% in the new tasks (and in the frontal plane task), suggesting that incorrect estimates of distance are not necessarily the cause of poor constancy.

Face Perception

C62 *376* Face inversion disproportionately impairs the perception of vertical but not horizontal relations between features

Valerie Goffaux[1,2] (valerie.goffaux@psp.ucl.ac.be), Bruno Rossion[1,2]; [1]Department of Cognitive Development, University of Louvain, Belgium, [2]Laboratory of Neurophysiology, University of Louvain, Belgium

Upside-down inversion is thought to disrupt the processing of spatial relations between the features of a face, i.e. its configuration, while largely preserving the processing of local features. However, recent studies challenged this view, suggesting that inversion equally impairs the perception of features and their relations (e.g. Yovel & Kanwisher, 2004). To resolve these discrepancies and clarify the impact of inversion on the perception of a face stimulus, we dissociated between the vertical and horizontal relations between face features. In three experiments, subjects discriminated pairs of faces that differed at the level of vertical relations (eyes upper or lower in the face), horizontal relations (eyes closer or further apart) and feature shape (eyes exchanged). Face pairs were presented upright and inverted. A dramatic performance decline for inverted faces was obtained in the vertical-relational condition, whereas an equally moderate impairment was observed in the featural and horizontal-relational conditions. This pattern was observed whether the differences to detect between faces in vertical-relational and horizontal-relational were equalized by considering the relative distance between the two eyes (experiment 1), or when they were considered as separate entities (experiments 2 and 3). Whether upright and inverted pairs were blocked or randomly interleaved in the experiment had no influence on this pattern of results (experiment 3). These experiments provide clear evidence that inversion dramatically disrupts the ability to extract vertical relations between facial features but not horizontal relations, and support the view that upright and inverted faces are processed by qualitatively different mechanisms.

C63 *377* Effective Frequency Tuning of Three Face Categorization Tasks

Daniel Fiset[1] (danielf@psy.gla.ac.uk), Caroline Blais[2,3], Frédéric Gosselin[2,3], Philippe Schyns[1]; [1]University of Glasgow, Department of Psychology, [2]Université de Montréal, Département de Psychologie, [3]Centre de Recherche en Neuropsychologie et en Cognition

Using a new application of the Bubbles method (Gosselin & Schyns, 2001), we estimated the frequency tuning of three face categorization tasks (Identity, Gender and Expressive or not (Exnex)) applied to 20 face pictures (5 males and 5 females identities, smiling and neutral). On each trial, we exposed 4 observers to a continuous sample of Spatial Frequency (SF) information. The continuous sample of spatial frequencies involved several computations. For each trial, we first produced a white noise curve of random numbers (between 0 and 1) convolved with a Gaussian function (std = .07 of the Nyquist). We also computed the complement curve (1 – white noise curve). We Fourier transformed a randomly chosen face and multiplied the amplitude of Fourier coefficients with the same random curve, for each orientation of the SF in Fourier space. The complement curve similarly multiplied the Fourier coefficients of face noise. The full spectrum stimulus summed the resulting random sample of the Fourier coefficients of the face and complement face noise. In each task, we maintained observers' accuracies halfway between chance and ceiling (75% for gender and Exnex, and 55% for identity) by adjusting on each trial the sampled amplitude of face frequencies. Multiple linear regressions on response accuracy and sampling noise revealed task-dependent frequency tuning: In Gender, a narrow band peaked at 4 cycles per face (cpf); in Exnex, a broader band covered 5 to 12 cpf. In Identity, two bands (one peaking at 5 cpf, the other at 12 cpf) characterized performance.

C64 *378* Faces and Familiarity: Not all Fame is the Same

James Intriligator[1] (j.intriligator@bangor.ac.uk), Jennifer Kaltreider[1]; [1]University of Wales, Bangor

Purpose. Extremely familiar faces (e.g. one's own face) can be found rapidly in visual search tasks (e.g. Tong and Nakayama, 1999). We now investigate whether similar benefits can be found for faces of other levels of familiarity (for example, moderately famous faces). **Stimuli and Procedure**. In all conditions, participants searched for a target face among a set of novel distractor faces. A present/absent response was required (targets were present on half the trials). We chose the target faces to include various levels of familiarity (e.g. unknown, familiar, well-known, famous). Half the trials were standard visual search trials and the other half were presented in a novel "overlay condition". In this condition, each stimulus was presented behind a transparent novel face (40% transparency). This condition, which requires the observer to segregate the two images, was created to put unique demands on the face-recognition system. **Results**. In our standard search condition, search benefits increased as a function of familiarity. In other words, each increase in familiarity yields additional search benefits. However, in the overlay condition such a quantitative performance increase was not found. In this condition, we found search benefits only for highly familiar faces. **Discussion**. Task demands determine how familiarity impacts search performance. In some tasks, each increase in target familiarity leads to better performance. But, in other cases, increases in familiarity have little or no effect until the stimuli are extremely familiar. We discuss these results in terms of the mental representations required to facilitate task performance.

C65 *379* CATEGORIZING BLURRED IMAGES

Peter N Steinmetz[1] (Peter.Steinmetz@asu.edu), Flavio DaSilva[1]; [1]Arizona State University

Previous studies have examined how well individual images of faces can be recognized even after blurring (Gold, Bennett and Sekuler 1999, Kornowski and Petersik 2003). We were interested in how well normal subjects can categorize images drawn from several picture categories (unfamiliar faces, animals, tools, outdoor scenes, buildings), both when blurred and unblurred, since this task with unblurred images has been used to investigate single neuron responses in the human medial temporal lobe (Kreiman et. al 2001). Subjects were shown images on a computer screen for one second. Each image was unblurred or blurred by low pass filtering with cutoffs of 0.39, 0.59, 0.78, 1.17 cy/fw. Subjects were asked to indicate, as quickly as possible, whether the image belonged to a target category or not by pressing a mouse button with either the right or left hand.

We examined the accuracy of categorization for each image category as well as response times as a function of blur level. Preliminary results suggest that categorization of images is much more tolerant of image blur than image recognition: 75% correct for 0.78 cy/fw (categorization) vs. 8 - 16 cy/fw (recognition). Additionally, the categorization of faces is consistently 54 ± 8 ms faster than the categorization of non-faces for all blur levels. These results are consistent with the existence of a separate form of rapid low frequency sub-cortical processing of faces.

C66 *380* Orientation congruence judgments in faces & words

Carl M Gaspar[1] (gasparcm@mcmaster.ca), Patrick J Bennett[1,2], Allison B Sekuler[1,2]; [1]McMaster University, [2]Centre for Vision Research, York University

Thatcher faces - images with eyes and mouth rotated - have a striking appearance. Thatcher and normal faces are easy to tell apart when upright, but not when inverted (Thompson, 1980; Lewis, 2001). These phenomena have been cited as evidence that normal face processing relies on a comparison between parts and wholes, and that these comparisons become less accurate when faces are shown upside-down. However, previous tasks involving the detection of Thatcher faces could be done successfully by attending to only a single facial feature. Here, we introduced uncertainty about which feature could be incongruent, forcing observers to monitor more than a single feature. The second experiment forced observers to make comparisons between parts and wholes by mixing trials of upright and inverted faces; now an upside-down eye could be congruent or incongruent, depending on how the rest of the face was oriented. In addition, we applied the same paradigms to study the perception of part-whole congruence in words. There is evidence that part-whole relationships play a role in word/letter identification (e.g., the word-superiority effect), but no one has studied how observers discriminate normal words from words containing an inverted letter. Both faces and words are familiar categories with canonical orientations. As such, one might expect judgments of orientation congruence to be similar for both categories. Indeed, our results show that congruence judgments are always enhanced by stimuli being presented in their normal orientation. However, our results also suggest that the benefit gained from uprightness differs for words and faces.

C67 *381* Behavioural Tuning of Face-Selective Neural Populations

Nicole D. Anderson[1] (anderson@hpl.cvr.yorku.ca), Hugh R. Wilson[1]; [1]Centre for Vision Research, York University

Recent fMRI evidence demonstrates that face-selective mechanisms are tuned to face identity in a manner consistent with geometric face space. We evaluated the spatiotemporal properties of identity tuning for synthetic faces using a behavioural reverse correlation technique proposed by Ringach (1998). With this technique, different faces were rapidly (~80ms) flashed on the screen and subjects were required to respond when a target face was presented as quickly as possible. Spatial and temporal tuning were assessed by correlating the probability that a particular stimulus was presented in the recent history of a subject's response. Spatiotemporal tuning plots were measured for face detection (detection of an intact face in the presence of scrambled faces) and for face identification (detection of one face identity in the presence of other identities). When asked to detect an intact face, subjects were most likely to respond on average 497.4 ms after an intact face was presented in the stimulus history. When asked to detect a specific identity, on the other hand, subjects were most likely to respond on average 587.9 ms after the target identity was presented. This temporal response difference is inconsistent with previous research demonstrating similar reaction times for face detection and identification. Moreover, subjects tended to be less likely to respond when a geometrically opposite 'anti-face' was presented at the same point in the stimulus history. These results suggest that inhibitory mechanisms may contribute to the tuning of face-selective mechanisms, similar in principle to opponent mechanisms that are observed in the orientation domain.

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C68 *382* The timecourse of expert and novice visual object encoding

Kim M. Curby[1] (kim.curby@vanderbilt.edu), Isabel Gauthier[1]; [1]Vanderbilt Vision Research Center, Vanderbilt University, Nashville Tennessee

Face processing experiences a temporal advantage relative to that of other categories; electrophysiological responses in categorization tasks suggest that processing begins 25ms earlier for faces than objects (e.g., Caldara et al., 2003). This advantage appears to be specific to upright faces (Rossion et al., 2000). It has been argued that identity-level representations are available for faces and objects of expertise earlier than for other categories (Tanaka & Taylor, 1991; Tanaka, 2001), although this claim has been challenged (Grill-Spector & Kanwisher, 2005). Here, we attempt to measure more precisely a possible temporal advantage for encoding upright, relative to inverted, faces, in the context of identification judgments. We also investigate the same question with non-face objects of expertise. Experiment 1 compared the timecourse of upright and inverted unfamiliar face processing using a backward masking identity-matching paradigm with a range of stimulus-mask onset asynchronies (12ms-1000ms). Matching performance for upright faces rose above chance at around 40ms, approximately 70ms earlier than that for inverted faces. Experiment 2 compared the processing timecourse for car identity matching among car experts and novices. Notably, car experts' performance demonstrated an initial 'head-start' of approximately 40ms over novices' performance, also rising above chance at around 40ms. Our results are consistent with faster access to the subordinate-level by experts observed in studies with coarser temporal resolution (e.g.,Tanaka, 2001). This early advantage could reflect a difference in processing strategies (e.g., holistic vs. part-based) or the benefits of the automatic weighing of diagnostic features for very familiar categories.

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C69 *383* Familiarity accentuates gaze-following in women but not men

Robert O Deaner[1] (deaner@neuro.duke.edu), Stephen V Shepherd[1], Jelena Ristic[2], Michael L Platt[1,3,4]; [1]Department of Neurobiology, Duke University Medical Center, [2]Department of Psychology, University of British Columbia, [3]Center for Cognitive Neuroscience, Duke University Medical Center, [4]Department of Biological Anthropology & Anatomy, Duke University Medical Center

People rapidly shift their attention in the direction other individuals are looking, following gaze in a manner suggestive of an obligatory and unmodifiable reflex. Recent studies indicate, however, that such gaze-following may be modulated by social variables, such as gender, social status, and state of arousal. We hypothesized that familiarity with the viewed individual should also influence gaze-following. Male and female human subjects viewed the face of a male looking left or right and then responded by pressing a keypad to indicate the location of a target appearing randomly left or right. Crucially, subjects in the experiment were drawn either from the same academic department as the individuals whose faces were used as gaze cues or from outside the department. Replicating previous studies, subjects followed gaze by more quickly responding when viewed gaze predicted the location of the target. However, female subjects from within the department showed significantly greater gaze-following than did females from outside the department; no differences were found between the two groups of males, or between males and females outside the department. In addition, females, but not males, showed greater gaze-following for individuals whom they reported seeing frequently within the department. These results suggest that both gender and familiarity influence the strength of social attention.

C70 *384* The "Angry = Black" Effect Across the Lifespan

Yarrow C. Dunham[1] (dunhamya@gse.harvard.edu), Mahzarin R. Banaji[1]; [1]Harvard University

Much social information is derived from facial displays of emotion, sometimes in surprising ways. For example, Hugenberg & Bodenhausen (2004) reported that racially-ambiguous angry faces were more likely to be classified as racially "Black", while the same faces were more likely to be classified as "White" when presented in a happy expression. Thus a negative emotion (anger) is associated more strongly with Black than White – the very same face is perceived to be Black when the face displays anger and White when the face displays a smile. An advantage of this simple classification procedure is that it can be used to test the strength of the angry=black effect with young children. We tested 145 non-Black children (ages 3 to 13) and 60 adults on this ambiguous face classification task, thus beginning with the earliest ages children can successfully perform racial classifications. Remarkably, the angry = Black effect was present in the youngest children tested and the magnitude of the effect remained invariant into adulthood. However, other processes related to racial classification did show age related change. Both the tendency to exclude ambiguous faces from the ingroup (ingroup overexclusion) and the use of facial hue as a cue to race category became more pronounced with age. Attributes of good and bad begin to affect perception of social groups very early in childhood (even in children with little direct contact with the outgroup). Future work will examine whether this effect is specific to Angry=Black or is more generally Angry=Outgroup.

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C71 *385* A Self-range Defined by Gaze Perception Affected by Characteristics of Personality

Yuko Isogaya[1] (gayan-tky@umin.ac.jp), Kazushi Maruya[2,3], Yutaka Nakajima[1], Yusuke Tani[1], Takao Sato[1]; [1]The University of Tokyo, [2]The Jikei University, [3]Intelligent Modeling Laboratory, the University of Tokyo

Self-range is defined as a range of gaze direction of a looker within which the person being looked at feels like he/she is actually being looked at. We have been studying gaze perception in laboratories by using lookers' picture displayed on a CRT screen. In this study, we used life-size pictures printed on paper and examined if similar results can be obtained in more relaxed settings. In addition, we administered several personality inventory, and examined correlations between self-range and the indices. The stimuli were life-sized full-color pictures of four young people with gaze shifted in 11 steps between 15 deg to the right and to the left from the center. Participants were asked to judge whether the stimulus person was looking at them. The pictures were presented at a distance of 57 cm in a randomized order. The self-ranges obtained were quite similar to those from past studies with CRTs. The estimated self-range ranged between 5-10 degs, and the average was approximately 8 deg. The correlations between the self-range and subscales of personality inventory revealed intriguing tendencies. The self-range had negative correlations to depressiveness and feeling of inferiority for males. However, for females, the self-range had positive correlation to self-display. The present results indicated that the results from relaxed settings with paper stimuli are quite reliable. This, together with some relations to personality indices obtained in this study opened up a possibilities of extending gaze perception studies into clinical, developmental and educational environments.

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C72 *386* A systematic investigation of the gaze manipulation effect

Claudiu Simion[1,2] (claudiu@caltech.edu), Shinsuke Shimojo[1,2]; [1]Division of Biology, California Institute of Technology, Pasadena, California, [2]"Shimojo Implicit Brain Function" Project, JST.ERATO, Japan

We (Shimojo, Simion et al, 2003) have advanced the hypothesis that orienting behavior and cognition interact in a positive feedback loop forming the backbone of preference decisions. The fewer the cognitive "reasons" to prefer a stimulus in a comparison task, the stronger the influence of orienting behavior. We demonstrated that orienting can directly influence subjects' preference decision by manipulating subjects' gaze, and that the stimuli oriented towards for longer times were chosen as more attractive when the difference in base attractiveness rating was small. The effect was not due to mere exposure. The present study is a systematic investigation of the phenomenon of gaze manipulation under various cognitive loads. Observers rated a human face database for attractiveness, after which they were presented with pairs of faces drawn from this database. The pairing was done so that the difference in attractiveness rating varies from large to zero. One of the faces was the "target", and the subject was forced to orient to it longer. We show that, regardless of the initial difference in rating, the percentage of cases in which the target face is chosen is on-average 14 percent larger in the gaze manipulation compared to the control task. We conclude that orienting influences preference at all levels of cognitive load, making a stimulus initially considered less attractive more likely to be preferred.

C73 *387* Is the average face special?

Gillian Rhodes[1] (gill@psy.uwa.edu.au), Laurence T Maloney[2], Jenny Turner[1], Louise Ewing[1]; [1]School of Psychology, University of Western Australia, [2]Department of Psychology and Center for Neural Science, New York University

Faces can be represented as points in a multidimensional face-space with an average face at the center (Valentine, 1991). This average is dynamically updated by experience, resulting in compelling face aftereffects (MacLin & Webster, 2001; Rhodes, et al, 2003; Webster & MacLin, 1999). But does face adaptation have any functional significance? In low-level vision, adaptation can facilitate discrimination around the adapting stimuli (e.g., Clifford, et al, 2001; Phinney, et al, 1997; Regan & Beverley, 1985), although this is not always found (reviewed in Clifford & Rhodes, 2005). Wilson et al (2002) reported reduced discrimination thresholds around the average for synthetic, schematic faces, suggesting a similar functional role for face adaptation. However, subtle discriminations around threshold may not be important for natural face perception. We, therefore, examined suprathreshold discrimination of real faces. Converging evidence from three paradigms showed no enhanced discrimination around the average. Discrimination of interocular spacing differences was not enhanced for faces close to the average. Nor was perceived dissimilarity greater for face pairs close to (spanning) the average. Rather, these were judged to be more similar than other pairs, indicating reduced discriminability around the average. Finally, maximum likelihood difference scaling of similarity ratings (Maloney & Yang, 2003) revealed no enhanced discrimination or "crispening" around the average. Instead, linear functions were obtained, indicating constant perceived differences across the continua. These results suggest that there is no special region of enhanced discrimination around the average face. We consider other possible functions of face adaptation, including neural efficiency and attentional orienting.

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C74 *388* Attentional processes involved in facial attention capture

Karen Borrmann[1] (karen.borrmann@mcgill.ca), Nadine Furtado[1], Avi Chaudhuri[1]; [1]Department of Psychology, McGill University

Faces have been shown to hold an attentional advantage over non-face objects under certain conditions, and have even been demonstrated to overcome a number of situations associated with inattention. These phenomena are generally explained by way of an ability of facial stimuli to capture attention. We present evidence that sheds light on the type of attentional processes involved when task-irrelevant face stimuli influence the allocation of attention between simultaneously presented stimuli. Using an attentional cueing paradigm, we found that task-irrelevant face

stimuli, but not simultaneously presented task-irrelevant object stimuli, act as exogenous cues for attention. However, this face advantage disappears when the competing, task-irrelevant cues are presented without reaching awareness, suggesting that attention is explicitly, not implicitly, guided to face stimuli.

C75 *389* PERCEIVED HEAD ORIENTATION IS AFFECTED BY THE DYNAMIC ROTATION OF NEIGHBORING FACES

Claudine Habak[1] (chabak@yorku.ca), Nicole D. Anderson[1], Hugh R. Wilson[1]; [1]Centre for Vision Research, York University

Head rotation is a cue for perceived gaze direction in face perception. This work examined how perceived head orientation is influenced by the dynamic rotation of neighboring faces. Within each trial, two identical contextual faces were presented 3.2° to the left and right of fixation for 240ms. Halfway through the presentation of contextual faces, a static target face appeared briefly (27ms) at fixation. Observers reported whether the target face was rotated further to the left or right than the contextual faces. Target face orientation was varied from trial to trial, so that the point of subjective equality (PSE) for head orientation between target and contextual faces could be measured. Three conditions were interleaved: contextual faces were either dynamic (rotating from 4 to 16° or 16 to 4°) or static at a head rotation of 10°. All three conditions were similar during target presentation, in that dynamic contextual faces were oriented at 10° during the 27ms target exposure. The PSE (n=4) for the static condition was 9.9° (±1.1°) but for rotating conditions shifted to 15.1° (±2.0°) and to 3.0° (±1.0°) for the 4-16° and 16-4° directions, respectively. Results suggest that perceived head orientation is influenced by that of neighboring faces, and that when contextual faces undergo a dynamic rotation, the flashed face appears to lag behind. This demonstrates that the flash-lag effect applies to complex constructs and motions, such as head rotation. Implications for motion mechanisms and perceived gaze direction are addressed.

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C76 *390* An ambiguous-race illusion in children's face memory

Kristin Shutts[1] (shutts@fas.harvard.edu), Katherine D. Kinzler[1], Elizabeth S. Spelke[1]; [1]Psychology Department, Harvard University

Previous research has shown that infants, children, and adults are better at recognizing own-race than other-race faces (e.g. Sangrigoli & de Schonen, 2004; Pezdek et al., 2003; Meissner & Brigham, 2001). Moreover, adults show a cross-race recognition deficit when tested with sets of ambiguous-race faces that differ only in the presence or absence of an extraneous marker (hairstyle) of racial category (MacLin & Malpass, 2003). This "ambiguous-race illusion" provides evidence that face memory is not driven solely by perceptual expertise, but rather is also susceptible to higher-level processes of categorization. The goal of the present study was to investigate whether the ambiguous-race illusion obtains in young children. We presented children aged 2 to 5 years raised in predominantly White environments with a set of computer-generated White-Black morphs. During the experiment, each morph face was paired with either the White or Black face that contributed to the morph, and were told that the two faces were siblings. When tested for their memory of the morph faces, children were better at recognizing faces that had been previously introduced with their White sibling than faces that had been previously introduced with their Black sibling ($t(50) = 2.30$, $p < .05$), providing evidence that children's memory for perceptually identical faces is modulated by the racial context in which faces are presented. This suggests that an early own-race face memory advantage is not driven exclusively by perceptual familiarity. In-progress research is exploring this effect further with both children and adults.

Visual Development

C77 *391* Longitudinal Study of Chromatic and Luminance Contrast Sensitivity in Full-term and Pre-term Infants

RG Bosworth[1] (rbosworth@ucsd.edu), B Hinga[1], SL Robbins[2], KR Dobkins[1]; [1]Dept of Psychology, University of California, San Diego, [2]Dept of Ophthalmology, University of California, San Diego

Purpose: Previous VEP studies have investigated the development of chromatic (Chr) and luminance (Lum) contrast sensitivity. Here, we used a psychophysical technique to longitudinally track the development of Chr and Lum sensitivity between 2-7 months. In addition, we tested pre-term infants to determine whether Chr and Lum sensitivity are differentially affected by extra-uterine visual exposure.

Methods: Using forced-choice preferential looking (FPL), contrast thresholds were obtained for chromatic (Chr, red/green isoluminant) and luminance (Lum, black/yellow) sinusoidal gratings (15 by 15 deg; 0.27 cpd; 4 Hz; mean luminance = 12 cd/m^2). The Chr stimuli were set to isoluminance using the mean isoluminant point from 24 adults using a minimal motion technique. Cone contrasts of the stimuli were: Lum = 2-46%, Chr = 2-24%. Weibull functions were fit to the data to obtain a threshold, and then sensitivity, for each infant. Log Lum:Chr sensitivity ratios were calculated for each infant.

Results: Data from 25 full-term infants show that, consistent with previous results, Lum sensitivity is greater than Chr sensitivity at 2 and 3 months of age. By around 4 or 5 months, there is a reversal in the Lum:Chr ratio, such that Chr sensitivity is greater. Preterm infants show a similar change in Lum:Chr ratio with age, however, more subjects will be needed to determine whether their Lum:Chr ratios are dictated by *adjusted* age or *postnatal* age.

Conclusions: Infants become relatively more sensitive to chromatic stimuli with increasing age, which suggests differential rates of magnocellular vs. parvocellular pathway development.

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C78 *392* VEP measures of contrast sensitivity in infants and children from 2 months- 15 years of age.

Julie Calvert[1,2] (j.calvert@gcal.ac.uk), Michael S Bradnam[1,3], Velitchko Manahilov[2], Daphne L McCulloch[2], Ruth Hamilton[1,3], Gordon N Dutton[1,2]; [1]Yorkhill Division NHS Greater Glasgow, [2]Glasgow Caledonian University, [3]University of Glasgow

Purpose Children with neurological impairment often have visual dysfunction, including reduced contrast sensitivity (CS). However, a lack of co-operation or developmental delay can make subjective testing slow and inaccurate. We have developed an automated, objective CS test using steady-state visual evoked potentials (ssVEPs) suitable for this difficult to test group. In the present study we show the normal development of CS using the ssVEP test as well as age-appropriate psychophysical tests.MethodsThe rationale for our technique is to acquire the most important information as quickly as possible, before the child loses co-operation. This is accomplished by real-time analysis of the individual's ssVEP which determines the subsequent contrast levels to be presented. The stimulus presentation technique is based on an adaptive staircase method. We assessed contrast thresholds in 72 infants and children using our VEP test as well as age-appropriate psychophysical tests (Hiding Heidi, Lea symbols, a PC based psychophysical staircase, F.A.C.T sinewave grating chart and the Pelli-Robson chart).ResultsWith the ssVEP technique, contrast thresholds, comparable to the psychophysical test results, were reached in less than three minutes. CS increased as a function of age until around 5 years, when it reached a plateau at adult levels. ConclusionsThe use of ssVEPs, combined with sensitive objective signal detection and a staircase stimulus presentation is a rapid and valid strategy for determining contrast sensitiv-

ity in infants and children. This direct method of assessing contrast sensitivity, when behavioural responses are not required, demonstrates increasing sensitivity to contrast throughout a child's first 5 years.

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C79 *393* INFANT VERNIER ACUITY IMPROVES AT LOW LUMINANCE

Ann M. Skoczenski[1] (ann.skoczenski@umassmed.edu); [1]University of Massachusetts Medical School

Although vernier acuity is a hyperacuity in normal adults, it is worse than grating acuity during early infancy, and takes several years of normal development to achieve hyperacuity. We investigated the nature of the vernier mechanism in human infants by comparing vernier acuity and grating acuity under two luminance conditions, 20 and 120 cd/m^2. Adult data and infant ideal observer simulations suggest that vernier acuity should follow approximately square root law in its dependence on luminance, while grating acuity should vary less with variations in luminance. We tested 40 infants aged 7 to 25 weeks, using steady-state visual evoked potentials (VEPs) and a within-subject design. Grating acuity stimuli were 5 Hz phase-reversing vertical sinewave gratings that varied in linear steps from low to high spatial frequency during 10-second trials. Vernier acuity stimuli were squarewave gratings containing six vernier offsets per bar; offsets appeared and disappeared at a rate of 5 Hz and offset size decreased in log steps during each 10-second trial. Thresholds were estimated by extrapolating the evoked response to zero microvolts, based on six trials per condition. In the youngest infants, vernier acuity was significantly better in the low luminance condition, compared to higher luminance. Grating acuity at low luminance was unaffected or slightly degraded compared to high luminance. In older infants, the luminance conditions had no significant effect on acuity. These data do not support infant ideal observer predictions. The results may reflect higher levels of neural noise in young infants.

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C80 *394* Early development of velocity sensitivity to rotational motion

Nobu Shirai[1,3] (o2341006@crow.grad.tamacc.chuo-u.ac.jp), So Kanazawa[2], Masami Yamaguchi[1]; [1]Department of Psychology, Chuo University, [2]Department of Psychology, Shukutoku University, [3]Japan Society for the Promotion of Science

We investigated velocity sensitivity to rotational motion in 2-3-month-olds, using same apparatus and procedure as used by Shirai et al. (2005), who reported rapid increment of the velocity sensitivity to radial motion in that age. A total of 25 2-3-month-old infants participated in the present study. We presented stimuli composed of one rotational motion pattern (clockwise or counterclockwise: counterbalanced across infants) and one translational motion pattern (up, down, left, or rightward motion: counterbalanced across infants) placed side by side. In each stimulus, the two motion patterns had same velocity value and each dot moved at constant velocity. There were two velocity conditions in the present study: the high and low velocity conditions. For 2 (or 3)-month-olds, the low velocity was 5.31 (or 2.66) deg/s and the high velocity was 10.62 (or 5.31) deg/s. Each infant participated in either of the two conditions. Each velocity condition composed of six stimuli presentations (duration of each = 5 s). Our progress data have indicated that both the 2- and 3–month-old infants preferred rotations to translations significantly only in the high velocity condition. Because the velocity value for the younger infants was twice as large as that for the older infants, these results suggest the velocity sensitivity to rotational motion may increase between 2 and 3 months of ages. We will discuss a possible model of early development of relative motion sensitivity, based on the results of the present and previous study (Shirai et al., 2005).

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C81 *395* Temporal frequency matters: sensitivity to second-order stimuli in 5-year-olds and adults

Vickie L Armstrong[1] (armstrvl@mcmaster.ca), Terri L Lewis[1], Daphne Maurer[1]; [1]McMaster University, Hamilton, Ontario, Canada

We compared 5-year-olds' and adults' sensitivity to moving second-order (SO) gratings in four combinations of temporal frequency (TF) and velocity (V). Contrast was modulated over trials to measure the minimum contrast modulation yielding 82% correct responses. Adults and 5-year-olds (n=64/ age grp) provided individual thresholds for one of the four TFxV conditions (TF = 6Hz and V = 6 or 1.5 d/s; TF = 0.75Hz and V = 6 or 3 d/s) and for two tasks (direction discrimination and discrimination of a moving from a simultaneously presented static grating). Five-year-olds had higher thresholds than adults for all TFxV conditions, especially when TF = 0.75Hz. Control studies with an orientation discrimination task indicate that 5-year-olds' higher thresholds cannot be explained solely by poorer sensitivity to the patterns. When TF = 6Hz, but not when TF = 0.75 Hz, participants at both ages were more sensitive to SO information when the task was to discriminate a moving from a static grating than when it was to discriminate direction. Based on Seiffert and Cavanaugh (1998), it is likely that when TF is 6 Hz, participants use position-tracking mechanisms to discriminate direction and they use flicker-sensitive mechanisms to discriminate a moving from a static grating. At lower TFs, they likely use position-tracking mechanisms for both tasks (Seiffert & Cavanaugh,1998). Thus, the differential immaturities evident in the results likely reflect different rates of development for these underlying mechanisms.

C82 *396* DETECTION VS. SALIENCE OF COLOR AND MOTION-DEFINED STIMULI IN 6-MONTH-OLD INFANTS

Zsuzsa Kaldy[1] (zsuzsa.kaldy@umb.edu), Erik Blaser[1], Melissa Kibbe[1]; [1]University of Massachusetts Boston, Department of Psychology

HYPOTHESIS: Basic visual functions develop rapidly during the first year of life. Since infants' endogenous attention system is not yet quite matured, salience has an almost exclusive role in controlling their visual attention. However, there has been little research on the relationship between detectability and salience in infants, or on the relative salience of different visual features.METHODS: We first measured detection thresholds and then the relative salience of iso-detectable stimuli, using a forced-choice preferential looking technique. *Detection*: Stimuli consisted of a dense 20x20 array of Gabor patches, where a 3x4 region either differed from the background elements in 'color' (red saturation: 6-31%, background: 0%) or in 'motion', with Gabors in the region phase-shifted with a constant velocity (0.3-1.2 Hz, background: static). This region appeared either on the left or the right side of the array. *Salience*: Iso-detectable (at the 70% and 80% level) stimuli were pitted against each other (on the same background as in the detection task). Gaze directions were coded in both experiments.RESULTS: Our results are based on data collected from six 6-month-old infants. Detection thresholds were successfully determined with our paradigm. In terms of relative salience (of iso-detectable stimuli), preliminary results indicate that color stimuli were more salient than motion stimuli.CONCLUSION: Consistent with the results of our earlier study on color vs. spatial frequency (Kaldy, Blaser, Kibbe & Pomplun, VSS 2005), detectability again did not fully predict salience. The inputs of different features into the computation of salience values are weighted differently.

C83 *397* The Development of Depth from Motion Parallax in Infancy

Elizabeth S. Nawrot[1] (nawrot@mnstate.edu), Mark Nawrot[2]; [1]Department of Psychology, Minnesota State University Moorhead, [2]Center for Visual Neuroscience, Department of Psychology, North Dakota State University

Infants' sensitivity to kinetic-depth develops earlier than sensitivity to binocular (and pictorial) depth and might serve as the foundation for cortical depth-processing networks. Previous studies on the development of depth-from-motion have used shape (i.e., rotating KDE figures), which is depth-sign ambiguous. Here we assess the unambiguous perception of depth from motion parallax (MP) which relies on the slow eye movement system which is developing at the same time as motion sensitivity. In this longitudinal study of the development of depth from MP, we used a Rogers and Graham random dot MP stimulus, which appears as a corrugated surface as it translates across a monitor at 0.2 Hz. Using the infant control habituation paradigm, looking time for the translating stimulus was recorded for each 10-sec trial until the infant reached habituation criterion. Then two test trials were presented: a depth-reversed MP stimulus, and a flat depthless stimulus. Dishabituation (recovery of looking time) to a test stimulus indicates the infant perceived the stimulus change. Four infants were followed from six- to twenty-four weeks-of-age, and tested monocularly to prevent binocular cues. By 20 weeks-of-age, three infants showed dishabituation to both the depth-reversed and flat test stimuli. One additional 20 week-old, tested cross-sectionally, also dishabituated to both test stimuli. One infant less than 20 weeks-of-age showed no dishabituation to the depth-reversed stimulus, but did dishabituate to the flat stimulus at 14 weeks. These results provide evidence for the development of unambiguous depth from MP between 14 and 20 weeks.

C84 *398* Visuospatial interpolation within illusory contours: evidence from Williams Syndrome and normal children

Melanie Palomares[1] (paloma@jhu.edu), Abha Gupta[1], Barbara Landau[2], Howard Egeth[1]; [1]Psychological and Brain Sciences, Johns Hopkins University, [2]Cognitive Science, Johns Hopkins Univeristy

Visuospatial interpolation is the estimation of object position or contour shape computed from known "anchor" positions as in Vernier acuity tasks. Our study investigates how illusory contours affect explicit interpolation of multiple positions in normal children, normal adults and in individuals with Williams Syndrome (WS), a genetic disorder that results in severely impaired global visuospatial construction abilities with a relatively spared language abilities. The visuospatial cognitive profile of WS individuals reflects abnormalities in dorsal visual areas with relative sparing in ventral visual areas (Meyer-Lindenberg et al, 2004). Do illusory contours, which involve ventral visual areas (Ritzl et al, 2003), improve judgment of relative position in normal children and WS individuals?We measured positional thresholds by asking participants to judge the position of a target relative to two flanking objects (target-flanker distances of 1.5-11.5 deg), which either formed an illusory rectangle or not. Our results suggest that integration of distal and proximal information is mediated by separate visual areas. For interpolating positions of distal elements, normal children and WS individuals have higher positional thresholds than normal adults, because they may have immature dorsal stream functions. Moreover, illusory contours, which are examples of implicit integration and recruit ventral visual areas, improve positional thresholds in all participant groups at large inter-element distances. For interpolating proximal elements, neither participant group nor the presence of illusory contours affected positional thresholds. Ventral visual areas might be involved in integration of proximal elements since they are likely to be grouped together as part of the same object.

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C85 *399* Protracted development of perception and memory for picture orientation

Anna Shusterman[1] (anna.shusterman@gmail.com), Kimberly Gutowski[1]; [1]Harvard University

Children and adults have difficulty distinguishing mirror-reversed images. We studied the developmental trajectory of this difficulty, asking whether preschool and school age children could perceive and remember the orientation of pictured objects. In the perception experiment, children simultaneously viewed a colorful picture and either its mirror-reversal or a novel picture, and they judged whether the two pictures were "exactly the same." In an immediate memory task, children viewed single pictures and, one second later, chose between a picture and its mirror reversal. In a longer-term memory task, children viewed five pictures and identified subsequent pictures in a sequence containing original, mirror-reversed, and novel pictures. Three-year-old children claimed that pairs of mirror-reversed pictures were "exactly the same," but succeeded when pictures differed in other ways. Four year-old children perceived the mirror-reversed pictures as "different," but did not remember which picture they had seen – the original or its mirror – after just one second. Six-year-old children attended to orientation in the immediate but not the longer-term memory task, and eight-year-old children, like adults, attended to orientation in all of the tasks. Remarkably, children younger than eight remembered the content of previously viewed pictures (labeling completely new pictures as "new"), even as they disregarded the orientation of the pictures (labeling both old and flipped pictures as "old"), ruling out a general failure of visual memory.

Acknowledgment: Elizabeth Spelke

C86 *400* New Developments in The Evolution of an Efficient Psychophysical Test of Spatial Contrast Sensitivity for Pediatric Patients

Russell J Adams[1] (michelem@mun.ca), James R Drover[2], Kaitlin J Penney[2], Avery Earle[2], Mary L Courage[1]; [1]Psychology/Pediatrics, Science/Medicine, Memorial University, St Johns ,NF ,Canada, [2]Psychology, Memorial University, St Johns, NF, Canada

Purpose: We have been attempting to develop an efficient psychophysical test of spatial contrast sensitivity (CS) for use with pediatric patients. To date, our CS card test (VSS, 2004) satisfies most of these requirements, except that it provides only rough estimates of CS threshold due to large step size and limited contrast range. Here we report on a new, more compact booklet version that addresses these limitations.Methods: The new test consists of (22 x 28 cm) sheets mounted in a spiral flip-binder. One half of each sheet contains a sine-wave grating of given spatial frequency (1.5, 3, 6, 12, or 24 cy/deg at 60 cm). For each SF set, contrast ranges from 3 to 160 CS units in 11 0.21 log CS steps. Testing is forced-choice and proceeds in modified staircase fashion. 150 preschoolers and 85 adults were tested with and without correction. Adults were also tested with the commercial Vistech CS chart. Results: Adult CSFs obtained with the CS booklet matched closely those obtained with the commercial CS test, both for corrected and uncorrected vision. Among children, those showing abnormal booklet CSFs also showed evidence of optical or ocular dysfunction.Conclusions: The CS booklet appears to be a significant improvement over previous psychophysical CS tests. It is very compact, easily portable, is tester and child-friendly, is relatively quick (about 4 min/eye), and appears sensitive to optical and visual pathology. An additional clinical advantage is its ability to estimate precise CS thresholds in children and adults with and without ocular pathology.

Acknowledgment: NSERC (Canada)

Poster Session D

Saturday, May 6, 2006

Attention: Divided Attention and Inattention (401-416), Object Recognition I (417-429), Perceptual Organization: Contours (430-445), 3D Cue Integration (446-454), Perception and Action (455-463), Working Memory II (464-474, 236), Shape and Depth from Motion (475-481)

Poster Session: 4:15 - 7:15 pm ***Municipal Auditorium***
Author presents: 5:30 - 6:30 pm

Attention: Divided Attention and Inattention

D1 *401* The Effect of Perceived Depth on Object Substitution Masking

Mary KL Baldwin[1] (mary.k.baldwin@Vanderbilt.Edu), Izabela Trolka[1], Amanda R Carson[1], Andrew F. Rossi[1]; [1]Department of Psychology, Vanderbilt University, Nashville TN 37203

Object substitution masking (OSM) is a type of backward masking that occurs during visual search (Enns & Di Lollo, 1997). OSM requires attention to the mask, which persists after the search array has been extinguished. Di Lollo et al. (2000) proposed that OSM occurs when there is a conflict between a reentrant target signal and subsequent lower level representation of the mask, resulting in a perceptual substitution of the mask for the target. Implicit in this hypothesis is that OSM operates on object-level representations. In our study, we tested whether a difference in depth between the target and mask disambiguates their representations, thereby eliminating OSM. Subjects viewed an array containing 8 objects positioned equidistant from central fixation. The display was viewed through a stereoscope and the perceived depth of the target and/or mask was defined by disparity relative to the fixation plane. Subjects reported whether or not a triangle had been presented in the location cued by the mask. Masking was observed in all conditions in which the mask and target were presented at different depth planes. The magnitude of the masking effect was between 75-100% of that observed in conditions in which the mask and target shared the same depth plane. In addition, masking was robust regardless of whether the target was perceived as in front, or behind the mask. Our findings suggest that OSM may operate at the level of object representation prior to the integration of disparity information.

D2 *402* Behavioral "baseline shift" effects of perceptual load

David Carmel[1,2] (d.carmel@ucl.ac.uk), Geraint Rees[1,3], Nilli Lavie[1,2]; [1]Institute of Cognitive Neuroscience, University College London, UK, [2]Department of Psychology, University College London, UK, [3]Institute of Neurology, University College London, UK

In all previous studies of perceptual load, high load was shown to modulate the processing of irrelevant stimuli that were always presented concurrently with the target. Here we report results from a new paradigm used to test the effect of perceptual load on detection of peripheral stimuli that were never presented concurrently with targets. Subjects performed either a feature search (monitoring for red crosses among other colors, low load) or a conjunction search (monitoring for upright yellow or inverted green crosses, high load), on a rapid succession of crosses presented at fixation. Results showed that detection sensitivity to peripheral stimuli presented during intervals between targets was reduced under high (compared with low) perceptual load. These results suggest that the mechanism for perceptual modulation by load involves baseline shifts in levels of spatial attention, which may be related to baseline shifts of neural activity in visual cortex (Kastner et al, Neuron 1999).

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D3 *403* Interrupting infants' persisting object representations: An object-based limit?

Erik W. Cheries[1] (erik.cheries@yale.edu), Karen Wynn[1], Brian J. Scholl[1]; [1]Yale University

Making sense of the visual world requires keeping track of objects as the same persisting individuals over time and occlusion. Here we explore a particular aspect of the processes and representations that support this ability in two ways, employing looking-time measures with 10-month-old infants. First, we demonstrate that persisting object representations can be maintained over brief interruptions from additional independent events — just as your memory of a traffic scene may be maintained through a brief glance in the rearview mirror. In particular, infants maintained accurate representations of the number of dolls in a display while they were behind a screen, despite an interruption wherein an additional novel salient object traversed the display between the initial presentation and test, while the dolls were out of view. Second, we demonstrate that this ability is nevertheless subject to an object-based limit: if the same extrinsic interruption is simply segmented into 4 (or even 2) objects, then it will impair the maintenance of other persisting objects: now the interruption — despite being perfectly equated in terms of overall salience, duration, and physical extent — destroys the representation of the number of dolls behind the screen. These experiments demonstrate how object representations can be studied via their 'interruptibility' and the results are consistent with the idea that infants' persisting object representations are constructed and maintained by capacity-limited mid-level 'object-files'.

Acknowledgment: (KW and BJS were supported by NSF #013244)

URL: http://www.yale.edu/perception/

D4 *404* Blindness to swapping features in simple dynamic events

Hoon Choi[1] (h.choi@yale.edu), Brian J. Scholl[1]; [1]Yale University

A prominent trend in recent visual cognition research has been the demonstration of impaired visual awareness without attention. An especially striking example is *change blindness*, wherein surprisingly salient changes can go undetected when the changed objects or regions are unattended. Most such demonstrations induce inattention to the changing object(s) by (1) using displays with at least several objects (yielding other possible foci for attention), and/or (2) using extrinsic disruptions such as eye movements, occluders, or global transients (to directly distract attention and/or to mask the change). Here we explored a type of change blindness in much simpler events, when observers viewed only two objects, with no extrinsic

interruptions, and had to fully attend to those objects -- reporting everything about them immediately after each 1-second trial. The two objects interacted in an ambiguous dynamic pattern, seen to be either 'bouncing' off each other or 'streaming' past each other on opposing linear trajectories. We nevertheless observed considerable change blindness: observers failed to notice when the two objects suddenly swapped colors at various points during their motions. This effect was not due to any baseline visual disruption from the motion, however, since observers readily noticed the sudden introduction of new colors into the display during the same events. These results thus demonstrate a type of change blindness in especially simple displays, and suggest that surface feature information is not reliably bound in memory to specific objects, but is rather tied to events as wholes.

Acknowledgment: (BJS was supported by NSF #0132444)

URL: http://www.yale.edu/perception/

D5 *405* Attention can operate independently of awareness

H.Steven Scholte[1] (h.s.scholte@uva.nl), Manon Mulckhuyse[1], Judith Tankink[1], Victor A. Lamme[1]; [1]Department of psychology, University of Amsterdam

Numerous experiments show that people are unable to report on unattended information, especially when subjects are not informed about the presence of these stimuli. Does this mean that attention determines what we are aware off?We investigated this by presenting subjects with an RSVP of letters that were either hard or easy to discriminate (manipulated by varying the contrast between target and non-target letters).With the onset of the target letter we presented a texture composed of homogeneously oriented line elements or a texture in which a checkerboard could be perceived. Subjects participated in an inattention condition in which they were only informed about the RSVP and we either measured EEG or BOLD-MRI. Subjects that, after the experiment, failed to identify the checkerboard texture participated in two other conditions: a condition in which they again responded to the RSVP and a condition in which they also had to detect the presence of the checkerboard textures. ERPs indicate that a figure induced occipital negativity (~160-200 ms) has lower amplitude when the letters of the RSVP are difficult to discriminate compared to easy to discriminate. This amplitude reduction is not influenced by condition. Later activity is influenced by condition. Results from BOLD-MRI are consistent with this pattern.This indicates that attention determines the amount of processing of stimuli, even when subjects are not aware of stimuli. Results also indicate that the amount of processing in an inattention paradigm is determined by the difficulty of the task that subjects are informed about.

D6 *406* Multi-level suppression during Motion-Induced Blindness

Camilo Libedinsky[1] (camilo_libedinsky@student.hms.harvard.edu), Margaret Livingstone[1]; [1]Department of Neurobiology, Harvard Medical School

Motion-induced blindness (MIB) is a phenomenon in which a highly salient visual stimulus is rendered intermittently invisible by a non-overlapping moving mask (Bonneh et al. 2001). Although the mechanisms by which MIB works are a matter of debate, experiments to date give us some clues as to what they might be. These include attentional mechanisms, grouping or depth ordering and surface completion. Low-level explanations such as sensory suppression, local adaptation or sensory masking have been rejected. Furthermore, adaptation studies hint to the possibility that the locus of suppression during MIB is located downstream of V1 and upstream of inferotemporal cortex. In the present study we used variants of the original MIB stimulus (such as long lines or multiple dots as targets as well as variations on the rotating-mask properties) to study the phenomenological details of the episodes of disappearance. Based on the different types of observed disappearances we propose that instead of a single suppression site, and a single suppression mechanism, there are multiple factors taking part in the phenomenon of disappearance during MIB ("high" and "low" level), that could be instantiated in multiple brain areas.

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D7 *407* Neglected Stimuli Influence Perception

Sarah Shomstein[1] (shomstein@cmu.edu), Marlene Behrmann[1], Rutie Kimchi[2]; [1]Carnegie Mellon University, [2]University of Haifa

The extent of attentional involvement in Gestalt-like perceptual organization has been the source of much ongoing debate. In particular, the question is whether perceptual organization takes place preattentively and if so, whether this is true for all forms of perceptual organization. In the present experiment, we investigated whether visual grouping processes operate preattentively by examining whether grouping takes place under conditions of "inattention" (Kimchi & Razpurker-Apfeld, 2004; Russell & Driver, 2005). Patients with visuo-spatial neglect, resulting from parietal lobe lesions, performed a demanding change-detection task on a matrix-like stimulus presented to the right of a central fixation point. Unbeknownst to the participants a task-irrelevant matrix of elements, organized perceptually by color similarity into rows/columns or into a coherent connected shape, was presented to the left of the fixation point (i.e., the neglected side). This task-irrelevant left-side distractor either changed or retained its grouping on each trial independently of whether the relevant right-side matrix stayed the same or changed, and therefore was either compatible or incompatible with the target response. We observed that task-irrelevant distractors appearing in the neglected (i.e., left) side of space nonetheless influenced accuracy and response time of change detection of information presented to the right of the fixation point. The magnitude of interference was modulated by strength of perceptual grouping (i.e., rows/columns vs. connected shapes), such that stronger grouping yielded greater interference. These results suggest that visual grouping may arise from perceptual processes that operate preattentively but that this is qualified by strength of organization.

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D8 *408* Diminishing attentional capture by attentional set

Sherman Chu[1] (jedelman@ccny.cuny.edu), Jay Edelman[2]; [1]Dept. of Psychology, City College of New York, [2]Dept. of Biology, City College of New York

Yantis and Jonides (1990) showed that attentional capture by a sudden onset is squelched if attention is first focused peripherally. We examined whether other spatial manipulations of attentional set, including cuing the location of a sudden onset, could also ameliorate attentional capture. 5 Ss covertly searched for 1 of 2 possible targets amidst distractors, all radially arranged (4° from center). Static distractors first appeared as figure 8s; line segments were then removed (simultaneous with sudden onset, if any) to reveal a character. 3 expts were performed. 1) Cued target: A 100% valid cue indicated target location (SOAs:200,1000ms). There were a) 2 static distractors, b) 3 static distractors or c) 2 static distractors and 1 sudden onset distractor (SOD). RTs were fast (~550ms) and a SOD increased RT minimally (~20ms). SOA had little effect on RT. 2) Uncued target: 3 possible targets were arranged in an equilateral triangle with a) no additional element b) an additional irrelevant static distractor or c) an additional irrelevant SOD. RTs were slower (~720ms). The SOD and the additional static distractor added 20ms to the RT. 3) Cued onset: Ss searched for a target amidst 2 static distractors and one irrelevant SOD. A 100% valid central cue indicated the location of the SOD (SOAs:200,1000ms). Surprisingly, RTs were higher with an SOA of 1000ms (790ms) than with 200ms (720ms). Thus, making a sudden onset irrelevant greatly reduces its ability to capture attention, unless the very act of ignoring it inadvertently directs attention to it.

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D9 *409* Attention Effects on Motion Processing are Larger in the Left vs. the Right Visual Field

Jennifer A Feeney[1] (jfeeney@psy.ucsd.edu), Karen R Dobkins[1]; [1]UCSD Department of Psychology

Purpose: Results from previous studies indicate that the magnitude of attention effects depends on stimulus features/task (e.g., Lee et al, 1997; Morrone et al, 2002). Here, we used a full/poor attention paradigm to investigate attention effects on two different stimuli/tasks: direction of motion and orientation discrimination. Data were obtained for central (CVF), left (LVF) and right visual field (RVF) to see if attention effects vary across space. Methods: On the motion task, subjects reported direction of a moving dot field ("left" vs. "right"). On the orientation task, subjects reported the tilt of a 0.8 cpd contrast grating ("clockwise" vs. "counterclockwise"). Stimuli subtended 5 degrees, and RVF and LVF stimuli were centered 5 degrees eccentric to fixation. Thresholds were obtained in two conditions: 1) *Full Attention*: Subjects performed a *single-task*, reporting direction (or orientation), and 2) *Poor Attention*: Subjects performed a *dual-task*, first counting the number of closed shapes at the fixation point, then reporting stimulus direction (or orientation). Attention effects were calculated as Thr_{poor}/Thr_{full}. Results: For *orientation*, attention effects were constant across space (LVF=1.29, CVF=1.45, RVF=1.20). However, for *motion*, attention effects varied across space (LVF=1.74, CVF=1.41, RVF=1.07; p=0.002). The difference between the LVF and RVF was driven by lower thresholds in the LVF under full attention (1.2-fold, p=0.045), yet higher thresholds in the LVF under poor attention (1.3-fold, p=0.006). Conclusions: The different attention effects for RVF vs. LVF motion suggest that attentional resources *for motion* may be enhanced in the RVF (perhaps from learning to read left-to-right, see Rayner 1998).

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D10 *410* Exogenous reconfiguration of the input filter: when it happens and when it does not.

S. M. Shahab Ghorashi[1] (ghorashi@psych.ubc.ca), Lisa N. Jefferies[1], James T. Enns[1]; [1]University of British Columbia

When two targets (T1, T2) are inserted in a stream of distractors, accuracy in identifying T2 is impaired if the interval between T1 and T2 is short. Di Lollo et al., (2005) proposed that this T2-deficit, known as the attentional blink (AB), results from a temporary loss of control over the current attentional set. Specifically, when the system is processing T1, it is vulnerable to an exogenously-triggered switch in attentional set caused by the items following T1. This exogenous filter reconfiguration leaves the system poorly prepared for T2 (if the items do not match) or well prepared (if the items match), thereby influencing the magnitude of the T2-deficit. The present study tested the limits of this system configuration process. Observers were presented with targets from a set of numbers and letters (1,2,3,A,B,C). Because targets were of both types, observers could not prepare optimally to select items based on class membership; each had to be coded separately. We varied whether the targets matched in class (numbers vs. letters) and whether the items intervening the targets were numbers or letters. An AB deficit was observed in all conditions, with no effect of the similarity between intervening items and T2. This finding establishes a clear limit on the nature of the task for which an input filter can be set optimally, and on when the system is vulnerable to exogenous reconfiguration. Additional experiments examined the conditions under which optimal task filters can be prepared in the perception of targets in rapid visual streams.

D11 *411* Face Identification in the Near-Absence of Spatial Attention

Leila Reddy[1,2] (lreddy@klab.caltech.edu), Lavanya Reddy[1], Pietro Perona[1], Christof Koch[1]; [1]California Institute of Technology, [2]Massachusetts Institute of Technology

Subjects can detect animals and vehicles in images while spatial attention is engaged by another visual task. The same is true for the gender of a face. By contrast, simple geometrical shapes cannot be discriminated in the same regime. We investigated whether the identity of faces may be also perceivedin the near-absence of spatial attention.Our subjects were asked to identify faces of celebrities, as well as relatively unfamiliar individuals while their attention was/was not engaged by a letter discrimination task. We found that both familiar and unfamiliar face identification were minimally affected by the concurrent letter task. These results thus suggest that the visual system is well able to make complex judgments of natural stimuli, even when spatial attention is not fully available.

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D12 *412* Effects of visual attention on depth discrimination in the peripheral visual field

Kaori Segawa[1] (segawa@u.ip.titech.ac.jp), Daisuke Kobayashi[1], Keiji Uchikawa[1]; [1]Tokyo Institute of Technology

Precious studies revealed that visual attention affected detection and discrimination sensitivities of most visual functions. It has not been fully investigated, however, whether depth discrimination is affected by visual attention. In the present study we measured reduction in sensitivity of depth discrimination for the stimuli presented in the peripheral visual field while the observer was engaged in a central attention task. The stimulus consisted of double rings with four possible gaps each, presented in the central visual field for 1000ms, and two pairs of squares, presented in the right and the left visual field, respectively, at eccentricity of 5, 10, 20 or 30 deg in the periphery for 500ms. One of two pairs was the target with binocular disparity between two component squares and the other was the reference with no binocular disparity. The observer detected the gaps of the rings and, at the same time, responded which pair was the target in the double-task condition (DC). The observer simply detected the target with no central attention task in the single-task condition (SC). The results showed that depth discrimination threshold was significantly higher in the DC than those in the SC, which indicated that the visual attention strongly affects depth discrimination sensitivity. Moreover, it was shown that distance from the observer to the stimulus plane had no effect on the threshold, which means that the central attention area is determined by the visual angle.

D13 *413* Components of feature-based attention for object perception

Bobby Stojanoski[1] (stojanoski@utsc.utoronto.ca), Matthias Niemeier[1,2]; [1]University of Toronto at Scarborough, Toronto, [2]Centre for Vision Research, York University, Toronto

Mechanisms of feature-based attention underlie facilitated processing of the attended feature throughout the visual field. We have previously shown this holds with collinearity: we demonstrated that perception of collinear-defined loops was better when attending to other collinear-defined loops rather than attending to motion-defined loops. Our results could provide evidence for high-level feature-based attention. Alternatively, it is possible this advantage was simply due to a low-level effect of symmetry. That is, presenting collinear-defined loops together with other collinear-defined loops created a more symmetrical display than when presented together with motion-defined loops. Here we investigated symmetry as a factor in explaining the effect of feature-based attention. To disrupt symmetrical processing we presented S-shapes together with loops. The experiment used a dual task paradigm, that included two concurrent rapid serial presentation streams of scattered gabors appearing in the left and right visual hemifield. The primary task, indicated by a fixation arrow, presented two S-shapes that were either (a) collinear-defined or (b) motion-defined. Coinciding with one of the two S-shapes was the appearance of the secondary collinear-defined loop. Perceptual thresholds were determined in a two-alternative-forced-interval fashion by manipulating the amount of orientational/rotational noise of the gabors. The results replicated our initial experiment in that attending to collinear-defined objects

facilitated the perception of collinearity on the unattended side. These results suggest that symmetry cannot explain the observed effects of feature-based attention. Furthermore, what appears to be important is not the global structure of the object but a specific feature – the collinearity of the object's contour.

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D14 *414* Sub-threshold task-irrelevant signals disrupt task performance more severely than supra-threshold signals

Yoshiaki Tsushima[1] (tsushima@bu.edu), Takeo Watanabe[1]; [1]Department of Psychology, Boston University, Boston, MA, USA

Despite the common belief that stronger task-irrelevant signals more severely disrupt task performance, we previously found that task-irrelevant coherent motion just below the chance-level detection threshold (subliminal threshold) more severely disrupts a task performance than supra-threshold motion signals. One possible explanation for this paradoxical result is that eye movements induced by task-irrelevant translating coherent motion disrupts the task performance. In order to examine this possibility, 15 subjects were instructed to perform an RSVP (Rapid Serial Visual Presentation) task at the center of the display while ignoring the background motion that contained contracting, instead of translating, dots. The ratio of contracting dots to randomly moving dots (contraction coherence ratio) was varied from trial to trial. After this main experiment, the subliminal threshold of contraction (2AFC) was measured with the same subjects. The results showed that the RSVP task performance was significantly lower when the contraction coherency ratio was just below the subliminal threshold than when it was supra-threshold. Thus, the worse performance just below the threshold cannot be attributed to eye movements. This phenomenon is possibly explained as follows: The attention system usually suppresses irrelevant signals such as coherent motion to minimize their effect on task-performance. However, the attention system fails to detect and, therefore, to suppress irrelevant signals whose strength is below the subliminal threshold. This allows the subliminal irrelevant signals to disrupt the task performance more severely than supraliminal irrelevant signals that are suppressed by the attention system.

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D15 *415* Measuring the cost of deploying top-down visual attention

Dirk Walther[1] (walther@klab.caltech.edu), Li Fei-Fei[2], Christof Koch[1]; [1]Computation and Neural Systems Program, 216-76 California Institute of Technology, Pasadena, CA, 91125, USA, [2]Department of Electrical and Computer Engineering and Beckman Institute for Advanced Science and Technology, University of Illinois Urbana-Champaign, Urbana, IL, 61801, USA

In many everyday situations, we bias our perception using task-dependent information. To explore the cost involved in shifting top-down attention to a new task, we adopted a task-switching paradigm, in which 'switch' and 'repeat' trials in mixed task blocks are contrasted with single task blocks. We use two visual tasks in our paradigm: object detection in cluttered gray-level natural scenes ('animal' vs. 'non-animal' and 'vehicle' vs. 'non-vehicle'); and discriminating the color of the frame enclosing these images ('orange' vs. 'purple' or 'blue', and 'blue' vs. 'orange' or 'purple'). We distinguished switch costs with (e.g. switching from detecting orange among purple/blue distracters to detecting animals in natural scenes) and without top-down attention shifts. We found significant switch costs in reaction time of 20ms for switching from a color task to an object detection task ($p<0.05$), and of 28ms for switching from an object detection task to a color task ($p<0.0001$). There are no significant switch costs for switches within a stimulus attribute, when no top-down attention shift is required. We conclude that deploying top-down attention to a different attribute incurs a significant cost in reaction time, but that biasing to a different feature value within the same stimulus attribute does not. ANOVAs of mixing and switch cost show significant ($p<10^{-8}$) differences among individual subjects for mixing cost, but no such effect for switch cost: shifting top-down attention has a fixed processing duration among individuals.

D16 *416* Object substitution masking on the fly

Takako Yoshida[1] (tyoshida@wjh.harvard.edu), Patrick Cavanagh[1]; [1]Harvard University

We tested the relative contributions of local interactions and position-independent analyses to object substitution masking by embedded the target and mask in an attentive tracking task. Six discs were presented circling the central fixation at a constant radius and speed; one disc was identified as the target to be tracked. Tracking continued for an average of 2 seconds and on 10% of trials, tracking accuracy was evaluated with a probe display. The remaining trials ended with a masking display. All the discs changed briefly to Landolt C and one of them was surrounded by four small dots. All items remained in motion during the masking phase. The dots indicated which item to report and also served as the mask of the probed item. To assess mask integration time, a blank ISI of variable duration (0 to 450 ms) was inserted between the initial 80-120 ms (varied across subjects) phase when both the mask and target were presented together and the 80 ms trailing phase when only the mask was present. Classic object substitution masking was seen at the short ISIs and neither the masking nor integration time was affected by the rotation speed during the masking phase (although a static presentation prior to the test generated an afterimage that degraded performance). Our results suggested that object-based, position independent masking was more important than any local interactions.

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Object Recognition I

D17 *417* View Sensitivity of Object Representations in Human Object-Selective Visual Cortex

David R Andresen[1] (andr0196@psych.stanford.edu), Kalanit O Grill-Spector[2]; [1]Department of Psychology, Stanford University

Humans can recognize familiar objects from almost any viewpoint. However, the neural representations underlying view-invariant recognition are not well understood. We conducted three fMRI experiments with 6 subjects to investigate the sensitivity of object-selective cortex to changes in object viewpoint. In Experiment 1, we examined whether all views of objects are represented equivalently, or whether different views elicit differential responses. For this experiment, blocks of animal and vehicle line drawings were shown in 15° (front), 75°, 135°, and 195° (rear) views. In Experiment 2 we used an immediate fMRI-adaptation paradigm, and in Experiment 3 we used a long-lagged fMRI-adaptation paradigm to characterize the sensitivity of neural populations to parametric changes in viewpoint. Subjects were adapted with either 15° or 195° views of vehicles and animals. Sensitivity to viewpoint was measured as the degree of recovery from adaptation after 0°, 60°, 90°, 120°, or 180° rotations in depth. Experiment 1 revealed that 15° views elicited a higher response than 195° views for animals, but not vehicles. Similarly, Experiments 2 and 3 revealed that fMR-adaptation effects differed with adapting view for animals, but not vehicles. These results suggest that different proportions of neurons are allocated to represent different views of animals. In addition, posterior regions in the lateral-occipital complex (LOC) recovered completely after small rotations, while anterior regions along the fusiform gyrus recovered more gradually with increasing rotation. Taken together, these results indicate that objects are represented by mixtures of view-dependent neural subpopulations within a hierarchy of increasingly view-invariant object representations.

D18 *418* A stereo advantage in generalizing over changes in viewpoint on object recognition tasks.

David J Bennett[1] (David_Bennett@Brown.edu), Quoc C Vuong[2]; [1]Department of Cognitive and Linguistic Sciences, Brown University, [2]Max Planck Institute for Biological Cybernetics

In three experiments, Bennett (VSS, 2003) found a stereo advantage in generalizing to unfamiliar views in a sequential matching task in which viewers matched the identity of shaded tube-like objects. We extended these results in an experiment in which subjects identified rotating wire-frame objects at the individual level under stereo and nonstereo viewing conditions; the new experiment tapped longer term memory representations, and provided subjects with multiple views of the training and test objects. During training these objects were presented from a particular view. After training, we tested subjects' ability to recognize the learned targets presented from familiar and unfamiliar views, where training and testing were conducted under either stereo or nonstereo viewing conditions. Though performance was view dependent under both stereo and nonstereo viewing (as in Bennett, VSS, 2003), subjects generalized better to unfamiliar orientations under stereo viewing. Taken together with Bennett (VSS, 2003), these results strongly argue against strictly 2D image-based models of object recognition, at least for the stimuli and recognition tasks used, and they suggest that observers used representations that contained view-specific local depth information.

D19 *419* Role of familiar object motion in recognising objects across viewpoints

Lewis Chuang[1] (lewis.chuang@tuebingen.mpg.de), Quoc Vuong[1], Ian M. Thornton[2], Heinrich H. Buelthoff[1]; [1]Max Planck Institute for Biological Cybernetics, Tuebingen, [2]Department of Psychology, University of Wales Swansea

Unfamiliar viewpoints can hinder visual object recognition from 2D static images. Here, we ask whether the same is true when visual input is in the form of dynamic spatio-temporal sequences, such as would accompany object or observer motion. Previous research has shown that such motion can be characteristic for a particular object and hence provide additional cues to identity. In two experiments we demonstrate that learned object motion can facilitate recognition across unfamiliar viewpoints. In each experiment, 24 participants were trained to discriminate between two novel amoeboid-like objects seen from a fixed viewpoint. These objects either deformed nonrigidly (Experiment 1) or rotated rigidly about a horizontal axis (Experiment 2). Both types of motion presented the observer with a coherent sequence of change that had a unique temporal order. After training, participants underwent a 2-interval-forced-choice task that tested their ability to discriminate the two learned objects from two novel objects. At test, objects were presented at 0°, 10°, 20° and 30° around the vertical axis relative to the learned viewpoint, and in the learned or reversed temporal order. The manipulation of temporal order has previously been used to study the contribution of motion to object recognition. In both experiments, accuracy decreased with increasing rotations away from the learned viewpoint and there was a constant benefit for learned object motion across all viewpoints tested (Experiment 1 = 4.9%; Experiment 2 = 5.3%). These results indicate that both rigid and non-rigid motion facilitated object recognition despite disturbances in 2D shape by viewpoint changes.

D20 *420* View-Invariant Object Category Learning: How Spatial and Object Attention are Coordinated using Surface-Based Attentional Shrouds

Arash Fazl[1] (arash@cns.bu.edu), Stephen Grossberg[1], Ennio Mingolla[1]; [1]Department of Cognitive and Neural Systems, Boston University

When learning a view-invariant object category, the brain does not incorrectly bind views of all the objects that the eyes scan in a scene. The ARTSCAN model predicts how spatial and object attention in the What and Where streams cooperate to selectively learn multiple views of an attended object. The model predicts that spatial attention employs an "attentional shroud" that is derived from an object's surface representation (Tyler & Kontsevich, 1995). This shroud persists during active scanning of the object. The Where stream shroud modulates view-invariant object category learning in the What stream. Surface representations compete for spatial attention to select winning shrouds. When the eyes move off an object, its shroud collapses, releasing a reset signal that stops learning of the object category in the What stream, before a new shroud forms in the Where stream and a new object category is selected. The new shroud enables multiple view categories corresponding to the shroud to be bound together in a new object category, while top-down expectations that realize object attention within the What stream stabilize object category learning. The model learns with 96% accuracy on a letter database. The model simulates reaction times in data about object-based attention: RTs are faster when responding to the non-cued end of an attended object compared to a location outside the object, and slower engagement of attention to a new object occurs if attention has to get disengaged from another object first (Brown et al., 2005).

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D21 *421* Spatial Updating during Locomotion does not Eliminate Viewpoint-Dependent Visual Object Processing

Weimin Mou[1] (mouw@psych.ac.cn), William G Hayward[2], Mintao Zhao[1], Guomei Zhou[1,2], Charles B Owen[3]; [1]Institute of Psychology, Chinese Academy of Sciences, [2]Department of Psychology, University of Hong Kong, [3]Department of Computer Science and Engineering, Michigan State University

Two experiments were conducted to investigate whether spatial updating during locomotion would eliminate viewpoint costs in visual object processing. Participants performed a sequential matching task for object identity or object handedness, using novel 3D objects displayed in a head-mounted display. To change the observed viewpoint of the object, both the orientation of the object in 3D space and the spatial position of the observer were manipulated independently. Participants were more accurate when the test view was the same as the learned view than when the views were different no matter whether the viewpoint change of the object was 50° or 90°. With 50° rotations, participants were more accurate when the test view was the same as the expected view (due to their own locomotion) than the two views were different, but performances were not different between expected and unexpected views when viewpoint change was 90°. These results indicate that spatial updating during locomotion occurs within a limited range of viewpoint differences, but that spatial updating did not eliminate the viewpoint costs in visual object processing.

D22 *422* Recognizing orientation of depth-rotated familiar objects

Ryosuke Niimi[1] (niimi@L.u-tokyo.ac.jp), Kazuhiko Yokosawa[1]; [1]The University of Tokyo

Familiar objects can be seen in various orientations depending on viewpoints. Visual recognition of object orientation seems important for numbers of cognitive tasks including object recognition. Visual representation of object is either viewpoint-invariant or viewpoint-dependent, yet object orientation will not be coded in viewpoint-invariant representations. Then we hypothesized that visual recognition of object orientation is influenced by viewpoints. Subjects detected differences of object orientation between simultaneously presented two pictures of identical familiar objects (Experiment 1). The performances were best at 0 and 180 degrees (i.e. the front and back views). 90 degrees (side view) yielded better performance than other oblique orientations, yet further analysis suggested it was due to local visual features such as orientation of linear object contours. Experiment 2, in which two pictures of different objects were presented, again produced best performances at 0 and 180 degrees, although the error rate increased overall. These results showed that recognition of object orientation is highly viewpoint-dependent. We assumed three determinants of the phenomenon: (a) Since front and back views are accidental, they pro-

vide highly viewpoint-specific representation and precise coding of object orientation. (b) Since the stimulus objects were bilaterally symmetric, the front and back views had symmetric contours and others had not. A presence-absence judgment of 2D symmetry could contribute to the high sensitivity in those views, although the subjects reported no introspection about symmetry. (c) Orientation of linear contours, especially in the side view.

D23 *423* **Learning about objects in motion: Better generalization and sensitivity through temporal association.**

Benjamin Balas[1] (bjbalas@mit.edu), Pawan Sinha[1]; [1]MIT, Department of Brain and Cognitive Sciences

When learning to recognize a new object, the visual system must learn to bind together disparate images of that object. Temporal association is a candidate mechanism for achieving this binding. By linking images that are close in time, invariance to observed appearance transformations can be achieved. This hypothesis has derived psychophysical support from studies showing that frames in a motion sequence can be perceptually bound in such a way as to lead to predictable errors in subsequent recognition performance; temporal neighbors are found to be harder to discriminate, even if they come from two different objects.Here, we demonstrate two distinct effects of temporal association using non-rigid objects. First, in contrast to predictions from previous work, we demonstrate that shape discrimination between images actually improves following temporal association. Second, we measure the extent of image binding over time. Our experimental procedure dispenses with explicit recognition judgments (since these are susceptible to cognitive interference) and instead uses a priming task as an implicit measure of generalization. We find that frames within short temporal windows eventually serve as equally effective priming cues, indicating a linkage of their representations. Taken together, these results suggest that temporal association can simultaneously yield improved discriminability between, as well as an implicit linkage across, frames of a sequence. We demonstrate that this pattern of results can arise from a model of object representation in which temporal association leads to coarse coding across a population of object units.

D24 *424* **Does Contrast Reversal Affect the Recognition of Common Objects?**

Jessie J. Peissig[1] (jessie_peissig@brown.edu), Quoc C. Vuong[2], Jean M. Vettel[1], Michael J. Tarr[1]; [1]Brown University, [2]Max Planck Institute for Biological Cybernetics

Previous research has shown that faces are difficult to recognize when viewed in reverse contrast (Galper, 1970). In a prior study, we demonstrated that this effect can be found with a set of novel objects (Greebles; Vuong et al. 2005), and that the effect was significantly greater for both faces and novel objects with pigment as opposed to those without pigment. This suggests that surface properties are integral in the representation of both faces and objects. However, it is an open question as to whether surface properties play the same role in the recognition of common objects which are not face-like. In addition, objects and faces shown in normal contrast are on average higher in luminance than those shown in reverse contrast. Here, we normalized all images to be equiluminant to eliminate this possible confound. We tested observers in a same/different sequential-matching task using gray scale images of common objects (cars and birds) as well as faces. Replicating prior results, faces were significantly more difficult to recognize when shown in reverse contrast. Importantly, we also found a contrast effect for the common objects; this effect was the same magnitude as the face contrast effect. These results indicate that performance costs associated with contrast reversal are not due to overall luminance differences between normal and reverse contrast images. Additionally, these data suggest that surfaces properties play a similar role in the recognition of all object types, not just those that are biological or face-like.

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D25 *425* **Predicting psychophysical similarity of complex shapes from measures of physical similarity.**

Marissa Nederhouser[1] (mneder@usc.edu), Xiaomin Yue[1], Irving Biederman[1]; [1]University of Southern California, Psychology Department

Subjects performed a match-to-sample task in which they judged which of two comparison stimuli, presented briefly, was identical to the sample. The stimuli were unfamiliar, smooth, asymmetric, complex 3D blobs produced by varying the orientations of the second and third harmonics of a sphere and then adding these orientations to the sphere and fourth harmonic. The (dis)similarity between the matching and distracting blobs was assessed by four measures: a) subjective pair-wise ratings made by human subjects, b) Euclidean distances in a 2D stimulus space defined by the differences in the angles of rotation of the orientation-varying harmonics, c) mean pixel luminance energy differences between pairs of images, and d) the von der Malsburg's Gabor-jet model (Lades, et al., 1993), designed to model aspects of V1 simple-cell filtering. The last is based on a wavelet-like filtering of the image by a lattice of Gabor jets, each composed of kernels over multiple scales and orientations. Similarity in the model is a function of the correlation of the activation values between corresponding kernels in corresponding jets. All four measures correlated negatively with error rates on the match-to-sample trials: Euclidean distance = -.804, judged similarity =-.846, pixel energy= -.891, and Gabor jet = -.940. In the absence of salient nonaccidental differences (e.g., differences in parts or whether contours are straight vs. curved), a model based on V1 computations does remarkably well in scaling the psychophysical similarity of complex, novel shapes.

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URL: http://geon.usc.edu

D26 *426* **What image measures are best correlated with the discriminability of 3D objects?**

James C Christensen[1] (christensen.68@osu.edu), James T Todd[1]; [1]The Ohio State University

A sequential shape matching task was performed to measure the relative discriminability of 3D objects. Each trial began with a brief presentation of a "sample" object, followed by a pattern mask, and the image of a "test" object with the same or different orientation in depth. Observers indicated whether or not the two depicted objects had the same shape by pressing an appropriate response key. For each standard object, eight possible shape differences were created by altering the relative length, curvature or orientation of its component parts. Half of these shape changes involved metric properties of the objects, whereas the remaining changes involved properties that are viewpoint invariant. Several different measures were used to calculate the similarity between each pair of images. These included Euclidean distances defined with respect to pixel intensity values or the outputs of Gabor filters at multiple scales and orientations. These low level measures were poor predictors of human discrimination, accounting for only 39% of the variance among different object pairs. Image similarity was also measured by the relative magnitude of the parameter change that had been used to produce each of the depicted shape differences. This latter measure was a much better predictor of human performance, accounting for over 78% of the variance. Viewpoint invariant changes were easier to detect than metric changes when the sample and test objects were presented at different orientations in depth, but both types of change were equally detectable when the objects were presented at the same orientation.

D27 *427* **Attneave's Cat revisited: Points of high curvature are not important for shape recognition**

Noah Z Schwartz[1] (nschwart@usc.edu); [1]University of Southern California, Dept of Psychology

The importance of curvature in visual shape recognition has long been a

subject of debate beginning with Attneave's seminal argument that points of maximal curvature are most useful for recognizing shapes (1954). More recently, this result has been both replicated by Norman et al (2001) and challenged by Kennedy and Domander (1985), the latter group claiming that recognition is well served by points of minimal curvature, and still better served by points located between areas of maximal and minimal curvature. The question of curvature in recognition was reevaluated in the current study where subjects were asked to identify a series of shapes displayed as a random presentation of dots placed along what would have been the boundary contour of the shape. Reverse correlation was used to identify the set of points that appeared most frequently during successful trials and also those points that appeared most frequently during unsuccessful trials. In terms of measured curvature, "successful points" identified in this manner did not differ significantly from "unsuccessful points." In an attempt to confirm the relative importance of each set of points, a second experiment was conducted in which naive subjects who were shown successful points and asked to identify the shape significantly outperformed naive subjects who were shown unsuccessful points. While these data suggest that successful object recognition does not rely exclusively on points of high curvature, it may still be the case that information distributed within regions of high curvature are critical for visual shape processing.

D28 *428* Curvature is encoded stronger than it is perceived

Promise McEntire[1] (pmcentir@usc.edu), Noah Z Schwartz[1]; [1]University of Southern California, Dept of Psychology

Attneave (1954) demonstrated that points of high curvature were most important for object recognition. While this conclusion has become the basis for much of modern computer vision theory, it is not consistent with psychophysical data showing that curvature, being a metric property, is not reliably perceived across viewpoints (Biederman and Bar, 1999). Having low viewpoint stability, one would not expect curvature to be a key component of a process as robust as object recognition. This weakness was further demonstrated by Foster and Gilson (2002) who, using a wire-shape discrimination task, found that changes in curvature were less discriminable than changes in the number of segments and as discriminable as segment length and angle of segment intersection (AOI). Assuming features are encoded with strength proportional to discriminability, the number of errors in a feature-dependent recall task should be inversely proportional to discriminability. This was tested using a delayed match-to-sample task in which subjects were presented with four alternatives that each differed from the target in one of the dimensions described above. Because there was no correct response, subject errors were interpreted as a reflection of the relative strength of feature encoding. Across feature contrast levels, the most errors occurred for AOI followed by length, curvature and segment number. That the relative accuracy of curvature recall is higher than curvature discriminability suggests that while human observers may not be very good at discriminating differences of curvature, information about curvature is encoded more strongly in subject memory than other features of similar discriminability.

D29 *429* Effects of right parietal TMS on object recognition

Irina M Harris[1] (irina@psych.usyd.edu.au), Carlo Miniussi[2,3]; [1]School of Psychology, University of Sydney, Australia, [2]Department of Biomedical Sciences and Biotechnology, University of Brescia, Italy, [3]Cognitive Neuroscience Unit, IRCCS Centro San Giovanni di Dio - FBF, Brescia, Italy

Patients with lesions to the right parietal lobe often have difficulty recognising unusual or rotated views of objects, while showing intact recognition of canonical views (Warrington & Taylor, 1973). It is not clear whether this represents a pure problem of object identification or whether it is related to impairments in spatial processing which indirectly impinge on the recognition process. In an attempt to answer this question, we delivered transcranial magnetic stimulation (TMS) to the right parietal region while subjects performed a picture-word verification task involving upright and rotated objects. In each trial, subjects viewed a briefly presented (80ms) photograph of a common object, sandwiched between 100ms pattern masks and followed 1s later by a word presented for 500ms. The object could be either in its normal upright orientation, or rotated by 120° in the frontal plane. The subjects had to decide as quickly as possible whether the word named the object or not. A train of 5 TMS pulses was delivered with a frequency of 12Hz to the right posterior parietal lobe, or to a control midline parietal site, starting 120ms after the onset of the object. TMS to the right parietal lobe improved overall recognition accuracy and sped up reaction times for rotated objects. These results confirm a role for the right parietal lobe in processing rotated objects, although they are more consistent with the idea that this brain region is involved in interpreting the spatial attributes of objects rather than playing a critical role in object identification per se.

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Perceptual Organization: Contours

D30 *430* The effects of task switching on age-related differences in shape perception

Eric D. Richards[1] (erichar@mcmaster.ca), Patrick J. Bennett[1,2], Allison B. Sekuler[1,2]; [1]McMaster University, Psychology Department, 1280 Main St. West, Hamilton, ON, Canada, L8S 4K1, [2]York University, Centre for Vision Research, Toronto, ON, Canada

Object and shape perception are important components of vision. However, little is known about how shape perception changes with age. Here, we examined whether aging affects global shape perception: Older and younger observers viewed complete rectangles or line fragments of rectangles (with or without occluders), and judged whether the overall shape was "tall" or "fat". The aspect ratio of these stimuli was manipulated, and a staircase procedure determined observers' thresholds in each condition at varying stimulus durations. Such a task enables us to compare the relative effects of age and duration under stimulus conditions in which all sensory information is provided (complete), partial information is provided (fragmented), or when partial information leads to integration processes (occluded). Age differences in shape discrimination were found when observers had to switch from one stimulus condition to another every 30 seconds, with older observers requiring larger aspect ratios than younger observers to perform the task. No age differences were found when observers switched less frequently across stimulus conditions. Regardless of switching condition, older observers were not differentially impaired by partial contour information, and both age groups showed similar patterns of performance across stimulus conditions and durations. These results suggest that aging may impact negatively on shape perception, but only under conditions of stimulus or task switching. Such a result fits well with the idea that the true extent of age-related deficits are more likely to be seen under conditions that challenge the visual system (e.g., in divided-attention or task-switching conditions).

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D31 *431* Development of 3D object completion in infancy

Scott P. Johnson[1] (scott.johnson@nyu.edu), Kasey C. Soska[1,2]; [1]Department of Psychology, New York University

As adults we know that a 3D object seen from one viewpoint is likely to have surfaces on its far side occluded by the visible portions of that object. Do infants, likewise, represent objects seen from a limited perspective as coherent volumes, or instead as consisting solely of the surfaces that are visible from the current viewpoint? We investigated age differences in 3D object completion by presenting infants with a computer-generated 3D wedge that rotated back and forth through 15 deg, providing opportunity to see only two faces of the object. Two displays were then shown in alter-

nation, both rotating through 360 deg. One display depicted a complete, solid wedge, and the other depicted an incomplete, hollow wedge composed of only two sides. We reasoned that consistently longer looking at one test display would reflect a novelty preference.We tested 20 infants in two age groups (M age = 114.6 days and 234.6 days). There were no reliable preferences for either test display by younger infants. Older infants looked longer at the incomplete object in the first test trial pair, $p < .05$; there were no reliable preferences in the other two trial pairs.Older infants, therefore, may represent objects as complete in 3D space despite having only a limited perspective. One possible developmental mechanism is rooted in manual exploration of objects afforded by upright sitting—which arises between four and six months.

D32 *432* Six-Month-Old Infants' Ability to Detect Contours

Thomas J. Baker[1] (tjb229@yorku.ca), James Tse[2], Peter C. Gerhardstein[2], Scott A. Adler[1]; [1]Department of Psychology and the Centre for Vision Research, York University, [2]Department of Psychology, Binghamton University

PURPOSE: Children's ability to perform contour integration of individual elements in the presence of stimulus noise develops slowly (Káldy & Kovács, 2003; Kovács, 2000). A recent study with 3-month-old infants has demonstrated a stark immaturity in their contour integration mechanisms (Gerhardstein, Kovacs, Ditre, & Feher, 2004). The goal of this study was to further investigate the developmental trend in infants' ability to integrate individual elements into whole contours. METHOD: Six-month-olds' discrimination of differently shaped contours was tested via a cueing paradigm in which a circle or square contour defined by the alignment of oriented Gabor patches, presented centrally and embedded in a background noise of randomly oriented Gabor patches, cued the subsequent presentation of a target on either the right or left. The relation of background noise spacing over contours spacing was set to 1.0 and 0.9. Eye movements were analyzed for correct anticipatory eye movements to the targets in response to which contour cue had been presented. RESULTS: All results were compared to random performance (no discrimination of contour cues) of 50% correct. Infants correctly anticipated for circles 70.8% and correctly for squares 69.5% in the 1.0 condition. For the 0.9 condition, infants correctly anticipated only 39.8% for circles and 60.1% for squares. CONCLUSIONS: These results indicate that infants are able to discriminate between circle and square contours better than chance in the 1.0 condition, but not for the 0.9 condition. These data suggest that 6-month-old infants' contour integration ability is not much different from that of 3-month-olds'.

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D33 *433* Contour Detection in Young Human Infants

James Tse[1] (jtse@binghamton.edu), Peter Gerhardstein[1]; [1]Binghamton University-SUNY

Less than a handful of studies have explored contour detection during early infancy. The theoretical relevance of investigating contour detection in young human infants lies in the finding that the development of long-range projections characteristic of the V1 begin to emerge around 4 months. These projections are believed to be the physiological implementation of the 'good continuation' or colinearity contour grouping rule. One prediction is that young infants' ability to spatially integrate orientation elements into contours should be limited, and this limitation cannot be explained solely by improvements in visual acuity. The present study assessed contour detection in 4- and 8-month-old infants using an eye tracker. Infants observed images consisting of pseudo-randomly oriented and positioned Gabor elements. A circle, defined by the alignment of 12 elements, was present in half of these images. Noise density also varied across images. Observers could use proximity cues in addition to good continuation to detect the circle at the lower noise levels. Only good continuation, however, would enable observers to detect the circle at the higher noise levels. The dependent measure was a difference score: fixation time on the circle minus fixation time on the corresponding region in the noise (i.e., circle-absent) stimuli. Four-month-olds fixated more on the circle only at lowest noise density. Eight-month-olds showed more fixations on the circle even at the higher density levels. Overall, the findings support the notion that grouping by good continuation is present, but limited, in young human infants.

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D34 *434* Element grouping with parabolic contours.

James L. Dannemiller[1] (dannemil@rice.edu), Melanie A. Lunsford[1]; [1]Rice University

Humans are remarkably good at detecting contours even when there are contour breaks and uncertainty regarding the global orientation of the contour (Geisler et al., 2001). We used a parabolic contour that comprised 13 oriented segments, each 0.2 deg in length separated by a center-to-center distance of 0.4 deg to examine the accuracy of contour detection when the contour shape was constant, but its orientation was uncertain on each trial. Orientation jitter was added to the contour elements in the range from +/- 25 deg, and these elements were embedded in a 7.7 deg field of 364 distractor elements with precisely the same orientations on each trial as those that comprised the orientation-jittered contour. Thus, we ensured that the distribution of distractor orientations was exactly uniform and identical on each trial to the distribution of the noise-jittered contour elements. The contour appeared randomly in one of four orientations for 167 ms with its apex offset from the center of the field. Across three observers (5120, 5120 and 2560 trials), we observed percentages of correct judgments of 92%, 86% and 87%. Based on the stimulus parameters in Geisler et al. most closely matching our stimulus (e.g., orientation jitter, contour smoothness and curvature), our high accuracy rates suggest that observers may be able to use the known shape of a contour to facilitate its detection in noise. This could imply additionally that grouping of elements in noise can be influenced by top-down information.

435 Abstract 435 moved to poster H66.

D35 *436* Real line masks “close the gap” in abutting line type illusory contour processing

Barbara Dillenburger[1] (barbara.dillenburger@vanderbilt.edu), Christian Wehrhahn[2]; [1]Dept. of Psychology, Vanderbilt University, TN, [2]MPI for Biological Cybernetics, Germany

Contextually induced illusory contours (ICs) allow us to perceive objects that are partly occluded or invisible due to poor contrast. Real contours (RCs) can not only induce, but also mask ICs. These interactions possibly reside in areas V1 and V2. How can RCs interfere with IC processing? Masking of abutting line IC induction by real lines might be either due to metacontrast masking of the inducing RCs or to inhibition of endstopped cells hypothetized to induce abutting line ICs.We tested this by measuring orientation discrimination thresholds of abutting line type ICs in a backward masking paradigm. Masking line patterns (continuous “RCmask”, or abutting “ICmask”) were oriented parallel or at angles -45, 45, or 90deg to the inducing line pattern.Masking effects depend on the processes mediating masking. If metacontrast masking interferes with inducing RCs, both RCmask and ICmask should interfere. If, however, inhibition of endstopped cells mediates interference with the IC, ICmasks should interfere less than Rcmasks.We found that ICmasks oriented different to the inducers interfered stronger than corresponding RCmasks, indicating metacontrast masking of ICs. ICmasks parallel to the inducers, however, showed decreased masking in comparison to RCmasks. Our data show, first, the masking of an IC by another parallel IC comparable to RC metacontrast masking. Second, these results suggest that RCmasks parallel to the inducers inhibit endstopped cells, thus “close the gap”, rather than metacontrast mask inducing lines. This is consistent with the hypothesis that endstopped cells induce abutting line type ICs.

D36 *437* A novel dynamically induced 'pure illusory contour'

Lillian Gu[1] (barbara.dillenburger@vanderbilt.edu), Barbara Dillenburger[1], Anna W. Roe[1]; [1]Dept. of Psychology, Vanderbilt University, TN

Classical illusory contours (ICs) are physically and perceptually complex. Kanizsa-stimuli induce both contour and surface percepts. In abutting line stimuli line-ends spatially overlap with the IC. Thus, both result in mixed activation of different inducing and induced processes. Here, we present a new stimulus which we term a 'pure IC'.Our stimulus consists of a series of five 50 msec frames. Each frame consists of six oblique inducers (randomized length and position) in two vertically separated sections (3 lines/section). This induces a pure IC in the gap (gapIC) between the two dynamic abutting line sections (see http://www.psy.vanderbilt.edu/faculty/roeaw/pureIC).We measured the gapIC's perceptual strength by subjective rating and by 2AFC orientation discrimination experiments. For 2AFC, subjects discriminate the gapIC's tilt induced by horizontally offset sections. We find discrimination thresholds are consistent with subjective gapIC strength ratings and are modulated by inducer contrast and gap length. We also observe an inverse Tilt effect in which the gapIC appears tilted in the same direction as the inducing lines. This is opposite to the classical Tilt effect which would be expected if the IC were directly induced by the abutting lines. This further supports the independence of the gapIC from the physical inducers. In sum, our stimulus, which is free of inducer line ends and surface percepts, leads to a strong IC-induction, and permits spatial separation of inducing and induced processes. Randomized presentation can also be used for reverse correlation, making this low contrast, dynamic stimulus useful for physiological studies of IC processing.

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URL: http://www.psy.vanderbilt.edu/faculty/roeaw/pureIC

D37 *438* Illusory contours formed by temporal interocular unmatched features

Rui Ni[1] (ruini@ucr.edu), Lin Chen[2], George J. Andersen[1]; [1]University of California, Riverside, CA, USA, [2]The Key Laboratory of Cognitive Science, Graduate School and Institute of Biophysics, Chinese Academy of Sciences, Beijing, China

Previous studies suggest that interocular unmatched features in stationary displays generated the perception of illusory contours under real-world constraints. In addition, interocular unmatched information formed in time could help to reveal depth order. The present study investigated whether the visual system could, basing on temporal interocular unmatched information, segregate the homogeneous occluding surface from the background, which in turn generated illusory contours. A Crystal Eyes Workstation was used to produce the stereo images on a Dell P1110 CRT monitor, 140Hz in refresh rate and 1024*768 in resolution. In the experimental displays, 3 white dots, each extending 9.1 min arc and being 1.67 degrees away from each other vertically, translated horizontally at the same speed of 2.2 degrees/sec for both monocular images within a range of 8 degrees. The only difference between the stimuli images in two eyes was that the dots disappeared first in one eye and then disappeared after a brief period of 70ms in the other eye. The subjects were asked to judge the orientation of the perceived illusory contours. The lifetime of the dots was manipulated in such a way that the apparent orientation of the illusory contours could be 15, 0, or -15 degrees. The orientation of the three aligned dots in each monocular image was 15, 0, or -15 degrees as well. The results showed that visual system could process the interocular unmatched information not only in space but also in time to generate the perception of illusory contours.

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D38 *439* Spatiotemporal contour interpolation and shape discrimination

Hideyuki Unuma[1] (hide.unuma@kgwu.ac.jp), Hisa Hasegawa[2], Philip J. Kellman[3]; [1]Kawamura Gakuen Women's University, [2]Aoyama Gakuin University, [3]University of California, Los Angeles

The world and our representations of it contain coherent objects and continuous surfaces. While, the input from the world to our eyes is spatially and temporally fragmentary. How do visual processes overcome this fragmentation to achieve accurate object perception? Shipley & Kellman (1994) found that limited temporal window governed the boundary formation process. Unuma & Hasegawa (2002) also studied the role of visual buffer in the spatiotemporal contour interpolation. While, Ringach & Shapley (1996) investigated spatial and temporal properties of illusory contour perception.We hypothesized that illusory contour interpolation between spatially and temporally fragmental elements could occur in a particular temporal span suggested in the previous studies. Specifically, we conjectured that if elements are integrated and produce a shape in the hypothesized temporal range, the performance of shape discrimination task should be better than those with fragmental elements. The method of constant stimuli was used. We measured the psychometric functions for the discrimination of the shape as a function of presentation cycle of inducing figures.Results show that discrimination of illusory contour shape was enhanced in the hypothesized temporal span. The threshold for illusory shape discrimination was compared to those in the control condition for local edge orientation discrimination, and the threshold for illusory contour was significantly lower than those for the edge orientation. These results support the notion that visual edges can be interpolated in the limited temporal span. Moreover, these suggest that contour interpolation in spatiotemporal domain could be used to improve shape discrimination performance greatly.

URL: http://www.kgwu.ac.jp/sinri/unuma/index.htm

D39 *440* Surface interpolation and slant anisotropy

James D. Hilger[1] (jdhilger@ucla.edu), Carlo Fantoni[2], Walter Gerbino[2], Philip J. Kellman[1]; [1]University of California, Los Angeles, CA USA, [2]University of Trieste, Trieste, Italy

Although the role of surface-level processes has been demonstrated, models of visual interpolation emphasize contour relationships. We report research on geometric constraints governing 3D interpolation between surface patches having no visible contours. In a previous study, we demonstrated that 3D relatability acts as a cue for spatial unification in the absence of explicit edge information. Observers were asked to classify pairs of planar surface patches -- specified by random dot disparities and visible through circular apertures in a fronto-parallel occluder -- as aligned or misaligned. On each trial, surfaces appeared in parallel or intersecting planes with equal amounts of absolute slant around the horizontal axis. We expected this task to be facilitated when patches were perceived as connected. We found enhanced sensitivity and speed for 3D relatable patches -- those joinable by a smooth, monotonic connection -- versus non-relatable patches. Here 3D relatability involves not oriented edges, but surface patch orientations computed from stereoscopic information. In a second experiment surfaces were inclined around a vertical, rather than horizontal, axis. Performance was markedly affected by slant anisotropy: both sensitivity and speed were worse for surfaces inclined around the vertical. We found nearly identical advantages of 3D relatability on performance, suggesting more isotropic unit formation effects. Results are interpreted as suggesting that, in the absence of explicit edge information, virtual lines -- as extracted on the basis of orientation disparity of surface elements -- constrain surface interpolation. The results suggest that 3D contour and surface interpolation may share common geometric constraints.

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D40 *441* Classification images reveal interpolation in dynamic displays

Brian P. Keane[1] (keane@ucla.edu), Philip J. Kellman[1]; [1]University of California, Los Angeles

Gold and colleagues (2000) employed a classification image (CI) technique to show that interpolated regions between inducers influence how observers discriminate ?fat? and ?thin? Kanisza squares. Here, we extend the technique to explore contour interpolation in dynamic illusory figures. In Experiment 1, two subjects (one naive) observed black disks translating left to right on a gray background behind the top and bottom corners of an (otherwise invisible) gray stationary figure. Interpolation was necessarily spatiotemporal in that inducing events at each corner occurred at different times. The observers' task in three conditions was to discriminate i) pairs of rectangles with real contours, ii) Kanisza (illusory) rectangles, or iii) fragmented figures (designed to produce no interpolation). Convolution and quantization techniques (Ahumada & Beard, 1998) showed that a) subjects were sensitive to regions between the inducers in the illusory (interpolation) condition but not in the fragmented control condition; and b) the illusory and real conditions yielded comparable CIs. In Experiment 2, disks were stationary and fourteen subjects (over 28,000 trials) judged whether a horizontally translating contour was convex or concave. Noise fields were as before (truncated, Gaussian white; power=3.7 * 10-5 deg2) except that there was a new field for each frame of the sequence. Six times more pixels reached significance in the illusory region than predicted by chance alone ($p<.001$), and a contour can be seen in certain frames. Thus even when an illusory contour moves, and even when its inducing events are sequential, subjects are influenced by pixels along interpolated contours.

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D41 *442* Efficiency of Contour Grouping Across Occlusions in Natural Images

Wilson S. Geisler[1] (geisler@psy.utexas.edu), Jeffrey S. Perry[1]; [1]Center for Perceptual Systems and Psychology, University of Texas, Austin TX 78712

To identify the sources of information used to group across occlusions, we propose a contour grouping task based directly on natural images. Prior to measuring performance, edge elements are extracted automatically from natural images and observers assign each edge element to a physical contour using the full image context [Vis. Res., 41, 711-724], providing an approximate "ground truth" of which edge elements derive from the same contour. On each trial of the experiment, a pair of edge elements is randomly selected from an image. In the stimulus display, an occluder is placed so its diameter just touches the center point of the two elements. The subject's task is to decide whether these two edge elements belong to the same or different contours. In the restricted case, only the two edge elements and occluder are displayed. In the unrestricted case, the full gray-scale image plus occluder is displayed. Results: (a) For the restricted case, naïve observers approach ideal performance as determined by the pair-wise statistics of edge elements in natural images. (b) For the unrestricted case, there is little improvement over the restricted case for small occluder diameters and modest improvement for large occluder diameters (here ideal performance is unknown). (c) Observers do not improve after practice with feedback. (d) Most of the information that humans use in performing contour grouping across occlusions in natural images is captured by the pair-wise statistics of the edge elements at the point where the contour becomes occluded.

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D42 *443* Snakes are as fast as ladders: evidence against the hypothesis that contrast facilitation mediates contour detection

Keith A. May[1] (keith@keithmay.org), Robert F. Hess[1]; [1]McGill University, Montreal, Canada

It is easy to detect a "snake" consisting of spatially separated, collinear elements, embedded in a field of randomly oriented elements (Field, Hayes & Hess, 1993, Vision Research, 33, 173-193). Performance is poor when elements are oriented 45 degrees to the contour, but improves when elements are orthogonal to the contour ("ladders") (Ledgeway, Hess & Geisler, 2005, Vision Research, 45, 2511-2522). Contour detection has been related to the phenomenon of contrast facilitation, whereby the contrast threshold for detection of an element is reduced when it is flanked by other elements: many models assume that contours are detected through the modulation of neuronal activity by the facilitatory signals that underlie contrast facilitation. If this were the case, one would expect contour detection to show similar temporal properties to contrast facilitation. Cass & Spehar (2005, Vision Research, 45, 3060-3073) used a psychophysical procedure to estimate the speed of propagation of contrast facilitation signals; their results suggest that the facilitatory signals from collinear flankers propagate much more slowly than those from non-collinear flankers. We investigated the effect of temporally modulating the orientation of contour elements from collinear to diagonal, or from orthogonal to diagonal. If contour detection and contrast facilitation are mediated by the same mechanisms, then the integration of snake contours should be much slower, and should be disrupted at much lower temporal frequencies, than the integration of ladder contours. We found identical temporal properties for both contour types, suggesting that contour integration is mediated by different mechanisms from contrast facilitation.

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D43 *444* Luminance-contrast properties of contour-shape processing revealed through adaptation

Elena Gheorghiu[1] (elena.gheorghiu@mail.mcgill.ca), Frederick A. A. Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, 687 Pine Avenue W, Montreal H3A 1A1, Quebec, Canada

Aim: We investigated the nature of 1st-order inputs to contour-shape mechanism using the shape-frequency after-effect (SFAE), in which adaptation to a sinusoidally-modulated contour causes a shift in the apparent shape-frequency of a test contour away from that of the adapting stimulus. We measured SFAEs for adapting and test contours that differed in the phase, scale (or blur) and magnitude of luminance contrast. **Methods:** Adapting and test stimuli were pairs of 2D sinusoidal-shaped contours and edges. The adapting pair were presented above and below fixation and differed in shape frequency by a factor of three. During the test period, subjects indicated whether the upper or lower test contour had the higher perceived shape-frequency, and a staircase procedure estimated the ratio of test shape-frequencies at the point of subjective equality. **Results:** SFAEs revealed (i) selectivity to luminance contrast polarity for both even-symmetric (contours only) and odd-symmetric (both contours and edges) luminance profiles; (ii) a degree of selectivity to luminance scale (or blur); (iii) higher selectivity to fine-scale (thin) compared to coarse-scale (thick) contours/edges and (iv) a small preference for equal-in-contrast adaptors and tests. **Conclusion:** Contour/edge shape encoding mechanisms are tuned to many luminance-contrast properties. This implies that contour shape mechanisms make use of a 'feature-rich' representation, and do not represent contour shapes as super-sparse cartoon-like sketches as might be presumed by local energy, i.e. non-phase-selective models.

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D44 *445* On the mechanisms for contour-shape after-effects

Frederick A A Kingdom[1] (fred.kingdom@mcgill.ca), Elena Gheorghiu[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Canada

Adaptation to a sinusoidally modulated contour produces a shift in the apparent shape frequency of a subsequently presented test contour, in a direction away from that of the adaptation stimulus. The phenomenon has been termed the 'shape-frequency after-effect' or SFAE (Kingdom & Prins,

2005, JOV, 5, 464). We describe an even larger after-effect of contour-shape *amplitude*, which we term the 'shape-amplitude after-effect' or SAAE. What underlies these after-effects? They occur even when the shape-phase of the contour is randomly changed every half second during the adaptation period, which would tend to lead one to reject the idea that local tilt (or orientation) after-effects (TAEs) are the underlying cause. However we show that even with adaptation contour phase-randomization, the geometrical relationships between adaptor and test are such that the TAE is difficult to rule out. We provide evidence against the TAE: sizeable after-effects are obtained for adaptors that are sine-wave-shaped and tests that are square-wave-shaped. In addition we test, and reject, three other candidates besides local orientation: global average curvature, local signed curvature and global spatial frequency. We suggest that contour shape after-effects result from adaptation to the sizes of local, partly-bounded regions defined by the contour's shape. This in turn implies that contour shape is processed by mechanisms that encode the sizes of partly-bounded regions of the stimulus.

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URL: http://www.mvr.mcgill.ca/Fred/research.htm

3D Cue Integration

D45 *446* Depth cues do not specify a unique Affine or Euclidean shape representation

Massimiliano Di Luca[1] (max@brown.edu), Fulvio Domini[1], Corrado Caudek[2]; [1]Brown University, [2]University of Firenze

To test whether perceived shape from shading, texture and motion is affine, we asked participants to compare the curvature at the tip of two surfaces of revolution with quadratic profile. The first surface was defined by shading or motion and the second was defined by texture information. This match was obtained by keeping constant the texture surface, and by varying the illumination direction for the shading surface, and the angular rotation for the motion surface.If the 3D shapes perceived from shading, motion or texture are related to the simulated surface by an affine stretching, then our procedure should produce identical values of perceived curvature, depth and slant also for all other local patches of the three surfaces. Our empirical results, however, show that this is not the case. This implies that the recovered 3D shapes from shading, texture and motion are not related to the simulated 3D surface by an affine transformation.These results are compatible with the hypothesis that the local analysis of image signals specifies different 3D properties. Shading specifies only local curvature; texture local slant and curvature; motion local curvature, slant and depth. Slant and depth from shading, and depth from texture can only be computed through spatial integration, which necessarily introduces noise in the recovery process. Therefore we expected that the perceived values of slant and depth from shading, and depth from texture will be smaller and less reliable then those specified by motion information. Empirical results confirm this hypothesis.

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URL: http://www.cog.brown.edu/~max/demo/properties/index.htm

D46 *447* The Intrinsic Constraint model for Stereo-Motion integration

Fulvio Domini[1] (Fulvio_Domini@brown.edu), Corrado Caudek[2]; [1]Brown University, [2]University of Firenze

Many visual tasks are carried out by using multiple sources of sensory information to estimate environmental properties. In this work, we present a model for how the visual system combines disparity and velocity information. We propose that, in a first stage of processing, the best possible estimate of the affine structure is obtained by computing a composite score from the disparity and velocity signals. In a second stage, a maximum likelihood Euclidean interpretation is assigned to the recovered affine structure. Observers were asked to match the perceived amount of depth of two 3D smooth surfaces. One surface was defined by disparity or motion alone; the other presented both cues together. Condition 1: In each 2AFC trial, the combined-cues stimulus simulated a constant depth amount. Within three separate staircases, the simulated depth of (i) a disparity-velocity stimulus (with consistent simulated depth magnitudes from each cue), (ii) a disparity-only stimulus, and (iii) a velocity-only stimulus was varied. Condition 2: Within three separate staircases, the simulated depth of the combined disparity-velocity stimulus was varied, while maintaining constant the simulated depth of (i) a disparity velocity stimulus (with consistent simulated depth magnitudes from each cue), (ii) a disparity-only stimulus, and (iii) a velocity-only stimulus. Our results are consistent with the predictions of our model (Domini, Caudek and Tassinari, in press), both for the PSEs and the variability of observers' judgments. The present findings are also discussed in the framework of another theoretical approach of the depth cue combination process termed Modified Weak Fusion (MWF).

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D47 *448* Learning a new cue to depth

Erika Scilipoti[1] (Erika_Scilipoti@brown.edu), Fulvio Domini[1], Corrado Caudek[2]; [1]Brown University, [2]University of Firenze

Can learning transform a non-informative 2D shape into a new cue for 3D depth perception? To answer this question, we determined (i) whether the visual system can associate, through learning, a specific depth-order to the features of an ambiguous 2D shape, and (ii) whether the learned association can successively affect the perceived depth-order, when a 3D depth-map is attributed, through disparity information, to the same 2D shape.The experiment comprised two phases. During the learning phase, observers repeatedly viewed a 2D shape coupled with a depth-map specified by disparity information. In the test phase, two versions of the 2D shape used in the learning phase were presented. For the target stimulus, disparity information specified a (near threshold) depth map, having either the same sign as in the learning phase, or the opposite one; for the comparison stimulus, disparity specified a 2D shape. Observers were asked to choose the 3D stimulus. Performance improved across sessions when the depth-order of the learning phase was preserved in the test phase; performance decreased across sessions when the depth order of learning and test phases had opposite signs. Our results indicate that observers associated, through learning, a specific depth-order to an ambiguous 2D shape. Such results imply that a short-term associative process can transform an uninformative 2D signal into a novel cue to depth.

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D48 *449* How effective are disparity and motion parallax cues for depth perception in monkeys and humans?

Veronica S. Weiner[1] (vsw@MIT.EDU), Peter H. Schiller[1], Ying Zhang[1]; [1]MIT, Cambridge, MA

Using a random-dot display that makes it possible to provide disparity and motion parallax cues separately or in combination, we examined how effectively these two cues can be processed by monkeys and humans when contrast, size, and spatial separation between target and background are systematically varied. Monkeys and humans were trained to first fixate a central fixation spot and to then make a saccadic eye movement to the target that appeared either singly in one of four locations (detection task) or simultaneously with three identical distractors (discrimination task). In monkeys correct choice was rewarded with a drop of apple juice. Our results show the following: (1) Providing both disparity and parallax cues yielded higher percent correct performance and shorter saccadic latencies than when disparity or motion parallax cues were provided singly. (2) Reducing the size and contrast of the display reduced performance more

dramatically for stereopsis than for motion parallax. (3) As spatial separation between the background and the target was increased, performance fell off more dramatically for motion parallax than for stereopsis. (4) When the stimuli were presented at isoluminance, the deficit was more pronounced when the display was blue/yellow than when it was red/green.Our findings suggest that depth based on disparity cues is processed preferentially by the midget system, whereas motion parallax cues are processed preferentially by the parasol system. The koniocellular system that processes color information in the blue/yellow domain appears to make a limited contribution to depth perception.

D49 *450* Near optimal depth cue combination from binocular disparity and motion parallax

Julian M. Fernandez[1] (julian_fernandez@isr.syr.edu), Bart Farell[1]; [1]Institute for Sensory Research, Syracuse University

The visual system combines information from different depth cues to estimate 3D shape. Previous studies show that humans can optimally combine texture and binocular disparity cues in estimates of surface slant. These estimates agree with predictions of a maximum-likelihood estimation model (MLE), which weights each cue in accordance with its relative reliability. We have tested a MLE model for combining motion parallax and binocular disparity in estimates of surface curvature. The structure-from-motion stimuli consisted of monocularly presented rotating cylinders whose axis of rotation—which coincided with their longitudinal axis—could be inclined away from the frontoparallel plane. The same stimuli, but static and binocular, generated the disparity cue. In a first experiment, reliability for each cue was measured using a 2AFC procedure, in which subjects had to discriminate between two slightly different elliptical cross sections. These reliability estimates were used to predict MLE weights for stimuli containing both cues. In a second experiment we obtained perceived-shape judgments using a method of adjustment on the cross sections when only one cue, and when both cues, were present. When both were present, the cues might signal consistent or inconsistent values of the cross section and of the inclination of the axis of rotation. We compared the observed weights with the MLE predictions obtained from the first experiment. We found that most observers combine disparity and motion parallax cues near optimally in judgments of surface curvature, resulting in more reliable estimates of object's shape than can be obtained from either cue alone.

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D50 *451* Dependency of the manner to integrate depth cues on perceptual tasks.

Makoto Ichikawa[1] (ichikawa@yamaguchi-u.ac.jp), Yuko Masakura[2]; [1]Dept. of Perceptual Sciences & Design Engineering, Yamaguchi University, JAPAN, [2]National Institute of Advanced Industrial Science & Technology, JAPAN

Previous studies about the integration of binocular disparity and motion depth cues (motion parallax, and kinetic depth cues) at suprathreshold level claimed that the depth magnitude information from those cues are processed by independent modules, and that those information are integrated in a linear manner, using weighted averaging. The studies at near threshold level, however, reported that the processing of disparity is not independent of the processing of motion depth cues, and that those cues are integrated in a nonlinear manner in depth detection task. We investigated whether the way to integrate depth magnitude information from those cues at suprathreshold level differs from that at near threshold level. In the experiment, observers were instructed to report the apparent depth magnitude for the random dot display (16 X 14 deg) by the use of which a previous study found non linear combination for disparity and parallax by the use of depth detection task (Ichikawa et al., 2003, Vision Research). The stimulus specified sinusoidal undulation (0.13 cpd) in terms of disparity and parallax. The sizes of disparity and parallax ranged from depth threshold level to six times of the threshold level, which were measured for each observer in preliminary tests. We found that, at any sizes of disparity and parallax, the depth magnitude information from disparity and parallax are integrated in a linear manner (weighted averaging). Our results suggest that the manner to integrate depth information from disparity and motion cues varies with the problem that the visual system has to solve.

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D51 *452* Integration of motion and disparity in reconstructing 3D surface shape.

Kevin J. Mackenzie[1] (kjmacken@yorku.ca), Laurie M. Wilcox[1], Miloš Jovanoviæ[2]; [1]Centre for Vision Research, Department of Psychology, York University, Toronto, ON, [2]Computer Science Department, York University, Toronto, ON

There is convincing evidence that the visual system acts as an optimal integrator when combining texture with disparity or motion to interpret 3D surface shape. Unfortunately, similar experiments with motion and disparity have proven challenging due to the presence of additional shape cues. Our experiments address these stimulus issues and evaluate how stereo and motion cues are combined to resolve 3D form. Three-dimensional cylinders were covered with a random-element greyscale texture. A black occluder with randomly positioned, 1.5 degree circular holes was placed in front of the display to limit observers' ability to track local features, or extract shape from texture. Using an implicit standard technique, with the method of constants, we assessed the accuracy and precision of observers' curvature discrimination judgments for a range of implicit reference curvatures (radii of 15, 16 and 17.50 deg). We did this first for motion and disparity alone, and in combination (equivalent and conflicting). In the combined conditions the relative strength of the disparity and motion cues was determined by selecting the 70% correct point from each individual psychometric function obtained in the single cue condition. Combined-equivalent results showed a marked increase in the slope of the psychometric function for all test curvatures. In the conflict conditions there were considerable individual differences in the weighting of the two cues. However, in all cases, there is support for cue integration rather than a vetoing process. These results and analyses will be discussed in the context of current models of cue integration.

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D52 *453* Encoding perceived depth

Christopher W. Tyler[1] (cwt@ski.org), Lenny L. Kontsevich[1]; [1]Smith-Kettlewell Eye Research Institute, San Francisco

Purpose. Our visual experience operates at the level of integrated perceptual cues, which are derived from an array of cue modalities. A classical example is perceived depth, which is derived from a variety of monocular, binocular and kinesthetic depth cues. We ask at what level in the visual processing stream perceived depth is encoded. FMRI methods are used to identify the locus in visual cortex where matched depth percepts from stereoscopic, motion, texture and shading cues generate matching signal strengths.Methods. The stimuli consisted of arrays of bulges formed from fourth-power (flat-topped) Gaussian-like functions. The observer's task was to match the depth of the bulges from various depth cues in the one hemifield to the fixed depth from the disparity-defined bulges on the other hemifield. Cortical activations to a) depth modulation, b) cue modulation with invariant depth, were recorded by fMRI in a 3T scanner with 40 planes at 3 x 3 x 3 mm3 resolution at 3 s TR.Results. The main site of activation by the depth modulation was in the ODS(KO) region that responds to depth structure, including kinetic contour structure (Tyler et al., 2005, NeuroImage) or adjacent retinotopic areas V3A/B. This region typically showed well-matched activations for all four depth cues, with no significant response for alternation between cues that generated matched depth percepts.Conclusion. A region in the lateral occipital cortex of each observer was identified that exhibited the requisite behavior for the site of

the generic depth representation from multimodal visual cues.

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D53 *454* Interactions of motion, distance and texture on perceive slant of planar surfaces

Nadejda Bocheva[1] (nadya@percept.bas.bg); [1]Bulgarian Academy of Science

When the texture on a ground surface is discontinuous, its more distant part appears as slanted towards the observer (Wu, Ooi & He, 2004). If exists, for a slanted surface such an effect will reduce the perceived slant of the further parts. The present study examines the effect of motion and distance on perceived slant of a planar surface textured either with one or with two textures and divided by a horizontal gap. The textures had amplitude spectrum with falloff of 1/f or 1/f1.5. The observer had to adjust the slant of the upper or of the lower part so that they appeared coplanar.Results. For the plane translated under perspective projection, there were less errors in the adjusted slant when both planar patches had the same texture irrespective of its amplitude spectrum. For rotating planes in orthographic projection, the performance was best for lower (and closer) planar patch when both parts were covered with 1/f noise texture. Largest errors were observed when the patches were covered with 1/f1.5 texture due either to the lower density of the motion signals or to the discrepancy between the motion information and the perceived depth of this texture. The results suggest that motion information can improve to a limited extent the integration of depth information over a gap and its effect depends on the variability of the texture anisotropy during the motion.

Perception and Action

D54 *455* Getting Credit Assignment Right in Visuo-Motor Behaviors

Dana H Ballard[1] (dana@cs.rochester.edu), Constantin Rothkopf[2]; [1]Dept. of Computer Science, University of Rochester, [2]Dept. of Brain and Cognitive Science, University of Rochester

Composite visuo-motor behaviors can be synthesized from simpler behaviors. For example in walking down a sidewalk, a pedestrian may have goals of staying on the sidewalk, avoiding pedestrians and picking up litter. [Sprague 03], showed in a virtual reality simulation that these individual behaviors can be learned by reinforcement learning. However that simulation assumed that the rewards associated with the individual behaviors were known. In practice this is unreasonable as only the total reward for the composite behavior is likely to be available. This is a long-standing problem in learning known as the credit assignment problem. [Chang 03] showed that an estimate for the individual rewards could be obtained by assuming that the total reward was assigned to each behavior and the variations in that reward were assumed to be noise. This model made sense in their setting, which had the individual behaviors embedded in different agents, but introduced a problem in that the resultant reward estimates were biased and could be suboptimal. We show that the credit assignment problem has a solution when the visuo-motor behaviors all are embedded in the same agent. Each behavior needs to know which other behaviors are simultaneously active. It can then keep a running estimate of its share as its current estimate adjusted by the total instantaneous reward minus the reward estimates of the concurrent behaviors. The simulations show that, as long as the behaviors are updated in a random order, the estimated reward for each behavior converges to its true value.

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D55 *456* Predictive eye movements in physically possible and impossible worlds: evidence for internal models

Constantin Rothkopf[1] (crothkopf@bcs.rochester.edu), Mary M. Hayhoe[1], Keith Parkins[2]; [1]Center for Visual Science, University of Rochester, Rochester, NY, USA, [2]University of Rochester, Rochester, NY, USA

There is considerable evidence for internal models of the body's dynamics for control of movement. However, internal models of the environment are less well established. Especially under time constraints, it is advantageous to utilize complex properties of the environment extracted from visual cues that allow prediction of future states of the world and movement planning in anticipation of those events.Subjects were immersed in a virtual scene and hit virtual balls directed towards them with a table tennis paddle, receiving vibrotactile feedback when hitting, and audible feedback from the bounce. This setup allows to control the trajectories, the physical properties of the ball and world, and their uncertainties. There were four conditions: 1. the ball had a controlled spatial distribution of bounce points; 2. the bounce point distribution varied with ball color; 3, subjects were rewarded differentially depending on where the ball bounced; 4. the physical properties of the balls and environment varied on each trial, including physically impossible trajectories. We recorded eye, head, and hand movements while subjects caught balls thrown with a bounce. Subjects fixated the initial position of the ball, then saccaded to the anticipated bounce point, and then pursued the ball until it is close to the rendered position of the paddle. Fixation distributions varied with ball color, and balls were more difficult to catch in the condition with physically impossible balls. The data further suggest that observers maintain an internal model of the dynamic properties of the world, and adjust this model when errors occur.

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D56 *457* Characteristic ontogenesis of vision-for-action and vision-for-perception revealed by two spatial tasks

Nicola Bruno[1] (dirpsicologia@units.it), Lorena Giovannini[1], Alessandra Jacomuzzi[1], Luca Surian[1], Carlo Semenza[1]; [1]Dipartimento di Psicologia, Università di Trieste

According to the two-visual-system hypothesis (Milner and Goodale, 1995), after V1 the visual system splits into "vision for action" and "vision for perception" modules. Perceptual modules may exhibit characteristic developmental pace and sequencing (Fodor, 1983). To test this hypothesis, we investigated two spatial tasks in typically developing school children, autistic children, and adults. The tasks consisted in blindwalking with no delay to a near target and in matching the frontal extent to the sagittal extent of an L-pattern formed by ropes on the ground. The blindwalking task was assumed to tap into the action module, whereas the L-pattern matching task was assumed to tap into the perception module. In the blindwalking task, typically developing children and adults were accurate whereas autistic children exhibited an underestimation bias. Conversely, in the L-pattern matching task adults showed underestimation, typically developing children showed even greater underestimation, and autistic children were accurate. Control experiments ruled out alternative interpretations based on differences in eye-height and testing rooms. Overall, these results are consistent with two visual modules that develop and function in different ways as a function of age or pathology. The surprising performance of autistic children suggest that autism may involve anomalies in the use of spatial reference frames in visual cognition.

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D57 *458* A negative test of the sensorimotor dissociation via a trial-by-trial analysis of Response Times and Temporal Order Judgments

Andrei Gorea[1] (Andrei.Gorea@univ-paris5.fr), Pedro Cardoso-Leite[1], Pascal Mamassian[1], Florian Waszak[1]; [1]Laboratoire de Psychologie Expérimentale, CNRS & René Descartes University, 92774 Boulogne-Billancourt, France

The relationship between Temporal Order Judgment (TOJ) and Response Time (RT) has been an object of debate since Exner and even more so in the context of the ongoing dispute on the sensorimotor dissociation[1,2]. If anything, the most pervasive fact in the TOJ-RT literature is that the two sorts of behavior display a non-systematic relationship whether across studies, experimental conditions within the same study and even across subjects within the same study and for the same experimental conditions. The present work presents a first time trial by trial analysis of paired RT-TOJ performances appraising the relationship between motor and sensory decisions. Observers produced speeded key presses (simple RTs) to pairs of equal and different contrast increments, orientation changes, and a combination of the two applied with a variable SOA to two spatially distinct Gabor pedestals; for the same trial, they also made a TOJ. RTs simulated as a function of SOA with a simple model assuming that they reflect the same internal response temporal distributions as those inferred from the measured TOJ psychometric functions[3] fit the measured RTs for both "correct" and "incorrect" TOJ judgments. These findings bias the current sensorimotor dissociation debate in favor of a common source of information subtending motor and perceptual decisions and suggest that inconsistencies in the literature result from uncontrolled stimulus parameters and/or response strategies.[1]Gegenfurtner et al. (2003). J. Vision 3, 865-876 ; [2]Osborne et al. (2005). Nature 437, 412-416; [3]Adams & Mamassian (2004). Proc. R. Soc. Lond. B 271, 139–146.

D58 *459* Perception and action at a distance

Flip Phillips[1] (flip@skidmore.edu), Brian Gaudino[1], Brian Prue[1], Martin G Voshell[2]; [1]Skidmore College, Department of Psychology & Neuroscience Program, [2]The Ohio State University, Cognitive Systems Engineering Laboratory

Teleoperation of robots and autonomous vehicles introduces an interesting series of questions with respect to perception and action at a distance. While the pragmatics of this problem has been considered in the human factors domain, there is little consideration of an overall theory of perception and action at a distance in the perceptual domain. Our work attempts to erect a scaffolding for the development of such a theory. Classically, studies of perception and action take place in the 1st-person, i.e., those where the embodiment of the perceiver and actor are the same entity. Our work considers the *2nd-* and *3rd-person* perspectives (e.g., watching a machine carrying out our action and watching *from* the machine carrying out the action). The framework is complicated by the fact that 2nd- and 3rd-person embodiments may have different action capabilities than the 1st-person, and 3rd-person embodiments may have additional sensor mechanisms able to provide information not available in the usual 1st-person sense. Our overall strategy consists of 2nd- and 3rd-person replication of classic 1st-person perception-action paradigms and investigation the resulting shifts (or lack thereof) in performance. Obviously some types of performance will have little or no difference when differently-embodied while others should experience significant modification. From these results, we can model and predict expected performance in alternative perception-action embodiments. Here, we present initial results from an affordance-based experiment modeled on Warren & Wang (1987) as well as navigation experiments after Foo et al. (2005), along with their relevant implications for our proposed theoretical framework.

D59 *460* Interpreting visual information in motor learning

Jennifer K. Dionne[1] (jdionne@yorku.ca), Denise Y. P. Henriques[1]; [1]School of Kinesiology & Health Science, Centre for Vision Research, York University, Toronto, Canada

Motor learning often requires generalizing previous experience to new situations. One form of generalization is known as bimanual or intermanual transfer, where learning a new task with one hand affects performance of the other arm on the same task. Our study investigates how intermanual transfer is influenced by the visual feedback available when the task is being learned. Previous studies have shown that learning to reach accurately with an imposed visuomotor rotation requires a remapping of the relationship between vision and motor output, and in this study we examined how well this learned remapping transferred between hands under different visual feedback conditions. In our task subjects learned to make accurate reaches to targets with a visuomotor rotation of 45° in two conditions: with normal visual feedback or with visual feedback of their hand reversed so that the subject's right hand looked like their left hand (or vice versa). After a training period with one hand subjects were tested with the opposite hand on the same task to determine how well the learned remapping transferred to the untrained hand. Preliminary findings suggest that learning the remapping with reversed visual feedback results in more transfer of learning to the untrained hand than learning under non-reversed visual feedback conditions. These results suggest that the visual feedback available during motor learning affects generalization to the untrained limb. More specifically, our learning mechanisms adjust motor commands to the limb based not only on proprioception and efference copy but also using visual feedback about the limb.

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D60 *461* Is active drawing of line configurations resistant to visual illusions?

Uta Wolfe[1] (uwolfe@hws.edu), Elizabeth Amis[1]; [1]Dept. of Psychology, Hobart and William Smith Colleges, Geneva, NY

We investigated whether both blind and visually guided production of line drawings is subject to the same distortion observed in the visual perception of such drawings. To this end we compared illusion extents associated with the perception, drawing and blind drawing of the inverted T configuration of the horizontal-vertical illusion.In the perceptual task, subjects (n=4) viewed the configuration on a computer screen and using the arrow keys adjusted the length of the vertical line to look equal to that of the horizontal. In the production task, subjects were asked to draw on paper both with and without vision an inverted T figure with equally long horizontal and vertical lines. Illusion extent (IE) was calculated as the percentage by which the vertical line was shorter than the horizontal at the PSE. Average IEs by subject ranged from 6-18% (perception), 16-27% (visually guided drawing) and 13-32% (blind drawing). IEs tended to be larger in the drawing conditions than in the perceptual condition. All four subjects had a significantly increased IE in at least one of the drawing conditions compared to the perception condition and only one instance of decreased IE for a drawing condition was observed. Two subjects showed a significantly larger IE for blind than for visually guided drawing, whereas one subject showed the opposite trend.These results suggest that active drawing of simple line configurations whether blind or visually guided is distorted in the same direction as and to a greater degree than the visual perception of such configurations.

D61 *462* EVOLUTION OF VISUALLY GUIDED BEHAVIOR IN ARTIFICIAL AGENTS

Dale Purves[1] (purves@neuro.duke.edu), Byron Boots[1]; [1]Center for Cognitive Neuroscience and Department of Neurobiology, Duke University, Durham NC 27708

Recent work on brightness, color and form has suggested that human visual percepts represent the probable sources of retinal images rather than stimulus features as such. We have investigated this empirical concept of vision by asking whether agents using neural network control systems evolve successful visually guided behavior based solely on the statistical relationship of images on their sensor arrays and the probable sources of the images in a simulated environment. A virtual environment was created with OpenGL consisting of an arena with a central obstacle, similar to arenas used in evolutionary robotics experiments. The neural control system for each agent comprised a single-layer, feed-forward network that connected all 256 inputs from a sensor array to two output nodes that encoded rotation and translation responses. Each agent's behavioral actions in the environment were evaluated, and the fittest individuals selected to produce a new population according to a standard

genetic algorithm. This process was repeated until the average fitness of subsequent generations reached a plateau. Analysis of the actions of evolved agents in response to visual input showed their neural network control systems had incorporated the statistical relationship between projected images and their possible sources, and that this information was used to produce increasingly successful visually guided behavior. The simplicity of this paradigm notwithstanding, these results support the idea that biological vision has evolved to solve the inverse problem on a wholly empirical basis, and provide a novel way of exploring visual processing.

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D62 *463* Performance of Basic Visual Tasks Using Retinal-Prosthetic Simulation

George N Scarlatis[1] (scarlati@seas.ucla.edu), Robert J Greenberg[2], Jack W Judy[1]; [1]University of California, Los Angeles, [2]Second Sight Medical Products, Inc.

PURPOSE. This study compared the performance of subjects with simulated low-resolution prosthetic vision on basic visual tasks to that of blind patients implanted with 4x4 epiretinal prostheses.METHODS. Nine participants with at least 20/30 monocular visual acuity performed seven independent forced-choice basic-visual tasks previously tested on three blind subjects implanted with 4x4 epiretinal prostheses. These tasks were performed under 4x4, 8x8, and 6x10 pixel resolutions and 256 levels of grayscale. After training, each subject completed 40 repetitions of each task:resolution combination in a random order determined by a customized C++ computer program. Performance was recorded as stimulus presented and answer provided and the time required to provide each answer.RESULTS. Of the 40 repetitions conducted at each setting, the number correctly identified divided by 40 provided the % correct. Participants performed similarly to implant patients at the 4x4 setting and quite better (>93% accuracy and up to twice as fast for all tasks tested) at the 8x8 and 6x10 settings. Variance in performance at the 4x4 setting was large and appears to be a function of the age of the subject tested. No significant difference in performance was observed between 8x8 and 6x10 settings. CONCLUSIONS. These results imply that sighted subjects wearing a simulator with our parameters perform visually-based tasks at a level similar to that of blind patients implanted with 4x4 epiretinal prostheses. Age-dependent differences in performance cannot be differentiated between intrinsic ability to perform visually-based tasks and time needed to adapt to new visual conditions.

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Working Memory II

D63 *464* The Nature of Space-Invariant Object-Based Attention II

Michi Matsukura[1] (michi-matsukura@uiowa.edu), Steven Luck[1], Shaun Vecera[1]; [1]University of Iowa

Visual attention can select objects as well as locations, and this object-based selection operates on both grouped-array and space-invariant levels (Vecera & Farah, 1994). Space-invariant selection has been typically examined by the feature-report task: Observers are presented with a box and a line that are superimposed. Each object has two attributes (height and gap for a box and tilt and texture for a line). Observers' accuracy is higher when two attributes are part of one object rather than two objects. This finding closely matches the properties of visual short-term memory (VSTM): Visual objects were remembered based on a number of objects rather than a number of object's features (Luck & Vogel, 1997). We demonstrated that space-invariant selection and VSTM shared the same underling mechanisms by loading the feature report task with a concurrent VSTM task (OPAM, 2005). Different concurrent VSTM tasks led to different interference patterns. Under an object load, observers exhibited an increased object-based effect for the second response trials. However, when the information of 2 to-be-reported attributes was withheld until after the object was masked, the object-based effect was abolished, although small object-based effects returned when salient object cues were available. We hypothesized that, when there was no salient object cue to indicate which object each attribute belonged, these floating attributes slowed the integration of features into an object file. In the current study, we examined whether the number of attributes makes a difference for the presence of space-invariant object-based selection.

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D64 *465* Effects of familiarity on visual working memory of upright and inverted faces

Hing Y Eng[1] (heng@fas.harvard.edu), Diyu Chen[1], Yuhong Jiang[1]; [1]Harvard University, Department of Psychology

Aim: Can we hold more familiar items than novel items in visual working memory (VWM)? Previous studies suggest not: familiar polygons are not remembered more efficiently than novel ones and upright letters are not remembered better than inverted letters. In this study we report an exception to this rule when faces of different familiarity were tested. Methods: Our study was revised from Buttle & Raymond (2003) who tested perception of briefly presented and masked faces. To study VWM rather than perception, we presented faces for a long duration (500ms or several seconds) and inserted a long retention interval (1000ms) in a change detection task. VWM for three types of faces was tested: superfamiliar faces of celebrities or one's friends, moderately familiar faces that had been viewed 160 times before, and novel faces. Subjects held 4 faces in VWM while performing an articulatory suppression task. Results: VWM for superfamiliar upright faces (celebrities or friends) was significantly better than that for novel upright faces, but this enhancement was not observed for recently trained upright faces and was eliminated by the inversion of faces. These results extend the superfamiliarity effect observed by Buttle & Raymond (2003) from a perceptual task to a VWM task. Conclusion: Our study suggests VWM can be influenced by long-term visual memory, but only if the set of items that must be distinguished in VWM are subtly different and that subjects have achieved superfamiliarity with the stimuli.

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D65 *466* Episodic Representation of Object Identity and Form

Robert D. Gordon[1] (robert.d.gordon@ndsu.edu), Megan L. Frankl[1], Sarah D. Vollmer[1]; [1]North Dakota State University

We investigated the nature of episodic object representations ("object files"), and the development of such representations over time, within a transsaccadic preview paradigm. While fixated on a central cross, participants viewed a preview display consisting of two objects located above and below a peripheral cross. One of the preview objects was a familiar object, while the other was a non-object. Participants initiated a saccade to the peripheral cross, either immediately upon the appearance of the preview display (no-delay condition), or after a 1500 ms delay. During the saccade, the preview display was replaced by a target display, consisting of a single familiar object in one of the previewed locations; the participant's task was to name the object as quickly as possible after the eyes landed. The target object's identity, location, and left-right orientation were manipulated. The results revealed an object-specific priming effect: that is, participants named the object more quickly when it appeared in its previewed location than when it appeared in the opposite location. Changing the object's orientation increased overall naming times in the no-delay condition, but not in the delayed condition. Surprisingly, however, orientation change did not affect object-specific priming, in either the no-delay or delayed conditions. The results suggest that, while object orientation may be represented over relatively short intervals, representations of ori-

entation do not play a substantial role in preserving object continuity across saccades during the performance of an object naming task.

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D66 *467* Enhanced Visual Working Memory for Angry Faces

Margaret C Jackson[1] (m.jackson@bangor.ac.uk), Chia-Yun Wu[1], Sandra JE Langeslag[1,2], David EJ Linden[1], Jane E Raymond[1]; [1]University of Wales, Bangor, [2]Erasmus University Rotterdam

Does the presence of emotional expression influence visual working memory (WM) capacity for faces? Previous research has shown that capacity for faces was enhanced for familiar versus unfamiliar faces (Jackson & Raymond, 2004). This suggests that face capacity may be modulated by some facial attributes. It is well documented that emotional faces, especially angry and fearful faces, attract attention better than neutral faces, and that attention is necessary for working memory processes. Could visual WM for angry faces be enhanced relative to happy or neutral faces? We measured visual WM capacity for angry, happy, and neutral faces. Stimuli were 18 different male (Ekman) faces: six individuals each expressed the three emotions. On each trial, between 1 and 4 faces displaying the same emotion were presented for 2000 ms in a two-by-two matrix. When less than four faces were presented, all other grid locations were occupied by a scrambled face. A 1000 ms blank retention interval followed, succeeded by a single face probe. Participants stated whether the probe was present or absent in the previous display (identity task). Emotion was blocked and counterbalanced within subjects and a verbal suppression task was administered. Task performance was significantly enhanced for angry compared to happy and neutral faces ($p < .01$), and capacity estimates (k) mirrored the angry face advantage ($p < .01$). Happy and neutral face performance did not differ. Thus, negative emotional expression appears to enhance visual WM for faces. Control experiments revealed that this effect was not attributable to arousal.

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D67 *468* Binding in Visual Working Memory is Impaired in Patients with Medial Temporal Lobe Amnesia

Katherine S Moore[1,2] (mooreks@umich.edu), Anjan Chatterjee[2,3], Katie Page[4,5], Mieke Verfaellie[4,5], Ingrid R Olson[2]; [1]University of Michigan, Department of Psychology, [2]University of Pennsylvania, Center for Cognitive Neuroscience, [3]University of Pennsylvania, Department of Neurology, [4]Boston University School of Medicine, [5]Boston VA Healthcare System

An important question in memory research is how best to characterize the role of the medial temporal lobes (MTLs) in memory. The *relational processing theory* proposes that some portion of the MTLs are critically involved in binding together different elements of a memory trace (Eichenbaum, 1999; Winocur & Kinsbourne, 1978). One limitation of this theory is that it does not specify whether MTL structures are needed for working memory (WM) tasks that require the retention of configural or "bound" items. Previous research has shown that feature binding and location-location binding are critically involved in visual WM (Luck & Vogel, 1997; Jiang, Olson, & Chun, 2000). Much of the existing literature would suggest that the MTL is not necessary for binding in WM because amnesic patients are thought to have intact verbal and visual STM. However prior studies have not examined amnesic performance on STM tasks that require binding. Here we test MTL amnesics and age-matched controls on two WM tasks for singular or bound information. Subjects were required to remember either three sequentially presented objects, locations, or object-location conjunctions. After a delay of either 1 s or 8 s, recognition performance was assessed. Results show that amnesic patients have intact object STM and location STM but impaired memory for object-location conjunctions. These findings extend the relational processing theory by showing that the MTLs are critical for mnemonic binding even at short delays.

D68 *469* How is Eye Gaze Affected by Cognitive Load and Visual Complexity?

Joseph C. Schmidt[1] (schmidtjoseph@hotmail.com), Gregory Zelinsky[2]; [1]Stony Brook University, [2]Stony Brook University

Do we choose to direct our gaze at uniform visual patterns when engaged in a cognitively demanding task? We addressed this question by investigating the relationship between working memory (WM) load, visual complexity, and gaze position. We hypothesized that when WM load is high, people may seek out regions of low visual complexity with their gaze. Subjects viewed Mondrian-type images consisting of variable-sized colored squares appearing on a mosaic background. Visual complexity was manipulated within each display by varying the size of the squares relative to the mosaic, under the assumption that higher edge content and diversity of color leads to greater visual complexity. We manipulated WM load using a serial recall task consisting of variable-length (3, 5, 7 or 9) digit strings. On each trial, subjects were presented with an image and an auditory sequence of digits. Following a 5-second retention interval, subjects were asked to report back the digits. The image remained visible to subjects throughout the trial, and their only gaze-related instruction was to refrain from closing their eyes. Analyses revealed no effect of WM load or visual complexity on eye gaze during either the encoding phase or the retention interval. However, during recall subjects looked more frequently to regions of low visual complexity, and this increased linearly with WM load. These findings suggest that the high cognitive demands during recall cause subjects to seek out areas of low visual complexity with their gaze, perhaps to minimize interference produced by automatic visual processes.

D69 *470* Effects of stimulus identity and distance on the interaction between perceptual representations: An encoding-related lateralization study

Eunsam Shin[1] (eshin1@uiuc.edu), Monica Fabiani[1], Gabriele Gratton[1]; [1]University of Illinois at Urbana-Champaign

This experiment investigates the interaction between the perceptual representations of the same or different letters presented at variable distances within the visual field. To assess the strengths of these representations, we used the encoding-related lateralization method (ERL, Gratton, 1998). With this method, perceptual representations are induced by flashing several items to the left or right fixation, and are subsequently tested by a foveally-presented test item that may or may not match one of the studied items. A matching test item elicits an ERP response that is lateralized depending on the side of the previously presented stimulus. We have previously shown (Shin et al., in press) that the ERP response is characterized by a series of deflections reflecting the reactivation of progressively more complex perceptual representations. One of these deflections, with a latency of 400-600 ms from stimulation, reflects the reactivation of a form of perceptual representation that includes a relational representation among different stimuli. Here we investigated whether this relational representation is affected by the relative distance between stimuli in the visual field (close or far) as well as their identity (same or different letters). Our data showed: (1) different behavioral responses between the same vs. different and close vs. far conditions, (2) larger ERL at a latency of 400-600 ms for the far/same condition than for the other three conditions. These results suggest that the long-latency ERL effect reflects a form of perceptual representation that is degraded by either contiguity or feature conflict between stimuli.

D70 *471* Functional connectivity within the neural system during maintenance period in visual working memory task

Sachiko Takahama[1] (takahama@cv.jinkan.kyoto-u.ac.jp), Masaya Misaki[2], Satoru Miyauchi[2], Jun Saiki[1,3]; [1]Japan Science and Technology Agency (JST), [2]Natural Institute of Information & Communication Technology, [3]Kyoto University

Visual working memory plays a key role in the interpolation of temporally occluded external objects by maintaining the representation of the objects.

Many fMRI studies have suggested the importance of frontal-parietal network in cognitive tasks. However, little is known about how the prefrontal cortex interacts with parietal cortex during the maintenance period in visual working memory. In this study, we used event-related fMRI to investigate (1) a neural basis of the maintenance period and change detection and (2) functional connectivity of prefrontal cortex with parietal cortex during the maintenance period in visual working memory task for feature-location binding. In terms of the necessity of feature-location binding, we conducted a multiple object permanence tracking task (Saiki, 2003) in three conditions: control (two of four colored targets turned gray), feature (one of four colored targets turned to a novel color), and binding (two of four colored targets were replaced with each other) conditions. Participants were asked to push a response button when they found a target change for each condition. Results showed that brain activation during change detection in the binding condition differed from that in the feature condition. In contrast, during maintenance of visual working memory, binding condition shared a common prefrontal-parietal network with feature condition. Our connectivity analyses revealed a top-down control of prefrontal cortex in the binding condition, but not in the feature condition, during the maintenance period. These results suggest task specific modulation during the maintenance of visual working memory for feature-location binding.

Acknowledgment: PRESTO from JST and 21st Century COE (D-2 to Kyoto Univ)

D71 *472* But you're staring right at it! Rapid resumption is not predicted by eye position alone

Wieske van Zoest[1] (wieske@psych.ubc.ca), Alejandro Lleras[2], Alan Kingstone[1], James T. Enns[1]; [1]University of British Columbia, [2]University of Illinois at Urbana-Champaign

Humans are exceptionally good at resuming a search that has been momentarily interrupted; making accurate detections in far less than the half second normally needed to begin a search (Lleras et al., 2005). It is proposed that rapid resumption depends on an iterative hypothesis testing mechanism that compares information stored in short-term memory with the display. Three experiments investigated the role of eye movements in rapid resumption. Experiment 1 monitored eye position passively during interrupted search and found that rapid resumption was correlated with relatively short distances between eye position and target location. We reasoned that if eye position alone was predictive (near fixation hypothesis), we should be able to increase the proportion of rapid resumption responses by using a contingent gaze paradigm to present the target near fixation, regardless of where in the display the eyes were pointed. Experiments 2 and 3 used two different methods for presenting the target to the point of eye fixation on a subset of the trials. The results showed, contrary to the near fixation hypothesis, that the proportion of rapid responses decreased dramatically when the target was offered directly to the eye. However, when two successive fixations occurred in a single target location virtually all responses were rapid. We conclude that the contingent gaze procedure interferes with participants' ability to compare their perceptual hypothesis with the sensory information in the display and that rapid resumption depends on the confirmation of a hypothesis regarding objects in a stable world.

D72 *473* Relational information in visual short term memory and context induced change perception.

Helene L Gauchou[1] (helene.gauchou@univ-paris5.fr), Juan R Vidal[1,2], Catherine Tallon-Baudry[2], Kevin O'Regan[1]; [1]Laboratory of Experimental Psychology, Paris 5 University, UMR 8581, CNRS, Paris, France., [2]Laboratory of Cognitive Neuroscience and Cerebral Imagery, UPR 640, CNRS, Paris, France.

Most studies about the capacity of VSTM implicitly consider each stored unit is stored independently of the others. Nevertheless there is evidence that relational information exists within each feature dimension in VSTM (Jiang et al., 2000), links information from individual units and needs no attention for its establishment (Vidal et al., 2005). The present study examines the role of relational information. In a change detection paradigm we presented a sample screen composed of 4 colored squares and, after a blank, a test screen where one of the items was cued as target. Subjects had to detect a target color change (Exp1,3-5), to rate their level of certitude (Exp3) and/or to recall the initial color (Exp1&2). On the test screen the non-target items can disappear (Exp5), change color (Exp1-4)) and be supplemented by four new squares (Exp4). We observed that non-target color changes do not impair change identification but do impair non-change detection performance (Exp1&2) and that subjects are sure to see the target changing even though it did not (Exp3). The same effect was observed when the non-target items disappeared (Exp 5) but not when irrelevant items were added on the test screen (Exp4). We concluded that a changing context induces an illusion of change for the non changing item and that this effect results from memory and not simply perceptual mechanisms. We propose a model of change detection including relational information that explains this "change illusion" and predicts change detection among items not stored in VSTM.

D73 *474* Keeping an eye on the spider in the corner: Biased visual working memory in phobic anxiety – a change detection paradigm

Andrea Reinecke[1] (reinecke@psychologie.tu-dresden.de), Mike Rinck[2], Eni S. Becker[2]; [1]Dresden Technical University, Germany, [2]Radboud University Nijmegen, The Netherlands

Background: According to cognitive theories of anxiety, cognitive processes play a significant role in the etiology and maintenance of phobic disorders. Many studies revealed enhanced attention to the feared object and greater distractibility by it. Results regarding memory biases in anxiety are very incoherent. Only a few studies investigated the effects of threat on visual-working memory (VWM), and apparently no study examined VWM for feared objects in phobics. Methods: In Experiment 1, 25 spider-fearfuls (SF) and 25 controls (NAC) were tested with an adaptation of the VWM-method introduced by Luck & Vogel (1997). We used complex objects, one of which depicted a spider. Subjects had to indicate whether two successively shown displays were identical or different. We varied display size (4,6,8), threat (neutral, spider) and encoding time (100ms, 500ms). In experiment 2, 25 SF and 25 NAC, both without fear of snakes, were tested. In three blocks, we varied the valence of the critical stimulus: it was either a spider, a snake, or a butterfly. Thereby, we sought to determine whether any group effects observed in Experiment 1 were merely due to a general threat effect or physical characteristics of the critical stimulus. Results: SF showed enhanced VWM compared to NAC when a spider was shown within the display. There were no group differences in the snake or butterfly condition. Discussion: The results will be discussed against the background of voluntary vs. reflexive attention and memory consolidation.

Acknowledgment: This work was supported by a grant from the German Research Foundation (DFG) to Eni S. Becker and Mike Rinck. We are grateful to Robert Muenster, Kira Marschner and Kristin Grundl.

D74 *236* Distractor Interference Stays Constant Despite Variation in Working Memory Load

Zhe Chen[1] (zhe.chen@canterbury.ac.nz), Celestien C. Chan[1]; [1]University of Canterbury, New Zealand

Previous studies show that working memory (WM) plays an important role in selective attention, such that high WM load leads to inefficient distractor inhibition compared to low WM load. However, because WM load is typically manipulated via varying the number of items held in memory, when the to-be-remembered stimuli are presented simultaneously, the number of stimuli is correlated positively with the extent of attentional focus. Because attentional focus is known to influence the efficiency of distractor inhibition, the systematic pairing between WM load and attentional focus makes it unclear whether the differential distractor interference in

the low vs. the high WM load conditions is primarily caused by a difference in WM load or a difference in the extent of attentional focus.

In four experiments we examine the effect of WM load on distractor processing while holding constant the extent of attentional focus. Our results show that WM load affected distractor processing only when it was positively correlated with the extent of attentional focus. When the latter was held constant, the effect of WM load became negligible. Furthermore, when low WM load was paired with a wide attentional focus and high WM load was matched with a narrow attentional focus, greater distractor processing was found when the WM load was low rather than when it was high. These results suggest that efficient distractor inhibition may require only minimal working memory resources, and that the effect of working memory on distractor processing is more complex than was previously assumed.

Shape and Depth from Motion

D75 *475* Shearing and compressive motions work cooperatively to reconstruct structure from motion

Kenchi Hosokawa[1] (hskwk@l.u-tokyo.ac.jp), Takao Sato[1]; [1]The University of Tokyo Graduate School of Humanities and Sociology

Past studies in structure from motion(SfM) revealed that different depth cues such as stereoscopic disparities disambiguate interpretation of SfM. The present study investigated the effect of adding two types of motion cues, shearing motion (e.g. Rogers and Graham, 1979) and compressive motion (e.g. Ullman, 1979) for interpretation of SfM. The stimuli were random dot kinematograms. Relative velocity between dots includes both shearing and compressive components. Both components were projection of a rigid rocking motion (rotation). However, they could be interpreted separately ether rigid or nonrigid motion. Observers were asked to distinguish whether the stimulus appeared rigid or not. In the first experiment, average velocity for shearing motion was fixed and that for compressive motion was manipulated. In the second experiment, averaged velocity for compressive motion was fixed, and that for shearing motion was manipulated. Observers perceived mainly nonrigid motion when the stimuli included only one component, regardless of motion types. However, they perceived rigid rotation as the other motion component increased. This tendency was found in both experiments. These results indicate that the mechanism for SfM utilizes both shearing and compressive motions, and perceptual rigidity increases as variation of cues increases, even when they are only motion components.

D76 *476* Size scaling equates the perception of 3D shape-from-texture and shape-from-motion across the visual field.

Rick Gurnsey[1] (Rick.Gurnsey@concordia.ca), Frédéric J.A.M. Poirier[2], Laurie Leibov[1], Patricia Bluett[1]; [1]Department of Psychology, Concordia University, [2]Neurodynamics and Vision Lab-Centre for Vision Research, York University

Purpose. The parameter E_2 in the equation $F=1+E/E_2$ is used to characterize the rate at which stimulus size must increase with eccentricity (E) to achieve foveal levels of performance in detection and discrimination tasks. Most previous research has employed 2D stimuli for which discrimination can be accomplished with V1 mechanisms. Here we ask whether size scaling is sufficient to equate the perception of 3D shape-from-texture and shape-from-motion tasks across the visual field.**Method.** Both tasks employed 3D surfaces comprising hills, valleys and plains in three possible locations. Therefore there were 27 different surfaces, yielding a 27 alternative forced choice task. Surface shape was conveyed by texture or relative motion. Subjects performed the task at eccentricities of 0 to 16 degrees in the right visual field over a 64 fold range of stimulus sizes.**Results.** For both tasks performance reached 100% correct at all eccentricities. Data for each subject were fit with a Gaussian integral at each eccentricity and from these fits E_2 values were recovered. For the shape-from-texture task the average E_2 was 1.52 and for the shape-from-motion task the average E_2 was .61.**Conclusions.** In all cases, scaling with $F=1+E/E_2$ eliminated all eccentricity variation from the data. The E_2s differed substantially but both average values imply cortical limitations; different limitations may be involved in the two tasks. The data show clear evidence that size scaling is sufficient to equate the perception of shape-from-texture and shape-from-motion across the visual field; at least for the class of stimuli studied here.

D77 *477* Perceived velocity gradients and the rigidity of 3-D shape percepts

Xin Meng[1] (xmeng@sunyopt.edu), Qasim Zaidi[1]; [1]SUNY College of Optometry

If one cycle of an upright, vertical, sinusoidal corrugation, centered at the zero-crossing, is rotated smoothly around the horizontal axis between +/- 30 degrees, the main component of the optic-flow is a horizontal velocity gradient with maxima in opposite directions at peaks and troughs, and minima at zero crossings. A feature correspondence algorithm (Koenderink & van Doorn, 1991) can recover the veridical 3-D shape with a rigidity or smooth deformation assumption. However, with central fixation, observers perceive a grossly non-rigid surface of two convexities rotating in opposite directions (confirmed by separate measures of perceived 3-D curvature and direction-of-rotation for each half-cycle of corrugation). This percept is consistent with a Helmholzian algorithm that assigns relative depth inversely proportional to relative velocity (Sperling & Landy, 1989). The non-rigid percept occurs whether the surface texture conveys veridical 3-D shape or not (Zaidi & Li, 2002) and even if the rotation begins after a static upright view.On prolonged viewing of the rotation, however, sometimes the percept changes to that of a rigidly rotating corrugation in either the veridical or the opposite phase. Is this due to changes in perceived optic-flow as fixation wanders? When fixation location was varied, observers reported the nearer half-cycle as having the greater curvature. It is possible that sensitivity to velocity waveforms falls rapidly with retinal eccentricity (Sachtler & Zaidi, 1995), and that in the absence of strong velocity gradients, 3-D shape capture takes place. Fixation variation alone, however, is not sufficient to reliably create rigid percepts.

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D78 *478* Eye Movement Suppression of Optokinetic After-Nystagmus Disambiguates Depth from Motion Parallax

Chad Stockert[1] (chad.stockert@ndsu.edu), Lindsey Joyce[1], Mark Nawrot[1]; [1]Center for Visual Neuroscience, Department of Psychology, North Dakota State University

The slow eye movement system has a role in the unambiguous perception of depth from motion parallax (MP). A large translating grating field (such as used to drive optokinetic response, OKR) can disambiguate the perception of depth from MP (Nawrot & Stockert, VSS, 2005). The proposed explanation invoked a pursuit signal, generated to countermand the OKR and maintain fixation on a stationary stimulus point, which concomitantly disambiguated perceived depth in the MP stimulus. However, considering that, "In humans and monkeys, the properties of the optokinetic system can only be separated from those of smooth pursuit by studying optokinetic after-nystagmus (OKAN) (Leigh & Zee, 1999)." we investigated whether OKAN, and a countermanding pursuit signal, can disambiguate the perception of depth from MP. Observers adapted to translating grating for 45 sec. followed by a 750 msec blank screen, a fixation point for 500 msec,and then the MP stimulus for 750 msec. The direction of local dot motion within the MP stimulus was varied making the observer's task a report of the MP stimulus depth phase, which depends on the directions of dot movement and pursuit eye movement signal. The pursuit signal should be opposite/countermanding the OKAN. Eye movements were recorded beginning in the last 5 sec of the adaptation phase. So far, two observers, who demonstrate pronounced OKAN during the blank phase,

show a disambiguation of the MP stimulus. Two other observers, who demonstrated little or no evidence OKAN during the blank phase, show no disambiguation of the MP stimulus.

D79 *479* Eye movements, not head translations, determine of perceived depth sign in motion parallax.

Lindsey B. Joyce[1] (mark.nawrot@ndsu.edu), Chad Stockert[1], Mark Nawrot[1]; [1]North Dakota State University

The unambiguous perception of depth from motion parallax (MP) relieson a pursuit-like eye movement signal, regardless of head translation(Nawrot, 2003; Naji & Freeman, 2004). That is, stimulus motion inthe same direction as the eye movement is perceived nearer than atranslating fixation point that drives the eye movement (andremains stationary on the retina). To determine whether thisrelationship is lawfully obeyed regardless of head translation, westudied depth from MP in several conditions where head, monitor,window-on-monitor translations were co-varied and either elicited orprevented a pursuit signal. Within the stimulus window was a Rogers &Graham (1979) type random-dot MP stimulus having local horizontal dottranslations which were varied to alter the phase and amount of depth.In all conditions, stimulus motion in the same direction as the eyemovement was perceived nearer than the fixation point. Headtranslation was neither required for, nor deterministic of, perceiveddepth sign in MP. Instead, head translations are important in thatthey elicit compensatory eye movements that are a combination oftranslation vestibulo-ocular response and pursuit-like visually-driveneye movement. For instance, with identical head translation and localMP stimulus dot movement, direction of stimulus window movementdetermined both the pursuit signal direction and the perceived depth.A stationary stimulus window and stimulus window that translatesidentically with the observer's head translation generate oppositedepth percepts. Indeed, an intermediate between these two extremesgenerates ambiguous depth because the TVOR provides the necessarycompensation and the pursuit signal is absent.

D80 *480* The stability zone of motion parallax with head movements for different velocity gradients

Haruki Mizushina[1] (hmizushi@infoseek.to), Hiroshi Ono[1]; [1]Department of Psychology and Centre for Vision Research, York University, Canada

The stability zone refers to a zone between the concomitant-motion threshold and the depth threshold of motion parallax driven by head movements. In this zone, depth is seen but not motion (i.e., location constancy holds). Ono and Ujike (2005, Perception, 34, 477-90) determined the extent of the stability zone for a stimulus with four horizontal bands of grating. In their stimulus, the adjacent bands moved in opposite directions and the movement of the bands was slaved to the head movement. In this study, we measured the stability zone for stimuli with the four different velocity gradients examined by Rogers and Graham (1979, Perception, 8, 125-34). We found that a different stability zone exists for each gradient, although the sizes of the zone for stimuli with sine and triangle gradients were similar to each other. Moreover, the concomitant-motion thresholds for the stimuli with the sawtooth and square gradients were lower than those for the sine and triangle ones, and therefore the zones were smaller. This result suggests that stimuli with gradients that contain abrupt changes have smaller stability zones.

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D81 *481* Perception of 3-D shape from moving cast shadow in human infants

Tomoko Imura[1] (imura@pri.kyoto-u.ac.jp), Masami K Yamaguchi[2], So Kanazawa[3], Nobu Shirai[2], Yumiko Otsuka[2], Masaki Tomonaga[4], Akihiro Yagi[1]; [1]Department of Psychology, Kwansei Gakuin University, [2]Department of Psychology, Chuo University, [3]Department of Psychology, Shukutoku University, [4]Primate Research Institute, Kyoto University

Motion of cast shadow improves the perception of motion trajectory of the objects (Kersten, Mamassian, & Knill, 1997). Our previous studies showed that moving cast shadow was also effective for 6- and 7-month-old infants to perceive the spatial layout of objects (Imura et al., 2005), however, there are no developmental studies about 3-D shape perception from moving cast shadow. The present study attempted to examine whether infants aged from 4- to 7-month-old discriminate between two 3-D objects' shapes from moving cast shadows using habituation-dishabituation procedure. While an expanding ellipse without a cast shadow is perceived as no rigid and ambiguous for adult observers, manipulating the motion and shape of cast shadows occur two different three-dimensional impressions of objects although the their shapes are identical: one is raising "capsule", and the other is expanding objects like "gum". During habituation phase, infants were presented two identical expanding objects without shadows side by side, and then they were tested "capsule" and "gum". If infants perceive the expanding objects as no rigid objects, they will prefer to look more the "capsule", containing novel 3-D objects, than "gum" during test. The 6- and 7-month-old, but not the 4-and 5-month-old, infants looked significantly longer "capsule" than "gum". These findings suggest that 6- and 7-month-old infants discriminate between two objects' shapes during test. These results revealed that depth perception from cast shadow develops around 6 months, and it is consistent with other pictorial depth cues.

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482 Abstract withdrawn.

Sunday Talk Sessions

Sunday, May 7, 2006

Spatial Vision II (1084, 483-487), Multi-Sensory Processing (488-493), Color Constancy, Lightness and Transparency (494-499), Goal-Directed Hand Movements (500-505), Receptive Fields, Organization, Plasticity (506-512), Cue Integration (513-519), Color: Appearance and Context (520-524), 3D Visual Processing: Space (525-529)

Spatial Vision II

8:00 - 9:30 am

Hyatt Ballroom North

Moderator: Jocelyn Faubert

8:00 *1084* Abnormal contour filling-in process in patients with depression

Uri Polat[1,3] (upolat@sheba.health.gov.il), Ativ Levi[1,3], Anna Sterkin[1,3], Revital Amiaz[2,3]; [1]Goldschleger Eye Research Institute, Tel Aviv University, [2]Dept. of Psychiatry, [3]Sheba Medical Center, 52621 Tel Hashomer, Israel

Cardinal signs of depressive disorder are impairment of cognitive tasks and symptoms that may be mediated by an impairment of the brain reward system (that involved in decision making). We showed (Polat & Sagi, VSS 2005) that collinear interactions (YES-NO paradigm) induce high rate of false alarms (FA) in the Mix by trials condition, probably due to lateral excitation, inducing illusory percepts when targets are not present. Here, we probe the filling in process in three groups; hospitalized patients with depressive symptoms (N=26), out patient (N=6) and control (N=15). We measured sensitivity (d'), response criterion, FA and Hit rate for a Gabor target with different target-flankers separations of 3-12ë (wavelength). In the control group, the probability of reporting target present (FA and Hit) was very high at the shorter separations (3,4ë) and decreased with increasing separation. The performance of the patients is similar to the control group in d', FA and Hit for the larger separations, but FA is reliably different at the short separations (3,4ë). Response criterion at 3ë is significantly increasing with increasing depression level and thus, becomes more different than the control group. Since the differences are restricted for the short separations, global cognitive dysfunction in depression cannot account for the reduced filling in. Rather, it may suggest that the filling in process is compromised,probably due to reduced excitation between neurons. Neural excitation is a key factor in the neural processing involving in the reward system and decision making.

Acknowledgment: Supported by the National Institute for Psychobiology in Israel founded by Charles E. Smith family

8:15 *483* Contrast-modulated stimuli detection is unaffected by luminance-modulated noise

Remy Allard[1] (remy.allard@umontreal.ca), Jocelyn Faubert[1]; [1]Visual Perception and Psychophysics Lab, School of Optometry, University of Montreal

In a previous study, we have shown that the sensitivity difference between luminance- (LM) and contrast-modulated (CM) stimuli results from a difference of internal equivalent noise and not from a difference of calculation efficiency. The objective of the present study was to seek the source of the internal noise limiting the sensitivity to CM stimuli. Three types of noise were used: band-pass LM noise near the carrier (LMN-carrier) or envelope (LMN-envelope) spatial frequency and band-pass CM noise near the envelope spatial frequency (CMN-envelope). For the five observers, the noise contrasts were adjusted to increase the detection thresholds by 0.5 log units for their respective stimuli: carrier, LM and CM. LM and CM detection thresholds were subsequently evaluated in these three noise conditions using a constant stimuli paradigm. As expected, LMN- and CMN-envelope increased the detection threshold of their respective stimulus. However, no cross-type interactions were found: LMN- and CMN-envelope had no significant impact on CM and LM stimuli detection respectively, and LMN-carrier did not affect the detection thresholds of LM and CM stimuli. This double dissociation is strong evidence suggesting that both stimuli are processed, at least partially, by separate mechanisms and that they are not merged after a second-order rectification applied to CM stimuli. The results also suggest that, in the tested conditions, pre-rectification noise affecting the carrier visibility is not a limiting factor for CM stimuli sensitivity.

Acknowledgment: This research was supported by NSERC graduate fellowship to RA and NSERC operating grant to JF

8:30 *484* New insights into amblyopia from classification images

Uma Shahani[1] (u.shahani@gcal.ac.uk), Velitchko Manahilov[1], William A. Simpson[2]; [1]Department of Vision Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, Scotland, UK, [2]Department of Life Sciences, University of Toronto at Scarborough

The amblyope's view of the world is scrambled compared to that of a normal observer, with deficits in processing global motion and orientation. The Classification Image technique was applied here to reveal the strategies used by normal and amblyopic eyes in tasks that required the global integration of information over large areas of the visual field. Two tasks were used: (1) an orientation task requiring a global judgement of an array of Gabor patches having some average orientation, (2) a motion direction task requiring a judgement of global motion direction of moving discs. Each element had an orientation or direction that varied randomly about the mean. Observers judged whether the near-threshold global orientation or motion direction were to the left or right of vertical. Classification images were calculated by adding (element-by-element) noise samples eliciting correct responses and subtracting noise samples producing incorrect responses. The results showed that normal observers had a surprisingly narrow "perceptive field", using motion or orientation information from the central 1-2 deg of their visual fields. A similar picture was seen in amblyopes for the global orientation task with both amblyopic and fellow eyes. However, amblyopic eyes could integrate global motion BETTER than normal eyes: their performance was higher and perceptive fields wider than that of normal or fellow eyes, with sparse sampling of stimulus elements. This sparse sampling over a wider area of the visual field is actually an advantage in global motion judgement tasks and may reflect reduced inhibition in motion processing mechanisms.

8:45 *485* **Orientation discrimination in noise: 7-year-olds are noisier than adults**

Terri L. Lewis[1] (LewisTL@mcmaster.ca), Dorita H.F. Chang[1], Kathryn M. Murphy[1], Daphne Maurer[1], David G. Jones[1]; [1]McMaster University, Hamilton Canada

We used a new high contrast stimulus containing a variable amount of orientation signal in unoriented noise (Jones et al., 2003) to test orientation discrimination in visually normal 7-year-olds and adults (n = 16/grp). The task on each trial was to indicate whether the signal was oriented horizontally or vertically. Percent signal was varied according to a QUEST staircase procedure and thresholds were taken as the lowest orientation signal for which performance was 82% correct. Across 4 runs, stimulus size decreased systematically from 6 – 0.75 deg. In a 5th run, we retested the 6 deg stimulus to rule out fatigue effects. Thresholds were higher in children than in adults and varied with stimulus size (ANOVA, $p < .0002$ for both). Specifically, at both ages, thresholds improved as size increased from 0.75 – 3 deg ($p < .005$ for all) and then reached an asymptote, showing no further improvement beyond 3 deg ($p > .70$). At asymptote, children required 18% signal to discriminate orientation accurately whereas adults required only 12%, indicating that intrinsic noise may be 1.5 times higher in 7-year-olds than in adults. Because contrast sensitivity and motion coherence thresholds are mature by 7 years of age (Ellemberg et al., 1999, 2002), the ability to extract a stationary oriented signal from noise likely involves different neural mechanisms that mature more slowly.

Acknowledgment: Support: CIHR grants MOP-36430 & MOP-13624 NSERC grant 175437-05.

9:00 *486* **Visual and visuo-cognitive development in children born very prematurely: 'dorsal vulnerability' extended.**

Janette Atkinson[1] (j.atkinson@ucl.ac.uk), Oliver J Braddick[2], Marko Nardini[1,2], Shirley Anker[1], Frances M Cowan[3], A David Edwards[3], Mary A Rutherford[4]; [1]Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK, [2]Visual Development Unit, Dept of Psychology, University College London, Gower St, London WC1E 6BT, UK, [3]Department of Pediatrics, Imperial College Faculty of Medicine, Hammersmith Hospital, London, UK, [4]Imaging Sciences Department, Imperial College, Hammersmith Hospital, London, UK

Because visual cortical functions develop rapidly in the months after term, they provide a sensitive indicator of disruption to normal brain development (Atkinson, *The Developing Visual Brain*, OUP 2000). We have used two indicators of early cortical development, the orientation reversal VEP, and attention shifts under competition, to test at-risk infants born very prematurely (<32 weeks gestation). In healthy neurologically normal preterm infants these measures show a similar developmental course to that of term infants. Deficits and delays in these functions correlate with the severity of white matter damage seen on term MRI in infants in the at-risk group.Follow up of these preterm infants to age 6 (n=78), with a range of measures of visual and perceptual function, visuomotor development, spatial cognition, attention and executive function, show that even those who showed little or no white matter damage on MRI nonetheless perform on average below norms of spatial, perceptual and attentional function, including motion coherence sensitivity, although language development and form coherence sensitivity are normal. The relation of these measures to early visual cortical indicators will be discussed.Principal components analysis on all these measures for preterm 6-7 year olds shows one component related to frontal function and another to broadly parietal function, with temporal lobe functions largely unaffected. The components revealed, and the relation between form and motion coherence sensitivity, extend the phenomenon of 'dorsal stream vulnerability' seen in a wide range of developmental disorders such as Williams syndrome, autism, and fragile X. Website: *http://www.psychol.ucl.ac.uk/vdu/publications.html*

Acknowledgment: Medical Research Centre grant G7908507

9:15 *487* **Stimulating "impossible" visual space with TMS.**

Daw-An Wu[1,2] (daw-an@caltech.edu), Junghyun Park[1], Shinsuke Shimojo[1,2,3]; [1]California Institute of Technology, USA, [2]JST/ERATO Shimojo Implicit Brain Research Project, [3]NTT Communication Science Laboratory, Japan

When peering through binoculars, one is aware of the darkness that frames the field of view. However, no such darkness frames our everyday field of vision. When we move our eyes to gaze at the periphery, substantial portions of the retina fall under shadow. But rather than perceiving the dark insides of our skulls, we experience a shrinking field of awareness. Hayhoe & Williams (1984) and Cavanagh & Barton (VSS 2001) used afterimages and scleral illumination to show that retinal stimulation at these "impossible" locations in space is blocked from visual awareness.Here, we directly stimulate visual cortex with transcranial magnetic stimulation, inducing percepts of brightness (phosphenes). Phosphenes are generally induced in the lower visual hemifield, in a retinotopically stable fashion. When participants look downward, these retinotopic locations can move outside the visual field. Participants were tested both in total darkness and under low illumination. They reported the spatial position and extent of their phosphenes with respect to various fixation points.Almost all participants reported one or both of the following: 1) In the dark, phosphenes could extend into impossible locations. Participants reported phosphenes "inside my cheeks/chest", "behind my ears", etc. 2) Under room lights, these percepts were abolished. Instead, participants reported retinotopic shifts in location or the "squashing" of shapes to fit within the visual field.TMS bypasses the mechanism which gates retinal input, allowing visual awareness to extend into ecologically impossible space. However, when environmental cues are present, it appears that spatial correspondences can be remapped to comply with visual field boundaries.

Multi-Sensory Processing

8:00 - 9:30 am

Hyatt Ballroom South

Moderator: David Burr

8:00 *488* **Changing and Steady Vection Effects on Simulator Sickness**

Frederick Bonato[1] (fbonato@spc.edu), Andrea Bubka[1], Stephen Palmisano[2]; [1]Saint Peter's College, [2]University of Wollongong

Vehicle simulators and other virtual environments often lead to *vection*, a form of self-motion perception that can significantly enhance the realism of simulator displays. Unfortunately, a form of motion sickness known as *simulator sickness* often accompanies vection. What is the relationship between vection and simulator sickness? A fuller understanding of vection may offer answers. Vection can increase or decrease in magnitude, change direction, or vary in perceived velocity (*changing vection*), or vection can be a steady perceptual experience (*steady vection*). It was hypothesized that changing vection is the main causal agent of simulator sickness. The underlying logic: the vestibular system responds only to changes in tilt, velocity, and heading. If a participant's head is immobilized and vection is steady, visual and vestibular sensory inputs should be the same as if actual self-motion were occurring. Under such conditions of actual self-motion, sickness is rare. Method: experiments were conducted using optical flow patterns on a CRT computer monitor and in optokinetic drums. The direction and velocity of the patterns were manipulated. Vection was measured using a computer interfaced slide control that participants were asked to push with increasing force to indicate that vection magnitude was increasing. Simulator sickness was measured using the Simulator Sickness Questionnaire designed by Kennedy and colleagues (1993). Results: stimuli that changed direction and/or velocity yielded significantly more simulator sickness. Conclusion: changing vection is the main cause of simulator sickness perhaps because it is accompanied by a higher degree of visual/vesti-

bular disparity compared to steady vection.

Acknowledgment: Supported by NSF Grant BCS-0447785

8:15 *489* Multi-sensory comparison improves signal discrimination

Ansgar Koene[1] (a.koene@ucl.ac.uk), Derek Arnold[2], Alan Johnston[1,3]; [1]University College London, Psychology Department, London, UK, [2]University of Sydney, Department of Psychology, Sydney, Australia, [3]University College London, CoMPLEX, London, UK

We asked whether a multi-modal signal provides benefits in discrimination performance over and above that afforded by having two samples. Observers judged whether the frequency of a sinusoidal amplitude-modulated 3kHz tone and/or Gaussian blob was greater or less than 10Hz. The signals were embedded in additive band-limited white noise centered on 10Hz. There were 6 conditions in which judgments were based on: single visual (1) or auditory (2) stimuli; simultaneous (3) or sequential bi-modal (4) stimuli (random order) or repeated visual (5) or auditory (6) stimuli. External noise amplitude was adjusted such that performance in conditions 1 and 2 was the same. In conditions 3-6 the signal in both repetitions/modalities was the same while the added noise was independent.Conditions 3 & 4 tested whether bi-modal effects require simultaneous bi-modal presentation. Conditions 5 & 6 tested whether performance improved when information was presented twice in the same modality. We found 1. frequency discrimination improved when stimuli were presented in two modalities; 2. performance improvement did not require simultaneous presentation in both modalities; 3. repeated stimulation in the same modality did not improve discrimination performance. In a separate detection experiment we found no difference between bi-modal and uni-modal repetitions. There was no difference between adding further noise to the first or second paired item demonstrating that both repeated items had equal weight. These results suggest that a-modal signal properties (e.g. amplitude modulation rate) are evaluated by a process of within-modality signal discrimination followed by weighted averaging of the uni-modal estimates.

8:30 *490* Moving ventriloquism: forward drifts and sharp resets in perceived audio-visual simultaneity

Shinsuke Shimojo[1,2] (sshimojo@caltech.edu), Ryota Kanai[1], Bhavin Sheth[3,4]; [1]Biology, California Institute of Technology, Pasadena, CA, [2]ERATO Project, Atsugi, Japan, [3]Electrical and Computer Engineering, University of Houston, Houston, TX, [4]Center for Neuroengineering and Cognitive Sciences, University of Houston, Houston, TX

Attention is known to modulate sensory inputs; however little is known on how the interactions between top-down and bottom-up cues dynamically evolve. Here, we show that auditory-visual perception changes systematically and non-monotonically from an interaction of sensory and attentional factors during the continuous viewing of a physically invariant stimulus. The stimulus was a visual target (flash) revolving about fixation. On every rotational cycle (60 cycles/trial x 534 ms per cycle = 32.04 s), a sound occurred in synchrony with the same angular position of the flash. For each cycle, observers (n=10) had to report on the perceived location of the flash coincident with the perception of sound (audio-visual synchrony). The initial estimate of the location of audio-visual synchrony was slightly behind veridical audio-visual synchrony, but then over subsequent cycles, gradually moved forward in the direction of the motion. This steady drift was followed by a sharp reset back to the initially judged position. This perceptual sequence was qualitatively common across observers. When we manipulated attention to specific positions of the cycle on a trial, the location of audio-visual synchrony moved and remained there. The results show a striking parallel to the continuous report data suggesting the transitions are mediated by an attractive effect on audiovisual timing exerted by attention. Motion seems to drag spatial attention forward from the location of veridical audio-visual synchrony. As attention drifts far beyond veridical, its effect is overruled by the near-veridical sensory synchrony signals and the perceived position of audio-visual synchrony snaps back to near-veridical.

8:45 *491* Auditory-motor delay adaptation modulates subjective simultaneity of visually observed other's action and auditory stimuli

Masataka Watanabe[1] (watanabe@sk.q.t.u-tokyo.ac.jp), Shion Shinohara[1], Shinsuke Shimojo[2,3]; [1]Dept. of Quantum Eng. and Systems Science, School of Engineering, University of Tokyo, [2]Division of Biology, California Institute of Technology, [3]NTT Communication Science Laboratories, NTT Corporation

Prolonged exposure to biased sensorimotor relationship leads to recalibration of the two modalities, spatially (Welch 1978) and/or temporally (Cunningham et al. 2001). We question if personal sensorimotor adaptation modulates the perception of others performing identical motor actions with sensory feedback. The experiment consisted of three phases: pretest, adaptation and post-test. In the adaptation phase, subjects were exposed to temporal misalignment of auditory stimulus and arm motion. Subjects moved a computer mouse horizontally while a delayed (150ms) "click" sound was delivered whenever the mouse ceased to move. We instructed the subjects to temporally align the "click" to a metronome "beep". Only a fixation spot was displayed on the monitor and the subject's arm was screened to eliminate possible auditory-visual adaptation.For the test of adaptation, we examined three types of subjective simultaneity on an event basis without the use of a metronome. In the "self" test, the participants judged the simultaneity of self mouse stoppage and a "click" sound. In the "other" test, the participants viewed the experimenter maneuvering the mouse and judged the simultaneity of mouse stoppage and a "click". Finally for control, we tested the subjective simultaneity of a simple visual flash and a "click".The psychophysical results indicated statistically significant shifts in subjective simultaneity toward the lag of auditory stimulus for both the "self" test (+72 ms) and the "other" test (+35 ms), but not for control. Our results suggest possible involvement of the mirror system in projecting personal sensorimotor recalibration to observation of other's action.

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9:00 *492* Auditory capture of visual stimuli in time is statistically optimal

David C. Burr[1] (dave@in.cnr.it), M. Concetta Morrone[2], Martin Banks[3]; [1]Department of Psychology, University of Florence, Italy, [2]Faculty of Psychology, Universita' Vita-Salute "San Raffaele", Italy, [3]School of Optometry and Department of Psychology, University of California Berkeley, USA

The "ventriloquist effect" (mislocalization of sound toward a visual stimulus) is consistent with statistically optimal integration of visual and auditory signals (Alais & Burr, *Curr. Biol.*, 2004). Here we report that "temporal ventriloquism", the tendency for a sequence of sounds to "capture" visual flashes in time (Shams & Shimojo, *Nature*, 2000), is also consistent with optimal integration. Subjects performed a temporal-bisection task, reporting whether the second (probe) stimulus in a 3-stimulus (800 ms) sequence was closer in time to the first or third. In single-cue sessions, the three stimuli were all either visual flashes or auditory tones. In two-cue sessions, all stimuli consisted of a flash and tone, presented simultaneously for the second stimulus, but at consistently different times for the first and third stimuli. The perceived point of bisection in the two-cue condition was determined more by tone than flash timing, but both cues influenced the bisection. The results were well predicted from optimal combination of the visual and auditory cues with relative weights derived from the single-cue thresholds. Importantly, bisection thresholds in the two-cue condition were significantly better than in either single-cue condition, strong evidence for inter-modal combination. Further discrimination experiments suggested that combination was not mandatory (Hillis et al., *Science*, 2002); rather subjects retain access to single-cue information as well as the combined information, calling into question the concept of mandatory temporal binding.

9:15 *493* **Role of Attention in Visual-Auditory Crossmodal Interactions**

Karla K Evans[1] (kevans@princeton.edu), Anne Treisman[1]; [1]Princeton University

The brain derives information from several sense modalities to enhance the speed and accuracy of detection of objects and events, and the choice of appropriate responses. There is mounting evidence that perceptual experiences that may appear to be modality specific are also influenced by activity from other sensory modalities, even in the absence of awareness of this interaction. In a series of speeded classification tasks we found natural spontaneous mappings between the pitch of sounds and the visual features of vertical location, size and spatial frequency. The facilitatory effects we observed during congruent bimodal stimulation hint at the automatic nature of these crossmodal interactions. In the present studies we examined the role of attention in the interaction between crossmodal features. Participants performed speeded classification or search task of low or high load while ignoring irrelevant stimuli in a different modality. We found in both paradigms that crossmodal irrelevant distractors were processed regardless of the difficulty of the classification or of the search task. Congruency between the visual and the irrelevant auditory stimulus had an equal effect in the low and in the high load conditions. A third experiment tested divided instead of selective attention, requiring participants to compare stimuli on both modalities and respond to the visual-auditory compound. Here too the congruency effect was no larger with attention divided across both modalities than when it was focused on one. These findings offer converging evidence that interaction between corresponding audio-visual features is not dependent on attention.

Color Constancy, Lightness and Transparency

11:00 - 12:30 pm

Hyatt Ballroom North

Moderator: Frans W Cornelissen

11:00 *494* **fMRI of relational color constancy in human visual cortex**

Frans W Cornelissen[1,2] (f.w.cornelissen@rug.nl), Just J. van Es[1,2], Tony Vladusich[1]; [1]Laboratory of Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands, [2]NeuroImaging Centre, School of Behavioural and Cognitive Neurosciences, University Medical Centre Groningen, Groningen, The Netherlands

Human subjects are able to judge colors relatively independently of illumination, a phenomenon called color constancy. Psychophysical studies indicate that color constancy is not a unitary phenomenon, and that processes of adaptation and spatial comparison may take place at multiple sites in the visual system. To explore the nature of cortical computations underlying different aspects of color constancy, we performed a functional magnetic resonance imaging (fMRI) study. Subjects judged whether a chromatic or achromatic target embedded in an array of patches (a) stayed the same across a simulated illumination change (local surface judgment), or (b) changed in a manner consistent with the illuminant change (relational surface judgment). Psychophysical evaluation of subjects? performance indicated that constancy was low in the local judgment task and high in the relational task. Color-sensitive cortical areas were localized through their preferential response to chromatic versus achromatic stimuli. Compared to a control task in which colors were viewed passively, the local judgment resulted in equally large increments in BOLD activation of color-sensitive areas. Similar results were obtained for chromatic and achromatic patterns. Earlier visual areas showed a similar pattern of results. These data suggest that task-related differences in color-area activation were aspecific and primarily associated with the use of surface color, rather than computations specifically associated with color constancy. Moreover, relational judgments were associated with additional activation of parietal and frontal regions, relative to local judgments, indicative of the spatial nature of the task.

Acknowledgment: This work was supported by grant 051.02.080 of the Cognition program of the Netherlands Organization for Scientific Research (NWO).

11:15 *495* **Colour constancy is not based on estimating the colour of the illumination**

Jeroen JM Granzier[1] (j.granzier@erasmusmc.nl), Jeroen BJ Smeets[1], Eli Brenner[1]; [1]Department of Neuroscience, Erasmus MC, Rotterdam, The Netherlands

Objects hardly appear to change colour when the spectral power distribution of the illumination changes: a phenomenon known as colour constancy. Colour constancy could either be achieved by basing the perceived surface colour on properties that do not change with the illumination (such as spatial colour contrast), or by estimating and compensating for the chromaticity of the illuminant. The advantage of the second approach is that knowing the illuminant's colour can itself be useful. Here we examined whether subjects can judge the illuminant's colour well enough to account for their own colour constancy under the same conditions. Subjects were very poor at matching the colour of the lamp illuminating a scene with the light from a single surface on a calibrated monitor. They were much better at choosing the sample that matches the colour of paint of a surface illuminated by the same lamp than one would predict from their judgments of the lamp's colour. We conclude that colour constancy must be achieved by relying on relationships that are insensitive to the illumination, rather than by directly judging the colour of the illumination.

11:30 *496* **Sensitivity to gradients in complex scenes**

Alexa I Ruppertsberg[1] (a.i.ruppertsberg@bradford.ac.uk), Anya Hurlbert[2], Marina Bloj[1]; [1]Department of Optometry, University of Bradford, Bradford BD7 1DP , UK, [2]Henry Wellcome Building for Neuroecology, Newcastle University, Newcastle upon Tyne NE2 4HH, UK

Image gradients – smooth changes in colour and luminance – may be caused by intrinsic surface reflectance properties or extrinsic illumination phenomena, including shading, shadowing and inter-reflections. In turn, image gradients may provide the visual system with information concerning these factors, such as the orientation of surfaces with respect to the light source. The colour gradients induced by mutual illumination (MI) may play a similar role to that of luminance gradients in shape-from-shading algorithms; it has been shown that 3D shape perception modulates the influence of MI on surface colour perception (Bloj, Kersten, & Hurlbert, 1999, Nature, 402, 877-879). Here, we assess human sensitivity to changes in MI-induced colour and luminance gradients that arise from changes in the light source position, within a complex natural scene. In Experiment 1 we tested whether observers were able to discriminate between gradients due to different light source positions. We found that observers reliably detected a change in the gradient information when the light source position differed by only 4 deg from the reference scene. This sensitivity was mainly based on the luminance information in the gradient (Experiment 2 and 3). Some observers make use of the spatial distribution pattern of gradients when discriminating between them (Experiment 4). The high sensitivity to gradient differences supports the notion that MI-induced gradients contain information that can support recovery of 3D shape and scene configuration properties.

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11:45 *497* **Scission and the Perception of Lightness**

Barton L Anderson[1] (bart.a@unsw.edu.au), Jonathan Winawer[2]; [1]UNSW, Sydney, Australia, [2]MIT, Cambridge, MA

A fundamental problem in vision science is determining the nature of the

computations and representations underlying lightness perception. One view is that lightness perception involves the explicit decomposition (or scission) of images into causal factors, with separate estimates of illumination, reflectance, and transparency. An alternative view asserts that the image is separated into 2-D frameworks, and principles of anchoring and grouping are used to determine relative lightness. According to the frameworks view, there is no need to posit distinct layers in order to estimate lightness. We have recently shown that layered image representations (scission) can play a decisive role in lightness perception in conditions of inhomogeneous transparency (Anderson & Winawer, 2005). We argued that the contrast relationships along borders play a key role in causing scission, which in turn was responsible for the lightness illusions in these displays. To further assess the causal role of scission in these illusions, we manipulated the contrast relationships along target/surround borders by simply introducing a thin grey outline around the targets. These outlines cause polarity reversals along the boundaries of the target/surround regions, and are therefore inconsistent with transparency. We find that these manipulations completely abolish the lightness illusions and percepts of transparency in these displays. We argue that these phenomena, in conjunction with demonstrations reported by Hering and Mach, and more recently by Kennedy & Bai (2000), provide strong evidence that the visual system computes lightness by decomposing images into layered representations.

12:00 *498* **Computing lightness at a slant: Taking light source direction into account versus a relaxed coplanar ratio model.**

Alan L Gilchrist[1] (alan@psychology.rutgers.edu), Ana Radonjic[1]; [1]Rutgers University - Newark

According to several recent reports, lightness constancy under target rotation (relative to light source) is achieved by taking target slant and light source direction into account. In fact there is a simpler explanation: a relaxed version of the coplanar ratio principle (Gilchrist, 1980); The strength of a ratio between two surfaces weakens as their coplanarity weakens, either when the surfaces are displaced away from each other while remaining parallel, or when one surface rotates away from the plane of the other. We pitted these accounts against one another using an actual scene containing blocks resting on the floor, spheres floating in midair, attached shadows, cast shadows, glossy highlights and luminance gradients. The target square, always attached to the middle of the right-facing side of a large cube, appeared in different orientations. The general light source was located to the upper left, except that the cube was shadowed from this light source and illuminated by a hidden projector located off to the right. This gave the right face of the cube a higher luminance than the left face. Thus, as a target of fixed luminance is rotated successively away from the general light source, the high-level taking into account theory predicts lower lightness values, while the relaxed coplanar ratio principle predicts darker values. We found that the target appeared about two Munsell steps darker in the extreme rotated position, compared to a position normal to the general light source. Our results support a mid-level, relaxed coplanar account over a high-level account.

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12:15 *499* **Multidimensional scaling (MDS) analysis of achromatic transparency**

Karin petrini[1] (karin.petrini@unipd.it), Alexander Logvinenko[2]; [1]Department of General Psychology, University of Padova, [2]Department of Vision Sciences, Glasgow Caledonian University

As an object is always viewed through some media (atmosphere), the intensity of light coming to the eye (L) is affected by both the object reflectance (r), and the media transmittance (t): L= Itr+a. Here I is the incident light intensity; and a is the scattered light intensity.A perceptual correlate of r is the object's lightness. A perceptual correlate of t is the apparent clearness (transmittance) of the media, a being experienced as "fogginess" of the media. The latter make up two perceptual dimensions of the media. When they are present in perception, achromatic transparency is said to be perceived. Yet, Robilotto, Khang & Zaidi (2002) claimed that achromatic transparency was one-dimensional. This is in line with the classical study by Metelli who used only two dimensions (lightness and strength of transparency) to describe a percept with achromatic transparency. Since lightness is a perceptual attribute of object rather than media, we conclude that achromatic transparency in Metelli's model was also one-dimensional.We used nine Adelson's tile patterns to produce an impression of achromatic transparency. The patterns simulated four different transmittances (t) and two levels of a. Pairs of the patterns were presented to five observers with an instruction to assign a rate of dissimilarity between the achromatic transparencies by a number on a 30 point-scale. The output configuration from the non-metric MDS was clearly two-dimensional, confirming the two-dimensionality of the achromatic transparency. One dimension correlated with t, the other one with a.

Goal-Directed Hand Movements

11:00 - 12:30 pm

Hyatt Ballroom South

Moderator: Pascal Mamassian

11:00 *500* **Visuo-Motor Synchrony**

Pascal Mamassian[1] (pascal.mamassian@univ-paris5.fr); [1]CNRS & Universite Paris 5

Our interaction with dynamic objects requires an accurate synchrony of motor actions with visual events. Such a synchrony must overcome two hurdles, namely delays and variabilities in both visual and motor processing. These two issues are addressed here in experiments that manipulate the gain of making movements synchronous with visual events. Participants were presented with six dots displayed at the vertices of a hexagon. The dots were presented in pairs, the stimulus onset asynchrony (SOA) between the first two pairs being equal to the SOA between the last two pairs (500 msec). Participants were instructed to press a key simultaneously with the presentation of the last pair. If they were accurate within a narrow temporal interval, they received 100 points. Depending on the condition shown graphically at the beginning of the trial, they could also lose 200 points if they were too fast or too slow. To maximize gain, there is an optimal time at which participants should anticipate the onset of the final stimulus based on their visual and motor variabilities. We estimated each participant's variabilities from the condition where there were no penalties and measured their efficiency in conditions where a penalty was introduced. We found significant inefficiencies consistent with risk aversion. The results indicate either that participants underestimate their motor variability or that they do not use an optimal strategy to time motor actions with visual events.

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11:15 *501* **Grasping trapezoidal objects**

Urs J Kleinholdermann[1] (urs@kleinholdermann.de), Eli Brenner[1], Volker H Franz[2], Jeroen B J Smeets[1]; [1]ErasmusMC, Rotterdam, The Netherlands, [2]Justus Liebig University, Giessen, Germany

The most simple view of grasping with a precision grip assumes that humans close index finger and thumb in opposite directions around the object. For circular and rectangular objects, this will result in a perpendicular approach of each digit to the surface. Thus they move in the right direction for the application of grip force after contact. Grasping trapezoidal objects at their non-parallel surfaces in this way will result in a non-perpendicular approach to the surface. However, Smeets & Brenner (1999)

assume that humans try to approach an object's surface perpendicularly in order to deal with spatial inaccuracies. We used trapezoidal objects to discriminate between these views. Twenty-three participants grasped trapezoids with angles between -20 and +20 degree in steps of 5 degree.We found a tendency to approach the objects' surfaces orthogonally. This suggests that during the grasping movement participants aimed for an optimal placement accuracy of the digits rather than for an optimal direction of grip force after contact.

Acknowledgment: Supported by the Studienstiftung des deutschen Volkes

11:30 *502* The Contribution of Visual and Proprioceptive Information to the Precision of Reaching Movements

Simona Monaco[1,2] (smonaco2@uwo.ca), Patrizia Fattori[2], Claudio Galletti[2], Melvyn A. Goodale[1], Grzegorz Kroliczak[1], Derek Quinlan[1], Jody C. Culham[1]; [1]University of Western Ontario, London, Canada, [2]University of Bologna, Italy

We examined how the precision of ballistic reaching movements was affected by the availability of visual and proprioceptive information. Twelve right-handed subjects made reaching movements with the index finger of their right hand either to an external target or to the fingertip of their left hand (body target), which had been passively moved to the target location by the experimenter. Subjects always had a 2-s preview of the target, followed by a delay of 2-s, after which the reaching was initiated under three different levels of vision: no vision, brief vision until the initiation of the movement, or full vision until the end of the movement. We measured the error of the final reaching position with respect to the target. The addition of proprioceptive information (body vs. external target) improved precision when vision was limited (no vision or brief vision) but not when full vision was available. Moreover, the addition of proprioceptive target information had different effects on errors in movement amplitude vs. heading (side-to-side direction). Movement amplitude errors were small when proprioceptive information was available, regardless of the amount of visual information. In contrast, heading errors depended on the amount of visual information available even when proprioceptive information was also provided. These results suggest that proprioception is particularly valuable in encoding the distance of the target (and the amplitude of the required reach), while vision is particularly valuable in encoding the direction of the target (and the heading of the reach).

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11:45 *503* Automatic adjustment of visuo-motor readiness

Joo-Hyun Song[1] (jhsong@fas.harvard.edu), Ken Nakayama[1]; [1]Harvard University

Subjects more rapidly initiated reaching to a single lone target than to an odd-colored target among distractors, reflecting differentiated states of sensori-motor readiness for easy vs. hard tasks. This occurred only when trials were presented in separate blocks. The pattern was eliminated when the two trial types were randomly mixed, showing homogenization; increased latencies for single trials, and decreased latencies for odd-colored trials. The faster movement initiation in the odd-colored target task was accompanied by curved trajectories, directed initially toward a distractor but corrected in mid-flight. Two possible hypotheses could account for this differentiated adjustment in visuo-motor readiness when the different trials are presented in separate blocks: (1) explicit knowledge of upcoming trial types (2) history of the very recent past, i.e. repetition of same type of trials. To distinguish between these two accounts, we included a third condition where the trial types were predictably alternated. Contrary to the explicit knowledge hypothesis, this also led to homogenization of initiation latencies and curved trajectories. From this and additional experiments manipulating the length of same type repetitions, we conclude that explicit knowledge of upcoming trials plays no observable role in determining visuo-motor readiness. This is determined only by the very recent history of trial repetitions.

12:00 *504* Practice makes perfect, but only with the right hand: Sensitivity to perceptual illusions with awkward grasps decreases with practice in the right but not the left hand

Claudia L. R. Gonzalez[1] (cgonzal6@uwo.ca), Tzvi Ganel[2], Robert L. Whitwell[1], Brendan Morrissey[1], Melvyn A. Goodale[1]; [1]Department of Psychology, University of Western Ontario, [2]Department of Behavioral Sciences, Ben-Gurion University of the Negev

It has been proposed that the visual mechanisms that control well-calibrated actions, such as picking up a small object with a precision grip, are neurally distinct from those that mediate our perception of the object. Thus, grip aperture in such situations has been shown to be insensitive to many size-contrast illusions. But most of us have practiced such movements hundreds, if not thousands of times. What about less familiar and unpracticed movements? Perhaps they would be less likely to be controlled by specialized visuomotor mechanisms and would therefore be more sensitive to size-contrast illusions. To test this idea, we asked right-handed subjects to pick up small objects with their right hand using either a normal precision grasp (thumb and index finger) or an awkward grasp (thumb and ring finger), in the context of the Ponzo illusion. Even though this size-contrast illusion had no effect on the scaling of the precision grasp, it did have a significant effect on the scaling of the awkward grasp. Nevertheless, after three consecutive days of practice, even the awkward grasp became resistant to the illusion. In a follow-up experiment, we found that awkward grasps with the left hand (in right handers) did not benefit from practice and remained sensitive to the illusion. We conclude that skilled target-directed movements are controlled by visual mechanisms that are quite distinct from those controlling unskilled movements, and that these specialized visuomotor mechanisms may be lateralized to the left hemisphere.

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12:15 *505* Attentional modulation of neural responses to action observation: implications for models of the human 'mirror' system

Trevor Chong[1] (trevorc@unimelb.edu.au), Mark A Williams[1, 2], Ross Cunnington[3], Jason B Mattingley[1]; [1]Cognitive Neuroscience Laboratory, Department of Psychology, University of Melbourne, Victoria 3010, Australia, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA 02139, [3]Neuroimaging and Neuroinformatics, Howard Florey Institute, Victoria 3010, Australia

Mechanisms underlying human action recognition are mediated by a network of cortical areas located within the premotor cortex, inferior parietal lobe and superior temporal sulcus. Current models suggest that activity within these regions arises relatively automatically during passive observation of meaningful actions, without the need for top-down control. Here we used functional magnetic resonance imaging to determine whether cortical activity associated with action observation is modulated by the strategic allocation of selective attention. Normal observers viewed brief movie clips of reach-to-grasp actions while performing a visual discrimination task at the fovea. The attentional demands of the central task were varied systematically to yield 'low' and 'high' load conditions, and the efficacy of these manipulations was verified behaviourally prior to scanning. Prior to the experimental runs, localiser scans were acquired to define functional areas involved in action observation. These areas were then used as regions-of-interest in subsequent analyses of the effects of the attentional task on neural responses to action observation. Our results suggest that cortical areas involved in action observation are significantly modulated by attentional load. Thus, although the areas that encode meaningful actions can be engaged relatively automatically, these regions are also influenced by the strategic allocation of selective attention. Our findings

have important implications for recent attempts to link the human action-observation system to response properties of 'mirror neurons' in monkeys.

Receptive Fields, Organization, Plasticity

2:00 - 3:45 pm

Hyatt Ballroom North

Moderator: Anna Roe

2:00 *506* **Functional stealing: reorganization of the retinotopic map after occipital lobe infarct.**

Lucia M Vaina[1,2] (vaina@bu.edu), Sergei Soloviev[1]; [1]Brain and Vision Research Laboratory, Biomedical Eng&Neuroscience Dept. Boston University, [2]Department of Neurology, Harvard Medical School

fMRI in a neurological patient with a right hemisphere infarct showed that the lesion partially involved the areas V1, V2d, V2v and VP. Method: To localize and quantify training related changes in activity over time we performed retinotopic mapping and hMT+ localization at: 3, 6 and 9 months after the infarct. Using surface-based measurements we quantified the reorganization and areas-shifts by measuring distances between the center of mass of functionally defined areas. Shifts between areas were computed in spherical surface-based coordinates. Results: Areas V1, V2v, V2d and VP were initially smaller in the affected side compared to the normal side, but increased significantly over time, at the expense of functional areas not involved in the lesion (V3, V4, hMT+) which became comparatively smaller. At 9 months there was an impressive reorganization of the early retinotopic areas in the lesioned (right) hemisphere but not in the normal hemisphere or in normal subjects. The most dramatic changes were seen in areas presumably involved in mediating the visual motion tasks that the patient was trained on over 9 month in weekly 3 hours sessions. Conclusion: The extent of shift and change in areas' surface demonstrate training-dependent large-scale reorganization in the retinotopic map around the lesion. Topography was maintained, but there was a dramatic functional stealing from nearby intact areas by areas involved in the lesion. Areas involved in the lesion and solicited by the motion tasks during training expanded, while areas not involved in lesion, but underlying the trained motion stimuli, became smaller.

2:15 *507* **Ocular Dominance Plasticity Maintained by Cyclic AMP-dependent Protein Kinase Activation: A General Mechanism in Visual Cortex**

Takuji Kasamatsu[1, 2] (takuji@ski.org), Kazuyuki Imamura[2]; [1]Smith-Kettlewell Eye Research Institute, 2318 Fillmore St., San Francisco, CA 94115, [2]Laboratory of Visual Neurocomputing, Brain Science Institute, RIKEN, Wako-shi, Saitama, 351-0198 Japan

Animals learn throughout life. Noteworthy is their innate capacity to shape individually brain function through own experience. This experience-guided modification of behavior is especially strong early in life and becomes substantially weak after the animal's maturation. Neural mechanisms underlying cortical plasticity have been extensively investigated till today, using changes in ocular dominance of binocular cells in visual cortex (ocular dominance plasticity, ODP). Higher mammals such as cats and monkeys have provided us with the best animal model of a developmental disorder of spatial vision in human called amblyopia-ex-anopsia, which affects ~3 % of the global population. Cortical infusion of an inhibitor of cyclic AMP-dependent protein kinase blocks shift in ocular dominance in young kittens following brief monocular deprivation. ODP is also lost in kitten cortex infused with either a catecholaminergic neurotoxin or a â-adrenoreceptor blocker. Activation of protein kinase A enhances ODP in adult cortex, which is usually not plastic. We then asked whether the same mechanisms could enhance ODP in kitten visual cortex that once lost the expression of plasticity due to prior pharmacological treatments. Cortical infusion of cyclic AMP-related drugs (cholera toxin A-subunit or dibutyryl cyclic AMP) in two types of aplastic kitten visual cortex, concurrently with monocular deprivation, resulted in clear shift in ocular dominance to the non-deprived eye. We conclude that, irrespective of the age of animals, activation of protein kinase A cascades is a general mechanism to enhance ODP, its strength being substantially higher in the immature than mature cortex.

2:30 *508* **Cortical states determine the polarity of orientation plasticity in primary visual cortex**

Ralf A.W. Galuske[1,2] (galuske@bio.tu-darmstadt.de), Wolf Singer[2], Matthias M.H.J. Munk[2]; [1]Dept. of Biology, Technical University Darmstadt, [2]Max-Planck-Institute for Brain Research

In the present study we examine in how far orientation maps in the visual cortex are susceptible to use-dependent modifications under conditions of enhanced synchronization of neuronal responses. To induce modifications, we paired visual stimulation with oriented gratings to electrical activation of the mesencephalic reticular formation (MRF). This structure plays a central role in regulating wakefulness and gating attention and is known to enhance stimulus-induced synchronization of cortical responses. Our results indicate that cortical responses to stimuli which were paired with reticular activation were enhanced as seen by optical imaging of intrinsic signals and extracellular recordings of cortical units. Orientation domains representing the repetitively presented stimuli were enhanced and enlarged into the neighboring regions. Simultaneously recorded cortical units likewise expressed a shift in orientation preference towards the paired orientation if their pre-pairing preference differed 10°-30° from the orientation of the conditioned stimulus. This effect was strongly dependent on the degree of cortical activation as determined by the amount EEG-power induced by MRF stimulation in the gamma-frequency range (25-65Hz). If no or very weak cortical activation was induced, cortical responses habituated upon repetitive stimulus presentation. This study shows that the representation of stimulus orientation in cat adult visual cortex is susceptible to use-dependent modification if the cortex is in a sufficiently activated functional state. The recruitment of additional cell populations by changing their response selectivity and synchronization pattern provides important constituents of the neuronal mechanisms for the modification of representations in neocortex.

Acknowledgment: This work was supported by the MPG

2:45 *509* **Preliminary studies examining the feasibility of a visual prosthetic device: 2. The laminar specificity of electrical stimulation in monkey area V1 and the visual percepts created.**

Peter H. Schiller[1] (phschill@MIT.EDU), Edward J. Tehovnik[1], Veronica S. Weiner[1]; [1]MIT, Cambridge, MA

We examined the effects of electrical stimulation of area V1 in the monkey to determine the feasibility of using implanted electrode arrays as a visual prosthesis. Area V1 in the monkey is lissencephalic making for easy access; the visual field is laid out topographically and the receptive fields of the neurons are quite small. Our experiments show the following: 1. Low levels of electrical stimulation reveal laminar specificity; when electrical stimulation is paired with a visual target presented in the receptive field of the stimulated neurons, in the upper layers target selection is interfered with whereas in the lower layers target selection is facilitated. 2. Systematic variation of the placement of the visual stimulus relative to the receptive field of the electrically stimulated neurons reveals that the interference produced is local and affects only a small circular area approximately the size of the receptive field of the stimulated neurons. 3. Examining the nature of the visual percept created with electrical stimulation shows that stimulation for 80 milliseconds at 200 Hz between 20 and 120 microamps applied to neurons with receptive fields at 2.5-3.5 degrees of eccentricity produces an image that has a contrast of 6-12 percent and a size of 14-18 minutes of visual angle in diameter.We believe that the use of implanted electrode arrays has the potential of providing visual information for the

blind. We infer, furthermore, that successive activation of electrodes will be able to provide motion information including motion parallax for depth perception.

Acknowledgment: Supported by NEI NIH EY014884

3:00 *510* Functional organization of color domains in V1 and V2 of Macaque monkey revealed by optical imaging

Anna W. Roe[1] (anna.roe@vanderbilt.edu), Haidong D. Lu[1]; [1]Department of Psychology, Vanderbilt University, Nashville, TN

Areas V1 and V2 of Macaque monkey visual cortex are characterized by unique cytochrome oxidase staining patterns. Initial electrophysiological studies associated cytochrome oxidase blobs in V1 with processing of surface properties such as color and brightness and the interblobs with contour information processing. Numerous studies followed, some supporting this proposal and others failing to find significant functional differences between blobs and interblobs. In V2, controversy also remains regarding the functional distinctness of the thin, pale, and thick stripes. In this study, to resolve this long-standing issue, we have used optical imaging to map color-selective responses in V1 and V2.In V1, we find striking 'blob-like' patterns of color response. Careful alignment of optical maps and cytochrome oxidase stained tissue revealed that color domains in V1 align well with cytochrome oxidase blobs in V1. Furthermore, consistent with cytochrome oxidase blobs, we find color blobs align along centers of ocular dominance columns and co-align with regions of high monocularity. Finally, we find color blobs in V1 are centers of low orientation selectivity and do not overlap with centers of orientation domains in V1. In V2, color domains overly thin stripes; orientation selective domains overly thick and pale stripes. We conclude that color and orientation selective responses are preferentially located in distinct cytochrome oxidase compartments in V1 and V2. We propose that the term 'blob' encompass both the concept of 'cytochrome oxidase blob' and 'color domain' in V1.

Acknowledgment: Supported by EY11744, Vanderbilt Vision Research Center, Center for Integrative & Cognitive Neuroscience.

3:15 *511* Receptive Field Shifts in Area MT during Smooth and Rapid Eye Movements

Till S Hartmann[1,2,4] (till@salk.edu), Frank Bremmer[4], Thomas D Albright[2,3], Bart Krekelberg[1,2]; [1]Center for Molecular and Behavioral Neuroscience, Rutgers University, [2]Salk Institute, [3]Howard Hughes Medical Institute, [4]Phillipps University Marburg, Germany

Although visual perception is generally quite robust against our ever present eye movements, there are cracks in this perceptual stability. For instance, briefly flashed objects are often mislocalized in the direction of both smooth and rapid eye movements. This perceptual mislocalization is hoped to provide insight into mechanisms that provide us with a stable percept outside the laboratory.Changes in receptive field (RF) location have been studied as neural correlates of perceptual mislocalization. We developed a technique to map RF dynamics. We presented a rapidly alternating pattern of black and white bars and reverse correlated the neural activity with this stimulus. With this method we estimated the RF - here defined as the average stimulus that preceded a spike – in a quantitative manner. We used this method in the macaque middle temporal area (MT). During fixation, our results matched those obtained with more traditional methods of RF mapping. Following this validation, we then mapped the dynamics of RFs during eye movements. We used a field of horizontally moving dots to induce optokinetic nystagmus (OKN): a typical alternation of slow following-movements interspersed with rapid backward eye movements. During the smooth eye movements, we found a clear shift in the spatial receptive field of MT cells in the direction of the eye movement. Briefly before the rapid saccadic eye movements, some receptive fields additionally shifted and expanded in the direction of the saccade. These RF changes were of the appropriate size and showed dynamics similar to the mislocalization observed in behavioral experiments.

Acknowledgment: Supported by NEI, DFG GRK-885, FOR-560, TDA is a HHMI investigator.

3:30 *512* Timing aftereffects in alert monkey V1

Alan B Saul[1] (asaul@mcg.edu), Yamei Tang[1], Elsie Wong[1]; [1]Medical College of Georgia, Augusta GA 30912

The importance of adaptation aftereffects lies largely in their specificity. One of the most specific examples of an aftereffect occurs in single cells of visual cortex, consisting of a delayed response onset to each cycle of a periodic stimulus, without any change in the offset. These timing aftereffects were previously reported in anesthetized cats (Saul 1995, 1999). They also occur in anesthetized monkeys, and could in principle be due to anesthesia.We recorded from single neurons of alert monkey V1, and measured responses to gratings drifting continuously during 5 s trials. Control responses were taken from the first 2 s of each trial, and adapted responses from the final 2 s. Across trials, contrast and spatial and temporal frequencies varied. Timing aftereffects occurred in nearly all cells whose response was modulated by the grating stimuli, including complex cells that gave first harmonic responses at low spatial frequencies. On average, adapted responses were shifted by about 0.03 cycles relative to control responses ($P<0.01$, $N=57$), as in anesthetized animals. Onsets were shifted by about 0.04 cycles whereas offsets were not changed. Amplitudes were decreased by a factor of 0.92 (geometric mean, not significantly different from 1). Amplitude aftereffects had a slight negative correlation with timing aftereffects.Adaptation may potentiate inhibition that is out of phase with the excitation to a cell, inducing these timing aftereffects. This process appears to operate in awake behaving monkeys as well as in anesthetized cats.

Cue Integration

2:00 - 3:45 pm

Hyatt Ballroom South

Moderator: Greg DeAngelis

2:00 *513* Role of area MSTd in cue integration for heading discrimination: II. Analysis of correlations between neural responses and perceptual decisions.

Gregory C. DeAngelis[1] (gregd@cabernet.wustl.edu), Yong Gu[1], Dora E. Angelaki[1]; [1]Dept of Anatomy & Neurobiology, Washington University School of Medicine

Neurons in area MSTd exhibit spatial tuning in response to optic flow and during inertial motion in darkness. To better understand MSTd's role in heading perception, we studied correlations between single-unit responses and perceptual choices during a fine heading discrimination task. Monkeys reported their heading relative to straight ahead in a Vestibular condition (inertial motion only), a Visual condition (optic flow only), and a Combined condition (congruent inertial motion and optic flow). To assess functional coupling between MSTd responses and perceptual decisions, we computed 'choice probabilities' (CPs), which characterize trial-to-trial covariation between neural responses and the animal's choices. Overall, CPs were strongest under the Vestibular condition, in which ~25% of MSTd neurons showed significant positive effects and the mean CP (0.55) was significantly > 0.5 ($p<0.001$). Under the Visual condition, ~16% of neurons showed significant CPs with similar numbers of positive and negative effects. The mean CP (0.51) was not significantly different from chance ($p=0.2$). Interestingly, 'congruent' MSTd neurons with matched visual and vestibular tuning preferences tended to be positively correlated with choices in the Visual condition (mean CP=0.56, $p=0.002$), whereas neurons with opposite tuning preferences tended to be negatively correlated (mean CP=0.45, $p=0.04$). Our findings suggest that vestibular signals in area MSTd contribute to heading perception. In addition, the Visual CP data suggest that visual responses of MSTd neurons are read out differently

depending on the congruency of visual and vestibular tuning preferences. This highlights the importance of studying multi-sensory integration for understanding heading perception.

Acknowledgment: Supported by EJLB Foundation, NIH-DC04260 & EY16178

2:15 *514* **Role of area MSTd in cue integration for heading discrimination: I. Comparison of neuronal and psychophysical sensitivity to visual and vestibular cues.**

Yong Gu[1] (yonggu@pcg.wustl.edu), Dora E. Angelaki[1], Gregory C. DeAngelis[1]; [1]Dept of Anatomy & Neurobiology, Washington University School of Medicine

Robust perception of heading involves integration of visual and non-visual (e.g., vestibular) cues. Area MSTd is thought to be involved in heading perception, as neurons in this area are sensitive to global patterns of optic flow as well as translation in darkness. To examine how visual and vestibular signals in MSTd contribute to heading perception, we recorded single-unit responses during a fine heading discrimination task. Heading direction was varied in small steps around straight forward in the horizontal plane. The task was performed in a virtual reality system and heading was defined in 3 ways: 1) inertial motion only (Vestibular condition); 2) optic flow only (Visual condition); and 3) congruent combination of inertial motion and optic flow (Combined condition). Stimuli were smooth motion trajectories with a Gaussian velocity profile. Psychophysical thresholds averaged ~2º in the Vestibular condition. Thresholds in the Visual condition were well below 1º for coherent motion, but were adjusted to match vestibular thresholds by reducing motion coherence. The most sensitive MSTd neurons had thresholds close to behavior, but the average neuron was much less sensitive than the monkey in both single-cue conditions. In the Combined condition, psychophysical thresholds were significantly improved compared to the single-cue conditions. Thresholds for 'congruent' MSTd neurons with matched visual and vestibular tuning preferences were significantly improved under cue combination, whereas thresholds for neurons with opposite tuning preferences were not. We conclude that selective pooling of responses of 'congruent' MSTd neurons may contribute to cue integration for heading perception.

Acknowledgment: Supported by EJLB Foundation, NIH-DC04260 & EY16178

2:30 *515* **Bias in three-dimensional motion estimation reflects the combination of information to which the brain is differentially sensitive**

Andrew E Welchman[1,2] (a.e.welchman@bham.ac.uk), Judith M Lam[2], Heinrich H Buelthoff[2]; [1]School of Psychology, University of Birmingham, UK, [2]Max-Planck Institute for Biological Cybernetics, Tuebingen, Germany

Perceiving objects moving toward us is a vital survival skill. Surprisingly, humans judging 3D motion report an object will miss them when on a collision course with the head (Harris & Dean, 2003 JEP:HPP 29 869 - 881). Here we propose that this bias is a consequence of the brain combining non-redundant information about lateral motion (Vx) and motion in depth (Vz) in a manner that reflects differential sensitivity to the information. We show that measured biases in 3D motion perception are accounted for by a model that incorporates estimates of observers' higher sensitivity to lateral motion than motion in depth. First, we estimate relative sensitivity to component motions by recording thresholds for detecting an increment in displacement when movement is lateral or in depth. Then we show that this model provides a good account of observers' behavior by recording their estimates of 3D motion trajectories for a range of trajectory angles left-right of the head. Finally, we show that observers' bias is decreased when external noise results in reduced sensitivity to lateral motion, as predicted by this model. These results provide novel evidence that the brain cannot help but take into account the reliability with which information is encoded even at the cost of perceptual bias when combining orthogonal sources of information about the environment.

Acknowledgment: Max Planck Society. BBSRC UK

2:45 *516* **Combining Slant Information from Disparity and Texture: When is it Optimal?**

Ahna R. Girshick[1] (ahna@berkeley.edu), Martin S. Banks[1,2,3]; [1]Vision Science Program, UC Berkeley, [2]Dept. of Psychology, UC Berkeley, [3]Helen Wills Neuroscience Institute, UC Berkeley

The brain often combines sensory measurements in a fashion approaching statistical optimality. If sensory measurements are represented as likelihood distributions, the optimal combined percept lies in between two single-cue percepts. When these measurement distributions differ greatly from one another (cue conflict), it may be more sensible to simply use the more reliable (less variable) measurement rather than a combination affected by the less reliable measurement, even if it is not statistically optimal. We investigated how disparity and texture are combined in estimating slant, and in particular how large conflicts affect slant percepts. Previous depth cue combination work has been restricted to small conflicts. We also investigated the effect of cue reliability.We measured two-cue slant percepts using a 2-interval matching procedure. One interval had a cue conflict and the other did not. We presented a large range of conflict sizes. As conflict size increased, observers' slant settings remained nearly optimal: up to surprisingly large conflicts, they followed the weighted average predicted from single-cue measurements and Bayes' Law. With even larger conflicts, the optimal weighted averaging no longer occurred; matches were instead dictated by the more reliable cue. When we increased the reliability of both cues, keeping the relative weights fixed, optimal weighted averaging broke down at smaller conflicts, compared to the less reliable stimuli.Thus, we found that optimal weighted averaging occurs when these distributions overlap substantially: either with smaller conflicts or less reliable cues. Slant percepts are dictated by the more reliable cue when the distributions only overlap minimally.

Acknowledgment: NIH R01 EY012851

3:00 *517* **Learning Bayesian priors for depth perception**

David C Knill[1] (knill@cvs.rochester.edu); [1]Center for Visual Science, University of Rochester

Purpose: We asked whether humans can prior probabilities used used to interpret a pictorial depth cue from visual information alone. In particular, we asked whether subjects learn to down-weight the compression cue (the bias to interpret elliptical figures as slanted circles) relative to stereoscopic cues in an environment containing randomly shaped ellipses. **Methods:** Subjects viewed stereoscopic images of elliptical figures and adjusted a 3D line probe to appear perpendicular to the figures. Test stimuli were near-circular ellipses at a slant of 35º. Non-test stimuli were ellipses at slants between 15º and 45º. Test ellipses were designed to suggest 5º conflicts between the compression cue and the stereoscopic cues. In experiment 1, non-test ellipses were all circles. In experiment 2, they had random aspect ratios. We used subjects' probe settings for test stimuli to compute cue weights in each of five successive daily sessions. **Results:** In experiment 1, subjects gave equal weights the compression cue (0.5) across all sessions. In experiment 2, subjects' compression cue weights shrank from 0.5 to 0.33 from the first to last session. Similar results were obtained when visuomotor performance (placing an object on the slanted stimulus) was used to estimate subjects' cue weights. **Conclusions:** Humans can adapt the prior distribution of object properties used to interpret a pictorial cue from visual information alone. These adaptations show up implicitly in the effective weight that subjects give to the cue. We describe a Bayesian learning model that accounts for subjects' performance.

Acknowledgment: Research supported by NIH grant EY-13319

URL: http://www.cvs.rochester.edu/knill_lab/learning_supplement.pdf

3:15 *518* **Statistical Robustness in a Three-cue Environment**

Carmel A Levitan[1] (carmel@berkeley.edu), Martin S Banks[1,2]; [1]Joint Graduate Group in Bioengineering at UC San Francisco and UC Berkeley, USA, [2]Vision Science Program, School of Optometry, University of California, Berkeley, USA

In combining information from multiple sources, the brain must determine which cues to use, and how to weight them. When the cues specify similar values, a maximum-likelihood model, which weights cues in proportion to their inverse variances, accurately predicts performance. In such cases, it is likely that discrepancies between the cue values are due to measurement noise, so using the weighted average is a good strategy. If, however, one of the cues specifies a very different value, the discrepancy relative to the other cues is more likely to be due to a bias in the cue estimate or to the cue coming from a different object. In this case, using the weighted average is not a good strategy. A statistically robust model would down-weight the outlying cue. We asked whether the signal from one cue is excluded when it conflicts greatly with signals from other cues. We created a three-cue environment in which visual, haptic, and auditory positions in space were specified independently. Observers indicated the perceived location of the stimulus when there were small or large conflicts between the cues. When conflicts were small, observers used the weighted average of the three cues with weights inversely proportional to cue variances. When the conflict between two cues was small, but was large relative to the third cue, the weight given the third cue was significantly reduced. We conclude that the brain displays statistical robustness in combining information from different sensory modalities.

Acknowledgment: AFOSR Grant F49620-01-1-0417

3:30 *519* **Nonlinear Integration of Texture and Shading Cues on a Slant Discrimination Task**

Volodymyr V. Ivanchenko[1] (vivanchenko@bcs.rochester.edu), Robert A. Jacobs[1]; [1]University of Rochester, NY 14627

Most studies of visual cue integration have found that observers' data can be modeled by a linear cue combination rule. We conducted an experiment in which, intuitively, a linear cue combination rule should not provide a satisfying model of observers' data. The experiment used a surface defined by texture and shading cues. At a coarse-level of detail, the surface was planar, but it also contained deformations resembling random bumps or waves. Subjects performed a slant discrimination task---they judged whether comparison surfaces were more or less slanted than a standard surface---in three conditions, namely when surfaces were defined by the texture cue alone, by the shading cue alone, or by both cues. The results indicate that when both cues were available subjects' discrimination thresholds were significantly lower than predicted by a linear model. We propose that the texture and shading cues to slant are each highly ambiguous when there is great uncertainty about the shape of the surface. When only a single cue is available, observers find it difficult to estimate surface shape (due to its irregularities) and, thus, find it difficult to interpret that cue for the purpose of judging slant. When both cues are available, however, estimates of surface shape are more accurate, thereby making it easier to interpret the cues as indicators of slant. The results are consistent with the hypothesis that observers estimate surface shape, and use this estimate when judging surface slant.

Acknowledgment: This work was supported by NIH research grant RO1-EY13149.

Color: Appearance and Context

4:15 - 5:30 pm

Hyatt Ballroom North

Moderator: Michael Webster

4:15 *520* **Nonlinearities in color appearance – compensating for the eye's spectral sensitivity**

Michael A. Webster[1] (mwebster@unr.nevada.edu), Yoko Mizokami[1], John S. Werner[2], Michael A. Crognale[1]; [1]University of Nevada, Reno, [2]University of California, Davis

The hue of most wavelengths changes when mixed with white light (the Abney effect). We show that these hue changes are qualitatively predicted if the visual system assumes that the desaturation results from a change in spectral bandwidth rather than a spectral dilution. Because of the filtering imposed by the receptor spectral sensitivities, broadening the bandwidth around a fixed peak wavelength alters the ratio of cone responses, and thus the peak must shift with increasing bandwidth to maintain a constant cone ratio. However, we found that observers instead choose the same peak when matching the hue of narrow and broad stimuli with roughly Gaussian spectra, consistent with a nonlinear adjustment that compensates for the eye's filtering effects. When the same chromaticity is instead formed by mixing a wavelength with white, this compensation results in an erroneous hue shift because the "right" response is applied to the "wrong" stimulus. This predicts curved or straight hue loci depending on both wavelength and individual differences in spectral sensitivity, and these are qualitatively consistent with measures of the Abney effect. Our model suggests a novel functional account of Abney effects and color appearance: in which hue is tied to a fixed expected property of the physical stimulus (eg spectral centroid) rather than a fixed mechanistic property of the observer (eg the cone ratios). Such effects also support recent suggestions that natural spectra may in some cases be better described by Gaussian than linear models (MacLeod and Golz, in Mausfeld and Heyer 2003).

Acknowledgment: EY10834

4:30 *521* **The span of cone ratios and color naming**

David Philipona[1] (david.philipona@univ-paris5.fr), J. Kevin O'Regan[1]; [1]Laboratoire de Psychologie Expérimentale, Univ. Paris 5, CNRS UMR 8581, France

It has been suggested that ratios of photoreceptor catches for the light reflected by pairs of surfaces play an important role in color vision (Foster & Nascimento, 1994). We provide results from simulations showing that L, M and S ratios obtained from surface pairs consisting of a colored surface and an achromatic surface of the same luminosity reach their extreme values for a few specific colored surfaces, namely red, green, blue and yellow surfaces. There is a striking correspondence between the colors singled out in this way and the ones singled out in cross-cultural studies of color naming (Regier, Kay & Cook, 2005). These results will be compared with a related approach proposed in Philipona & O'Regan (in press), which further addressed the question of unique hues and hue cancellation. References- Foster & Nascimento (1994) Relational colour constancy from invariant cone-excitation ratios. Proc. R. Soc. Lond. B 257, 115-121- Regier, Kay & Cook (2005) Focal colors are universal after all. Proc. Natn. Acad. Sci. USA 102:8386-8391- Philipona & O'Regan (in press) Color naming, unique hues and hue cancellation predicted from singularities in reflection properties. Vis. Neurosci.

4:45 *522* **Ideal white can be yellowish or bluish, but not reddish or greenish.**

R. Dirk Beer[1] (rdbeer@ucsd.edu), Ana Dinca[1], Donald I. A. MacLeod[1]; [1]University of California San Diego

What is white? We find that when subjects set white in a dark surround, settings are well constrained to be neither red nor green, but the amount of yellow or blue varies for each subject as well as between subjects. This scatter of settings according to unique hue, rather than along physiological cone-opponent axes, is at odds with discrimination experiments that result in threshold ellipses with an orientation nearer to the cone-opponent axes. Discrimination experiments are commonly done with two bordering half-fields, while our white settings were done without a reference. Is the abutting reference field critical? In this second experiment, subjects discriminated abutting and non-abutting near-white stimuli. Resulting threshold ellipses are nearer to the cone-opponent axes than to the unique hue directions. The difference between absolute judgments of white and discrimination of near white stimuli has two possible explanations. 1) White settings use unique-hue mechanisms while discrimination uses the physiological cone-opponent mechanisms. 2) Both white settings and discrimination use cone-opponent mechanisms. The trial-by-trial scatter in a subject's white settings may be generated by the subject choosing, on each trial, a slightly different assumed illuminant from the set of likely natural daylights. One would then expect subjects' settings to be scattered in the blue/yellow direction, as we found, since that is the direction of greatest variance of natural illuminants.

Acknowledgment: NIH EY01711

5:00 *523* **Contrast gain control accounts for both contrast and assimilation effects in simple achromatic color displays**

Michael E. Rudd[1] (mrudd@u.washington.edu); [1]University of Washington, Seattle, WA, USA

In past work, we have presented and elaborated a model of achromatic color induction in which lightness and darkness induction signals spread spatially from edges, decay with distance, and are summed to produce a total achromatic color signal. Our previous data indicate that multiplicative interactions between edge contrasts also play a role in achromatic color. To account for these edge interaction effects, Rudd and Arrington (2001) proposed that induction signals associated with remote edges are partially "blocked" by nearby edges, by an amount that depends on the nearby edge contrast. Rudd and Popa (VSS 2004, submitted) showed that this blockage effect can also operate in the opposite direction: that is, remote edge contrast can attenuate the effect of local contrast on target lightness. I will show how both of these effects can be produced by a simple neural mechanism by which cortical edge detector neurons interact spatially to control one another's gains prior to color induction and spatial integration. The theory makes the non-intuitive prediction that contrast and assimilation effects can be seen in the same simple disk-and-ring display over different ring luminance ranges, a prediction that I will support with data (Rudd & Zemach, submitted). The theory thus gives a unitary account of two of the most basic spatial phenomena of color vision, phenomena which have historically been thought to result from separate underlying mechanisms (Jameson & Hurvich, 1961), and suggests a mechanism by which contrast and assimilation effects may arise in more complex displays (Bindman & Chubb, 2004).

5:15 *524* **Color without consciousness: Dynamics of the McCollough effect**

Edward Vul[1,2] (evul@mit.edu), Donald IA MacLeod[1]; [1]University of California, San Diego, Dept. of Psychology, La Jolla, CA, US, [2]Massachusetts Institute of Technology, Dept. of Brain and Cognitive Science, Cambridge, MA, US

Recent studies have shown that certain aspects of unconscious visual processing have higher spatial and temporal resolution than conscious perception (e.g., He & Macleod, 2001). We investigated whether such differences exist in the temporal resolution of conscious and unconscious cortical color processing. A McCollough effect (McCollough, 1965) is an orientation-contingent color aftereffect: adaptation to (e.g.) red vertical and green horizontal gratings causes subsequent vertical and horizontal gratings to appear greenish and reddish, respectively. Because the adaptation occurs at V1 or later (Humphrey and Goodale, 1998), it is ideal for studying cortical color processing. Humans can consciously discern color alternations up to approximately 16 Hz (Kelly, 1983). We alternated a four-frame sequence of phase-shifted gratings that induced a McCollough effect at color alternation rates up to 50 Hz. At this rate the constituent red and green colors fuse together into a yellow field and can no longer be discerned. Despite the fact that the colors of the inducing stimulus were invisible, a McCollough effect was successfully induced at 50 Hz. These results show that V1 can track color alternations much faster than conscious perception. Furthermore, we found that the color contrast available to conscious perception is reduced at a much faster rate than that available to McCollough effect mechanisms as the color alternation rate increases. This suggests that color processing in V1 is faster than consciousness not just because of a high contrast threshold, but because extra steps of temporal integration interfere between V1 and visual awareness.

Acknowledgment: This work was supported by a grant from the University of California Regents and by NIH EY91711

3D Visual Processing: Space

4:15 - 5:30 pm

Hyatt Ballroom South

Moderator: Caspar Erkelens

4:15 *525* **Angle of Elevation Influences Distance Perception to Targets on the Ceiling**

Valentina Dilda[1] (valentina.dilda@psych.utah.edu), Sarah H. Creem-Regehr[1], William B. Thompson[2]; [1]Department of Psychology, University of Utah, USA, [2]School of Computing, University of Utah, USA

Consistent results show that distance perception to targets on the ground is indicated accurately by visually directed action tasks such as walking without vision. Recently, we (Dilda, Creem-Regehr, and Thompson, 2005) found similar accurate performance when targets were placed on the ceiling, a surprising result since the ground surface is likely an important source of information for distance. Base-up prisms lower the location of objects in the visual field and were used by Ooi, Wu and He (2001) to demonstrate that the visual system may use angular declination below the horizon to determine absolute distance to targets located on the ground. We asked whether a similar manipulation of angular declination/elevation off the horizon would influence absolute distance judgments to targets on the ceiling. We placed targets on the ceiling of a large room at distances of 5, 10, 15, and 20 feet. Participants were asked to walk without vision so that their bodies were aligned underneath the targets. They performed the task first with control goggles made of flat lenses and second with 10 Prism Diopter (5.73 degrees) base-up prism goggles. We replicated the results of accurate walking to targets on the ceiling with the flat lenses and found a consistent overestimation with the prism lenses relative to the control condition. The results suggest that the angle of elevation from the horizon to the ceiling informs the perception of distance to targets on the ceiling but leaves open the question of how accurate scaling is determined.

Acknowledgment: This work was supported by NSF grant IIS-0121084.

4:30 *526* **Background surface and horizon effects in the perception of relative size**

Kerem Ozkan[1] (kozkan@uci.edu), Myron L. Braunstein[1]; [1]University of California, Irvine

The projected height of an object relative to a ground surface influences its perceived distance in a scene, but the effect of height should change when the object is moved above the horizon. The present study examined the effects of background surface and object height on perceived relative size, for objects equal in projected size. The background surfaces were line drawings representing ground and ceiling planes. There were four background conditions: ground only, ceiling only, ground and ceiling and no surfaces. Two ellipses with horizontal major axes appeared in each scene. The vertical separation of the ellipses was constant, but the pair of ellipses varied in height, with either both below the ground horizon position, both above the ceiling horizon position, or one at the ground horizon position and one at the ceiling horizon position. Observers were asked to indicate which disk appeared larger. The type of surface did not have an overall effect on size judgments, but interacted with the height of the disks in determining perceived relative size. The ground-only conditions were replicated with cylinders displayed against a real scene background. The higher cylinder was always judged to be larger when the lower cylinder was below the horizon, but was most often judged to be smaller when the lower cylinder was at or above the horizon. These results suggest that the perceived layout of objects in a scene depends both on the positions of the objects relative to a background surface and relative to the horizon.

4:45 *527* **Localizing suspended objects in the intermediate distance range (>2 meters) by observers with normal and abnormal binocular vision**

Teng Leng Ooi[1] (tlooi@pco.edu), Zijiang J He[2]; [1]Pennsylvania College of Optometry, USA, [2]University of Louisville, USA

The visual system can construct a global representation of the ground surface for use as a reference frame to localize an object according to the relative depth cues between the object and ground surface. The relative depth cues include binocular disparity, motion perspective, cast shadow and nested contact information. We investigated if binocular disparity, which is not commonly considered an effective absolute distance cue beyond 2m (Wu et al, 2004), is nevertheless critical for localizing suspended objects in the full-cue environment. Spherical targets (diameter=0.51deg) were either located on the floor, or suspended 30cm, 67cm, or 90cm above the floor, at various distances (2.73m, 4.15m, 5.51m, 6.93m) from the observer in a lighted hallway. Viewing the targets with either one or both eyes, the observers judged target location using the blind walking-gesturing task. We found that observers with normal stereoacuity judged target locations with better accuracy and precision in the binocular than in the monocular condition. Strabismic observers with poor stereoacuity performed worse than normal observers in the binocular condition, while one observer without stereopsis exhibited no binocular advantage. But regardless of viewing conditions, all observers accurately localized targets on the floor. Overall, that binocular viewing improves performances over monocular viewing of suspended targets reveals that binocular disparity plays a major role in localizing objects with reference to the ground surface. This role of binocular disparity is remarkable given that our observers were situated in a full-cue environment where other relative depth cues were accessible.

Acknowledgment: NIH grant EY014821

5:00 *528* **Perceptual-Motor Recalibration of Imagined Walking**

Benjamin Kunz[1] (benjamin.kunz@psych.utah.edu), Sarah H. Creem-Regehr[1], William B. Thompson[2]; [1]Department of Psychology, University of Utah, USA, [2]School of Computing, University of Utah, USA

Adapting to a mismatch between speed of visual motion and biomechanical walking will change later visually directed locomotion, indicating a recalibration of the link between perception and action (Rieser et al., 1995). We investigated the recalibration effect for imagined walking, a task which has been proposed to be functionally similar to overt locomotion (Decety et al., 1989). In a pre-test, participants were instructed to imagine walking to targets on the floor at 6, 8, and 10 meters, while timing their imagined walking using a stopwatch. Participants then walked on a large platform treadmill for 10 minutes at a constant rate of 1.3 m/sec while viewing visual motion of a computer-rendered hallway projected onto three screens providing approximately 180-degree horizontal field of view. Speed of visual motion was either .5x their biomechanical speed (visually slower) or 2x their biomechanical speed (visually faster). Participants then repeated the imagined walking task in a post-test. A comparison of pre- and post-test imagined walking times revealed results consistent with the recalibration of walked distance seen in overt walking tasks. Post-test versus pre-test times increased about 15% in the visually slower condition and decreased about 15% in the visually faster condition. This evidence of a recalibration effect in the absence of overt action during pre-test and post-test supports the notion of a functional equivalence between overt and imagined actions, but also suggests that a biomechanical response is not necessary for a recalibration of the perception and action coupling.

Acknowledgment: This work was supported by NSF grant IIS-01-21084.

5:15 *529* **Metric of binocular visual direction in stereopsis**

Casper J. Erkelens[1] (c.j.erkelens@phys.uu.nl), Raymond van Ee[1]; [1]Helmholtz Institute, Utrecht University

Stereopsis is 3-D vision that results from small differences (disparities) between the image patterns formed on the retinas of our eyes. In spite of having two physical vantage points, the two eyes, the general belief is that we judge direction from a hypothetical eye, called the cyclopean eye. In this concept, depth and direction are treated as independent dimensions that can be studied in separation. Visual directions have mainly been investigated in alignment tasks. These tasks are not suited for studying metric properties. Here we measured the metric of binocular visual direction using a 3-D bisection task. The bisection stimulus consisted of three lines of which two were lying in one depth plane and the third line was placed in another. We find bisection errors for vertical lines that increase with disparity if the results are expressed in cyclopean directions. Bisection is almost veridical if the results are expressed in directions from the left or right eye. Which eye is used depends on the 3-D layout of the bisection stimulus. Two mutually exclusive models describe the results: 1) a cyclopean-eye model, in which visual direction depends on depth, and 2) a two-eye model, in which direction and depth are independent. We support the latter model because it is consistent with shape perception whereas the former is not.

Poster Session E

Sunday, May 7, 2006

Visual Evoked Potentials (530-533), Face Perception: Configural, Holistic Processing (534-545), Search I (546-561), Scene Perception (562-583), Eye Movements and Cognition (584-596), Eye Movements: Saccades and Fixations (597-611)

Poster Session: 8:00 - 11:00 am ***Municipal Auditorium***
Author presents: 9:30 - 10:30 am

Visual Evoked Potentials

E1 *530* Comparison of Contrast-Response functions from multifocal visual evoked potentials (mfVEPs) and functional MRI signals

Jason C Park[1] (korsakoff@gmail.com), Xian Zhang[1,2], John Ferrera[2,3], Diana Dakhlallah[1], Minha Popalzai[1], Joy Hirsch[2], Donald C Hood[1]; [1]Dept. of Psychology, Columbia University, [2]Functional MRI Research Center, Columbia Universisty, [3]Clinical Neuropsychology [PhD program], CUNY Graduate Center

Contrast response functions (CRFs) from multifocal visual evoked potential (mfVEP) recording and fMRI scanning were obtained to the same stimuli. The mfVEP, largely generated in V1 [1-4], was compared to the BOLD fMRI signal from V1 and extrastriate cortex. Four normal subjects participated in mfVEP and fMRI sessions using the same dartboard pattern stimulus, which had three rings (1.5°, 3.6°, and 8° dia; 24 sectors) of reversing checkerboards. The mfVEPs from three channels were recorded and analyzed with custom software and fMRI signals from a simple block design were averaged across six continuous blocks. The stimuli were presented in segments/blocks of 13.6 seconds. Each run had one of six contrast levels (4, 8, 16, 32, 64, and 90%). Retinotopic maps of each subject were acquired by standard wedge/ring stimuli [5]. SNR of mfVEPs and averaged z-scores of the BOLD signal in V1 and extrastriate area were used as the response measures. For all subjects, CRFs from mfVEPs and fMRI saturated beyond 32 % contrast. The shape of the mfVEP and fMRI CRFs from V1 area were almost identical. The fMRI CRFs from the extrastriate area had a similar shape but with a signal about one-half the V1 signal. In general, the overall agreement between mfVEP and fMRI is consistent with the claim that the BOLD signal is proportional to local (slow) field potentials [6]. 1. Basler & Sutter, (1997); 2. Slotnick et al (1999); 3. Zhang & Hood (2004); 4. Hood & Greenstein (2003); 5. Engel et al (1997); 6. Logothetis et al (2001)

E2 *531* Brain responses to global perceptual coherence

Oliver J Braddick[1] (oliver.braddick@psy.ox.ac.uk), Dee Birtles[1,2], Susanna Mills[1], Julien Warshafsky[1], John Wattam-Bell[2], Janette Atkinson[2]; [1]Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK, [2]Visual Development Unit, Dept of Psychology, University College London, Gower St, London WC1E 6BT

Coherence thresholds for concentric patterns of contour segments or dot trajectories have revealed differential development and vulnerability of extrastriate form and motion pathways respectively (Braddick et al, Neuropsychologia, 2003). Here we explore the properties of visual evoked potentials (VEPs) specific to form and motion coherence. Coherent contour or motion arrays alternate with incoherent arrays at 0.5-4 Hz. A 2nd harmonic VEP signal (F2) may arise from local changes occuring at each transition, but a first harmonic (F1) must reflect differential responses to coherence and incoherence, indicating global processing.F1 amplitude is approximately linear with coherence for both form and motion, confirming that F1 measures global processing. F2 is independent of coherence for form, and nearly so for motion, implying that it reflects local changes. Occipital F1 amplitudes for motion:form coherence are approximately 2:1. However, this does not reflect underlying sensitivity: psychophysical form and motion coherence thresholds are similar, and extrapolation of the linear region of F1 amplitude vs coherence reaches zero close to threshold coherence in each case. F1 amplitude for both displays increases gradually from 0.5-4 Hz. However, this is opposite to psychophysical coherence sensitivity, which falls over the same range. We conclude: (a) coherence-dependent VEPs provide measures of global form and motion processing, practical for infants and non-verbal (e.g. autistic) children; (b) this response is elicited efficiently at relatively high presentation rates; (c) the level tapped by the VEP does not provide the limiting factor on temporal integration in global perceptual processing.

Acknowledgment: Supported by MRC programme grant G7908507

E3 *532* Extending the multi-focal VEP method to complex stimuli

Thom Carney[1] (thom@neurometrics.com), Justin Ales[2], Stanley A Klein[2]; [1]Neurometrics Instutute, Oakland, CA, [2]Vision Science Graduate Group, School of Optometry, UofC, Berkeley, CA

The VEP multi-focal technique provides a method to study eccentricity dependent perceptual effects. It has efficiency advantages over traditional methods by being able to simultaneously record neural responses at multiple target locations. In addition, the multi-focal method in combination with the sparseness of cortical folding is an effective method for studying visual areas with retinotopic organization. The typical multi-focal cortically scaled stimulus patches are each independently flickered according to an m-sequence. Cross correlation of the EEG signal with the m-sequence results in a series of response kernels for each electrode and each stimulus patch. Commonly the number of target locations and target complexity has been graphics hardware limited. To overcome these limitations we have replaced standard look-up-table animation with true color graphic sprites to present arbitrary spatial patterns and record simultaneously from 192 patches each activating small areas of V1 (~4x4mm). Moreover, adjacent patch cross kernels effectively multiply the cortical sampling density. Our use of 96 recording electrodes and small stimulus patches enables us to identify rapid changes in cortical folding of early visual areas enabling accurate source localization when combined with MRI methods. Finally, using sprites we can multiplex stimuli such that at each patch location multiple stimuli can be presented thereby improving signal-to-noise over sequential methods. For example, we have presented patterns with different orientations (or spatial frequencies) at the same patch locations but independently temporally modulated to study cell population interactions.

URL: This research was supported by grant EY015825-01 and NEI training grant

E4 *533* Inter-subject Variability of the Visual Evoked Potential

Sangita Dandekar[1] (sdandekar@berkeley.edu), Justin Ales[1], Thom Carney[1,3,4], Stanley Klein[1,2,3]; [1]Vision Science Graduate Group, [2]Helen Wills Neuroscience Institute, [3]School of Optometry, University of California, Berkeley, [4]Neurometrics Institute

Background Multiple groups have informally observed that the two dominant temporal principal components (PCs) of the pattern reversal VEP obtained with singular value decomposition (SVD) exhibit little inter-subject variability relative to the inter-subject variability of the raw VEP. Using a unique application of SVD we quantify this variability. **Methods** The multifocal VEP stimulus consisted of a dartboard pattern containing 48 checkerboard patches modulated by a 16 bit m-sequence. The checkerboard reversal response for each patch at each of 96 electrodes was calculated by cross-correlation. SVD was applied individually to the data from each of 5 subjects to determine the two dominant PCs per subject. Application of SVD to a matrix formed by concatenating the two dominant temporal PCs of each subject was used to determine 'composite' inter-subject PCs. **Results** When SVD was performed on individual subject data within a time window of 220 msec approximately centered on the first peak of the VEP, the dominant pair of temporal PCs accounted for on average 77% of the variance. The composite first and second PCs (as determined via SVD of the matrix containing the pair of dominant PCs from each subject) accounted for 85% of the inter-subject variance.**Discussion** Standard VEPs are notoriously variable from subject to subject. These differences are assumed to primarily be a result of our unique cortical convolution patterns. SVD reveals a robust similarity between early cortical responses.

Acknowledgment: NIH EY015825, NIH T32 EY07

Face Perception: Configural, Holistic Processing

E5 *534* A whole-to-part advantage for processing faces in the occipito-temporal cortex

Bruno Rossion[1] (bruno.rossion@psp.ucl.ac.be), Christian Namèche[1], Bettina Sorger[2], Rainer Goebel[2]; [1]Department of Cognitive Development and Laboratory of Neurophysiology, University of Louvain, Belgium, [2]Department of Cognitive Neuroscience, Maastricht University, The Netherlands

Numerous experiments have shown that the recognition of a facial feature is dependent on the other features of the face stimulus, a phenomenon taken as evidence that faces are represented holistically (e.g. Tanaka & Farah, 1993). Even though this effect has been found in matching tasks with unfamiliar stimuli (e.g. Pellicano & Rhodes, 2003), supporting the view that it occurs at a perceptual stage, this remains controversial (Wenger & Ingvalson, 2002). Here, we used fast event-related fMRI-adaptation to test whether the regions responding preferentially to faces in the human visual cortex represent facial features independently or not. On each trial, subjects (N=8) were shown a whole face stimulus followed either by a whole face or a single feature (the eyes). The eyes feature in the second stimulus could either be identical to the first stimulus, or different, leading to 4 conditions. Subjects were better at matching or discriminating the eyes when two whole faces were presented, replicating behavioral observations. In face-sensitive areas of the inferior occipital cortex, there was an adaptation when the same feature was presented in the two stimuli of a pair, whether the feature was presented in the same format (whole-to-whole) or not (whole-to-isolated). In contrast, and as predicted, there was a much larger adaptation in the whole-to-whole than in the whole-to-part condition in the middle fusiform gyrus (MFG). These results supports the view that facial features are not represented independently but rather integrated into a global representation in the middle fusiform gyrus.

E6 *535* ULTRARAPID EXTRACTION OF CONFIGURAL INFORMATION FROM BIOLOGICALLY SALIENT VISUAL STIMULI: MAGNETOENCEPHALOGRAPHIC EVIDENCE

Hanneke K Meeren[1,2] (hanneke.meeren@uvt.nl), Nouchine Hadjikhani[3], Seppo P Ahlfors[3], Matti S Hämäläinen[3], Beatrice de Gelder[1,2,3]; [1]Cognitive and Affective Neuroscience Laboratory, Tilburg University, Tilburg, The Netherlands, [2]F.C. Donders Centre for Cognitive Neuroimaging, Nijmegen, The Netherlands, [3]MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical Imaging, Charlestown, MA, USA

We used magnetoencephalography (MEG) to investigate early visual processing of biologically meaningful stimuli. Healthy subjects had to make an orientation judgment while viewing 9 different stimulus conditions, consisting of photographs of faces, bodies and houses, which were presented in either their canonical (upright) or inverted (upside-down) orientations, or in a Fourier phase-randomized scrambled version to control for low-level visual attributes. MEG data were acquired with a 306-channel Neuromag VectorView system and were co-registered with structural high-resolution T1-weighted MR images. The underlying neuronal generators of the evoked responses were estimated with anatomically constrained noise-normalized minimum norm estimate. Time courses of the source estimates were extracted from several anatomically-defined regions of interest (ROI), amongst them the calcarine sulcus, i.e. the site where the primary visual cortex (V1) resides. The estimated source currents in V1 showed a prominent early component, starting around 50-60 ms and peaking around 95ms. This component was attenuated for meaningful stimuli compared to scrambled images. In addition, there was an early "inversion effect" for biologically salient stimuli (faces and bodies), with larger responses for inverted versus upright stimuli, whereas no such effect was found for houses. In particular, responses to upright faces were strongly suppressed and started to diverge significantly from the responses to inverted faces as early as 63 ms after stimulus onset. These findings show that the extraction of configural information from biological stimuli already starts at very early stages in the visual processing stream, before information enters the object recognition system of the ventral visual pathway.

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E7 *536* Configural Integration in Face Perception: Evidence from EEG Oscillations in the Gamma Band

Elana Zion Golumbic[1,2] (goloma@mscc.huji.ac.il), Shlomo Bentin[1,3]; [1]Department of Psychology, The Hebrew University of Jerusalem, [2]Department of Cognitive Science, The Hebrew University of Jerusalem, [3]Center for Neural Computation, The Hebrew University of Jerusalem

Previous studies associated synchronized EEG activity in the gamma band with mechanisms involved in binding visual features during the formation of coherent percepts. Supporting this hypothesis, "scrambled" objects elicited less gamma activity than coherent familiar objects with similar physical attributes. The sensitivity of gamma activity to configuration rather than details is also evident during processing of Mooney faces, which elicited higher gamma activity when presented upright than when their face configuration is obscured by vertical inversion. In contrast, the face-sensitive ERP component (N170) is larger for inverted faces and inner face components than for upright faces suggesting that it manifests a visual mechanism sensitive to face details rather than computing their spatial configuration. Here we compared the N170 and induced gamma activity elicited by regularly configured faces (RF), faces with scrambled inner components (SF), isolated inner components preserving their normal configuration (IC), and scrambled inner components (SIC). Replicating previous findings, the N170 was smallest for RF, larger for SF and largest when only inner components were present, regardless of configuration (IC/SIC). In contrast, gamma activity around 35Hz was larger for RF and IC than for SF and SIC. These results suggest dissociation between the perceptual

mechanisms manifested by N170 and those eliciting gamma activity during face perception. Specifically they support the hypothesis that N170 reflects the presence of physiognomic stimuli in the visual field, while gamma activity is enhanced by configuration and may play an important role in structural encoding of coherent face percept necessary for within category identification.

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E8 *537* Holistic and subordinate-level face processing in monkeys

Christoph D. Dahl[1] (christoph.dahl@tuebingen.mpg.de), Nikos K. Logothetis[1], Kari L. Hoffman[1]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Face perception in humans differs from perception of most objects: faces are recognized at the individual or subordinate level (e.g. Madonna, Collie), whereas objects are recognized at the basic level (e.g. face, dog). Additionally, faces are perceived holistically, i.e. features are not functionally independent. To date, these criteria have yet to be tested in monkeys.Using a dishabituation paradigm borrowed from developmental psychology, rhesus macaques elicited an image or blank square, alternately, by directing gaze towards the monitor, and terminated a stimulus by looking away. After 20 seconds of cumulative stimulus display time, a new image was presented, constituting the beginning of a dishabituation trial. Image preference was measured as the time spent looking at the new image versus the cumulative display time. In experiment 1, conspecific faces preceded by either another animal or face showed higher preference than those preceded by the mirror-reversed image, demonstrating individuation among monkey faces. In contrast, animals (dogs and birds) did not elicit higher preference when preceded by another same-category exemplar, than when preceded by the mirror-reversed image, demonstrating only basic level differentiation. In experiment 2, composite monkey faces consisting of top and bottom halves were either aligned or misaligned. In dishabituation trials, only the bottom half was replaced. If monkeys perceive faces holistically, this would cause perception of a new face only in the aligned condition. Indeed, aligned faces elicited greater preference than misaligned faces in dishabituation trials. Thus monkeys, like humans, show individuation and holistic processing of conspecific faces.

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E9 *538* Reduced configural processing abilities in congenital prosopagnosia

Claus C. Carbon[1] (ccc@experimental-psychology.com), Helmut Leder[1], Thomas Grueter[3], Martina Grueter[3], Joachim E. Weber[2], Andreas Lueschow[2]; [1]Faculty of Psychology, University of Vienna, Vienna, Austria, [2]Dpt. of Neurology, Charité-Universitätsmedizin Berlin, Germany, [3]Münster, Germany

Prosopagnosia is an impairment in the recognition of faces which is known in two variants, congenital (cPA) as well as acquired prosopagnosia (aPA). Recently, it was shown that cPA often leads to a reduction of face specific processing in general and face specific configural processing in particular. In two experiments using a Thatcher illusion paradigm and a simultaneous matching paradigm with faces and houses, we tested 14 patients with cPA that is associated with impaired face recognition but with no macroscopic brain lesions. As a control group, normal participants with an adjusted age range were used. In Exp.1, for subjects with cPA the speed of a grotesqueness decision (RT) in a Thatcher illusion task (a highly demanding configural task) where faces were rotated in steps of 30° was strictly linearly related to the magnitude of the deviation from upright. In Exp.2, subjects with cPA showed face-specific reduction of face matching performance, but no reduction of performance when houses had to be matched. Moreover, the face-specific matching problems did occur most strongly when faces differed in relational aspects only. Results from both experiments indicate that cPA is tightly linked with reduced face-specific configural processing abilities.

E10 *539* Normal configural processing of non-face stimuli in prosopagnosia

Bradley Duchaine[1] (b.duchaine@ucl.ac.uk), Galit Yovel[2]; [1]Institute of Cognitive Neuroscience, University College London, London WC1N 3AR UK, [2]Department of Psychology, Tel Aviv University, Tel Aviv 69978 Israel

It is well established that faces are processed by configural mechanisms. This configural processing could be the product of a face-specific mechanism or a content-general configural processing mechanism. If they are content-general, prosopagnosics (individuals with impaired face recognition) should show impairments with a wide range of tasks involving configural processing. To determine whether our sample of prosopagnosics have problems with face configural processing, they were tested with a task requiring discrimination between faces that differed in either part configuration or the face parts themselves. The prosopagnosics showed deficits with face configuration discriminations but also showed comparable deficits with face part discriminations. We then assessed non-face configural processing using three independent measures. On a task with houses that was parallel to that used with faces, the prosopagnosics performed normally with house configuration and house part discriminations. When tested with a Navon global-local task, the prosopagnosics showed normal levels of global interference on local response times and local interference on global response times, and they showed a normal sized advantage for global response times compared to local response times. Finally the prosopagnosics scored normally on three tests of visual closure, which have been argued to require configural processing. Taken together, these results suggest that the prosopagnosics have impairments with domain-specific face processing mechanisms. These mechanisms appear to process faces holistically rather than processing facial configuration and facial parts separately.

E11 *540* Categorization of face race modulates holistic face processing

C. Michel[1] (caroline.michel@psp.ucl.ac.be), O. Corneille[1], B. Rossion[1]; [1]Unité Cognition & Développement, University of Louvain, Belgium

Using the face-composite illusion (the extent to which the recognition of the upper part of a 'composite face' is disrupted by the - to be ignored – lower part; Young et al., 1987) in Asian and Caucasian subjects, we have recently shown that same-race (SR) faces are perceived more holistically than other-race (OR) faces (Michel et al., in press, Psychological Science). Here we tested the hypothesis that this differential holistic processing of SR and OR faces could be due to a modulation of holistic face processing by the race-categorization of the face. We measured the face-composite illusion on a set of 'ambiguous-race' faces in 50 Caucasian subjects. These faces were created by morphing Asian and Caucasian faces and extracting the stimuli categorized equally often as Asian and Caucasian by Caucasian subjects (N=34). These stimuli were inserted in blocks of original Asian (group 1) or Caucasian (group 2) faces. As expected, the composite illusion was larger for SR than for OR faces on these original faces, replicating our previous observations. Most importantly, the same 'ambiguous-race' face stimuli were processed less holistically when they were included in Asian blocks (considered therefore as Asians) than when presented in Caucasian blocks (therefore considered as Caucasians). These results support the view that categorization of race could play a substantial role in the differential holistic processing of SR and OR faces.

E12 *541* The configurational and featural information in the age perception of face

SooJin Park[1] (eulb@yonsei.ac.kr), Jung Woo Hyun[1]

To examine the role of configurational information and featural information in the facial age-perception, two experiments were performed. The

stimuli were made from 50 facial images of Japanese female from 20s to 60s. In experiment 1, two kinds of facial images were made: the faces without hair(FWH) and the faces without hair and facial outline(FWHO). These were presented randomly upright or upside-down. The participants estimated ages for these stimuli and original facial images and the differences between these two estimations were analyzed as dependent variables. The result of experiment 1 showed that the age estimations of FWH were better than FWHO, and upright images were better than upside-down images. The no-outline effects are relatively strong in younger faces and the upside-down effects are strong in older faces. In experiment 2, the contributions of eyebrows, eyes, nose, and mouth were compared. For 20s' and 30s' facial images, the eyes took an important role in the age perception, whereas for 40s' and 50s' nose was important. Farah et. al.(1998) suggested configurational information is important in the recognition of facial identity. According to Jung and Park(2004), featural information plays an important role in the recognition of facial expression. The results of this study show that both featural information and configurational information of face is used in the age perception. These imply that age perception is related to both channel processing invariant properties and channel processing changeable properties of face.

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Sunday Posters

E13 *542* Configural and Featural Processing of Human and Animal Faces: Thatcherization, Spatial Distortion and Inversion.

Lawrence A. Symons[1] (Larry.Symons@wwu.edu), Brian W. Roberts[1]; [1]Psychology, Western Washington University

The impact of manipulations known to affect configural and featural processing of faces was assessed for human and animal faces. Two experiments were performed where either the features of the face were altered and/or the orientation was changed to assess whether configural or feature information was being used to process the faces. In Experiment 1 the Thatcher Effect was applied to pictures of both human and animal faces and the pictures were presented as either upright or inverted. Observers rated the perceived grotesqueness of the face pictures. Thatcherization resulted in higher ratings of grotesqueness for the human faces than the animal faces, but inversion of the stimuli yielded similar results for both types of pictures. In Experiment 2, spatial distortions were applied to pictures of human and animal faces, and the resulting pictures were rotated to varying degrees. The human face pictures appeared the most grotesque at 0 and 45 deg, and were less grotesque at 135 and 180 deg. The effect of spatial distortion on the pictures of the animal faces was minimal and orientation had relatively little impact on the perceived grotesqueness. The results suggest that the processes used to encode human faces as well as animal faces are on a continuum of facial processing; and that human faces, in particular, are processed using an extreme form of configural processing supporting the theory that human faces are "special" due to the effect of expertise.

E14 *543* Uncovering the Perceptual Representation in Holistic Face Processing

Brandon M. Wagar[1] (bmwagar@uvic.ca), Danial Bub[1], James W. Tanaka[1]; [1]University of Victoria

In a standard demonstration of holistic face processing, differences in an irrelevant feature (e.g., mouth) change the perceptual representation of a relevant feature (e.g., eyes). Unfortunately, this simple demonstration cannot reveal the nature of the perceptual representation derived from holistic processing. We made use of a set of face stimuli constructed so that incremental differences in a single feature led to systematic changes in performance when pairs of faces were presented for same-different judgments. We then assessed the nature of the perceptual representation in holistic face processing by incrementally varying the degree of difference in relevant and irrelevant features. Participants saw two faces and judged if the relevant features (i.e., eyes) were identical while ignoring differences in the irrelevant features (i.e., mouth). Performance improved with each increment in degree of difference in the relevant feature if the difference between the irrelevant features was small. However, this was contextualized by an interaction in which incremental differences did not influence performance systematically. Rather, performance depended on a striking interaction between the perceptual difficulty of the relevant feature and the degree of difference in the irrelevant feature. When the relevant features were easy to differentiate, discrimination was good regardless of the irrelevant features. However, when the relevant features were difficult to differentiate, discrimination was especially poor if the irrelevant features were also hard to differentiate, but improved significantly if the irrelevant features were easy to differentiate. The implication of these findings will be discussed in reference to categorical perception.

E15 *544* Contextually evoked interference on the holistic processing of faces

Olivia S. Cheung[1] (olivia.cheung@vanderbilt.edu), Isabel Gauthier[1]; [1]Vanderbilt University

Previously, we reported that holistic processing (HP) of faces is reduced by a concurrent face, but not object, working memory load (WML; Gauthier & Cheung, VSS2005). Here, we ask if face discrimination is necessary for such interference. A recent study found that contextual processing of blobs atop bodies engages the fusiform 'face' area (FFA) as much as faces themselves, while bodies or blobs alone do not (Cox et al., 2004). HP was measured in a sequential matching task with two face composites, as participants attempted to selectively attend and compare one part of the composites (e.g., the top). HP was defined as a congruency effect, indicating that the to-be-ignored part influences judgments on the attended part. Three types of WML were imposed on this task, always consisting of 3 stimuli: faces on bodies, bodies alone or blurred blobs atop bodies. On face WML trials, different faces were always shown on the same bodies. The body and blob WMLs were identical except that blurred blobs were added atop the bodies. Consistent with prior work, the face WML reduced HP in the main task relative to the body WML. Critically, the blob WML reduced HP compared to the body WML, although the conditions only differed in the presence of undiagnostic blobs and WM performance was comparable. This suggests that the encoding or maintenance of diagnostic facial information is not necessary to interfere with face HP: rather, stimuli without any facial features but which elicit activity in FFA are sufficient.

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E16 *545* Infants' Sensitivity to Variability in Face Configuration

Scott A. Adler[1] (adler@yorku.ca), Thomas J. Baker[1]; [1]Department of Psychology and the Centre for Vision Research, York University

PURPOSE. Research has suggested that 2-month-old infants can perceive face-like stimuli as a unique configuration of features. The face configuration parameters necessary for infants to discriminate between faces, however, have not been examined. To investigate the configurational parameters that support discrimination, synthetic face stimuli (Wilson et al., 2002), both frontal and 20-degree side views, which equate faces on all parameters except geometric variability were used. Specifically, this study was designed to determine how much geometric variation between faces is necessary for infants to discriminate them. METHODS. A cueing paradigm was used in which 6- to 7-month-olds saw mean face cues that predicted the appearance of targets on one side and face cues that geometrically varied by either 3, 5, 7 or 10% predicted targets that appeared on the other side. Eye movements were analyzed for correct anticipation of the targets in response to which face cue had been presented. RESULTS. When seen in frontal view, infants exhibited above chance correct anticipations for mean vs. 5 and 10% face comparisons but not mean vs. 3%. When seen in the side view, infants exhibited above chance correct anticipations only for the mean vs. 10% variability comparison. CONCLUSIONS. Infants thus rely on the overall variability in config-

uration to discriminate between individual faces. Moreover, infants' discrimination is consistent with adults' (Wilson et al., 2002) in the amount of variability necessary and that less variability is needed for frontal than side views, suggesting the recruitment of the same neural mechanisms.

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Search I

E17 *546* What happens during search for rare targets? Eye movements in low prevalence visual search

Anina N. Rich[1,2,3] (rich@search.bwh.harvard.edu), Barbara Hidalgo-Sotelo[4], Melina A. Kunar[1,2], Michael J. Van Wert[2], Jeremy M. Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham & Women's Hospital, [3]University of Melbourne, Australia, [4]MIT

Searching a complex display for a rare target is involved in a number of socially important tasks, such as screening for cancerous cells, or checking passenger bags at airport security. Unfortunately, the probability of missing a target increases as target prevalence decreases. For example, in a search for weapons in a baggage-screening simulation, observers missed 40% of low prevalence targets but just 7% of high prevalence targets (Wolfe, Horowitz & Kenner, Nature, 435, 2005). These high error rates seem to occur because participants dismiss a display as 'target absent' too quickly, resulting in an error when the target is present. This might occur because in low prevalence search, participants only search a subset of the display before they make a decision. This would result in fewer fixations when targets are infrequent. Alternatively, participants might spend less time looking at each item in the display (and hence less time at each fixation), and simply fail to recognize the target item. We replicate the low prevalence result using a simple visual search task in which the target is a 'T' among 'L's, and measure eye movements on both target-present and target-absent displays. Participants make fewer fixations when targets are rare than when they are frequent, but there is little difference in fixation duration, suggesting that participants are less likely to search the whole display in low prevalence searches. These data have implications for strategies to improve the accuracy of searching for rare targets.

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E18 *547* Crossing Over: Different visual search tasks use different decision rules

Stephen J. Flusberg[1] (steve@search.bwh.harvard.edu), Evan M. Palmer[1,2], Jeremy M. Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

How do observers decide if targets are present in briefly presented visual search displays? They could base their decision on the biggest signal in the display (max rule), on the sum of all signals in the display (sum rule), or on a subset of items in the display (limited capacity). Baldassi and Verghese (2002) argued for a max rule for an orientation search task, while Davis et. al. (in press) measured change in d' by set size functions and found that a max rule worked for some orientation tasks while others showed evidence of limited capacity. We modified Davis' method to provide a clear diagnostic for the presence of at least two decision rules. We measured sensitivity to targets in brief displays (set sizes 1, 2, 4, 8). Three tasks were tested: orientation feature search, color-orientation conjunction search, and a search for a T among Ls. By staircasing dynamic noise, we arranged for d' at set size 1 to be greater for the T vs. L task than for feature search. At set sizes 4 and 8, however, the same stimuli produced larger d' for feature search than for the T vs. L. This crossover is critical because it cannot occur if both tasks use the same decision rule. Feature search data follow a max rule while the T vs. L data suggest limited capacity of two items processed in 100 ms. We conclude that unlimited capacity models can only explain a limited set of tasks.

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E19 *548* Measuring the Timecourse of Guidance in Visual Search

Evan M. Palmer[1,2] (palmer@search.bwh.harvard.edu), Michael J. Van Wert[1], Todd S. Horowitz[1,2], Jeremy M. Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

In search tasks, observers can guide attention to likely targets based on features such as color and orientation. Does guidance develop over time during search or does it act as a fixed filter, present from the start of a trial? We measured the timecourse of guidance by presenting guiding color information prior to the search array. Observers searched for a T among Ls in three conditions: *Large* and *Small* conditions consisted of monochromatic displays of 24 or 4 items, respectively; *Mixed* condition had 4 items of the target color and 20 of another color. Colored placeholders provided guiding information at a variable stimulus onset asynchrony (SOA) prior to appearance of the search array. Target color was either consistent or varied within a block. If guidance develops over time, we would expect that *Mixed* condition reaction times (RTs) would start off near *Large* condition RTs when SOA was 0 ms, then drop to asymptote at the *Small* condition RTs with increasing SOA. Results showed that when target color was consistent within a block, *Mixed* and *Small* conditions had comparable RTs from 0 ms SOA on, indicating immediate, sustained guidance. However, when target color varied within a block, RTs were consistent with guidance developing over 200 ms. We conclude that guidance takes 200 ms or less to become effective and, once established, acts like a filter to segregate displays immediately.

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E20 *549* Errors in low prevalence visual search: Easy to produce, hard to cure

Michael J. Van Wert[1] (mike@search.bwh.harvard.edu), Todd S. Horowitz[1,2], Skyler S. Place[1], Jeremy M. Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

In standard visual search paradigms, targets are present on 50% of trials. Many important search tasks (e.g., medical and baggage screening) involve much lower target prevalence. Previously, Wolfe, Horowitz, and Kenner (*Nature*, 2005) reported that a task yielding 7% miss errors at 50% prevalence produced 30% errors at 1% prevalence. Their task was quite artificial. Here we describe a replication using x-ray images of baggage, as well as two efforts to reduce errors. Stimuli were virtual bags assembled from actual x-ray images of weapons and other objects. Bags contained 3, 6, 12, or 18 objects. Target prevalence was 50% or 1-2%. Observers searched for guns and knives. The CONTROL condition replicated the prior study with these realistic stimuli: miss errors were 18% at 50% prevalence, 40% at 1% prevalence. At low prevalence, target-absent reaction times (RTs) become too fast. Thus, the SPEEDING TICKET condition warned observers when absent RTs dropped below a threshold based on the observer's average target-present RT. These warnings slowed absent RTs by about 700 msec but failed to reduce errors (40% at 2% prevalence). The DUAL OBSERVER condition showed two independent observers the same sequence of bags. If errors were independent, joint error rates would be the product of individual rates. Joint error rates were slightly lower in DUAL OBSERVER conditions. The extra errors produced at low prevalence are not independent between observers. Elevated errors at low prevalence are easy to produce, potentially dangerous, and hard to ameliorate.

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URL: search.bwh.harvard.edu

E21 *550* THE PREVIEW BENEFIT IS ACTIVE IGNORING

Harriet A Allen[1] (H.A.Allen@bham.ac.uk), Glyn W Humphreys[1]; [1]Brain and Behavioural Sciences, University of Birmingham, UK

In visual search experiments, when some distractors are previewed before the remainder, participants discount these distractors from search. Behav-

ioral data suggests active inhibition underlies this Preview Benefit. In an fMRI study, we localized and then measured BOLD activation in areas responsive to previewed, ignored and passively viewed stimuli. Participants performed a visual search task. Each trial consisted of 2 displays. The target, always in the second display, was defined by a conjunction of form (house/face) and color (red/blue). Experiment 1: Passive condition - the first display contained irrelevant distractors. Preview condition- the first display contained face distractors which remained on screen throughout both displays. Experiment 2: Replicated Passive and Preview conditions (except that the target could be either a face or house) and added an Ignore Category condition where the target was always the opposite category to items in the first display, and these items were repositioned in the second display. Search for the target was slowest in the Passive condition, faster in the Ignore Category condition and fastest in the Preview Search condition. In face- and house-specific brain areas, earlier and higher activations were associated with this preview benefit. This pattern of activations was different to that found for ignored items in the Ignore Category condition. The data are consistent with the preview benefit being an active process, involving different brain states to those correlated with simply ignoring a stimulus. Active ignoring of a preview is mediated by preactivation of the ignored items.

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E22 *551* Differentiating cross- from within-domain binding: Neuropsychological evidence from reversed search asymmetries

Glyn W Humphreys[1] (g.w.humphreys@bham.ac.uk), John Hodsoll[1]; [1]School of Psychology, University of Birmingham

We present neuropsychological evidence distinguishing binding between form and color (cross-domain binding) and binding between form elements (within-domain binding). We contrasted conjunctive search requiring feature binding, from difficult feature search, using control participants and patients with unilateral parietal or fronto/temporal lesions. The standard advantage for feature over conjunction search was reversed, to rule out effects of task difficulty or loss of top-down guidance of search, that could differentially affect conjunction targets. Despite this, parietal patients found search for color-form conjunctions harder than difficult feature search, when targets fell contralateral to their lesion. Controls and frontal/fronto-temporal patients, however, always found the feature search task more difficult. In contrast, the parietal patients showed the same pattern as the other participants with form conjunctions, with form conjunctions advantaged relative to feature search. These data indicate a qualitative difference between binding in the form domain and binding across form and color, consistent with theories that propose distinct binding processes in vision.

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E23 *552* Is Visual Search a Top-down or Bottom-up process?

Xin Chen[1] (chenxincx@gmail.com), Gregory J. Zelinsky[1]; [1]SUNY at Stony Brook

When bottom-up and top-down signals are present in a search task, how do these signals combine to guide search? To address this question we hid a 0.25 degree "x" or "+" among 9 photorealistic objects. The subject's task was to find this x/+ target and indicate its identity (i.e., "x" or "+"). All of the objects were grayscale except for one color distractor. Bottom-up salience was manipulated by the distractor's color saturation: 0% (grayscale), 50%, or 100% (vivid color). Top-down salience was manipulated by the availability of a target preview. The x/+ target was spatially associated with a search object; the target preview indicated the object on which the x/+ target could be found. The target preview was never the color distractor. Preview duration was either: 1000 msec, 100 msec, or 0 msec (i.e., no preview, subjects searched only for the x/+ target). RTs were significantly faster in the preview conditions compared to the no-preview condition, but did not vary with the saturation manipulation. Analysis of eye movements made during search revealed more initial saccades to the target preview object in the preview conditions; the color distractor failed to attract initial saccades when a preview was available. Only in the no-preview condition was there a tendency to fixate the color distractor. We conclude that visual search is primarily a top-down process; when top-down information is available, bottom-up control signals are largely ignored. However, in the absence of top-down information, these bottom-up signals can direct search behavior.

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E24 *553* Exploring Set Size Effects in Realistic Scenes

Mark B. Neider[1] (mneider@ic.sunysb.edu), Gregory J. Zelinsky[1]; [1]State University of New York at Stony Brook

Despite its bedrock status in the search literature, the notion of a set size effect breaks down almost entirely when ported into the real world, where objects are often difficult to delineate and typically far outnumber the set sizes used in most search experiments. To explore various forms of set size effects in real-world contexts, we had observers search for the presence of a target (a tank) in pseudorealistic landscapes created with 3-d modeling software. This approach allowed us to quantify the number of objects in the scene and to manipulate the types and proportions of distractor objects. Populating the landscape scenes were rocks, shrubs, and trees in varying proportions (25/25/25, 75/25/25, 25/75/25, 25/25/75). Distractor objects also varied in their color and size similarity to the target. Although RTs generally increased with the number of objects in the scene, there were exceptions to this standard set size effect. In displays dominated by rock distractors, observers searching 75 object scenes (25/25/25) were no faster at indicating target-absence compared to the comparable 125 object scenes (75/25/25). Slopes were also steeper in the target-present (~330 ms) and target-absent (~1470 ms) data when the dominant distractor group consisted of target-similar objects (e.g., bushes, trees), and eye movements were smaller in amplitude and more frequent under these conditions. We interpret these data as evidence for similarity-based grouping in realistic scenes. When distractors are dissimilar to the target, these distractors are more easily rejected as a group.

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E25 *554* Evidence for Guidance in Categorical Visual Search

Hyejin Yang[1] (hjyang@ic.sunysb.edu), Gregory J. Zelinsky[1]; [1]SUNY at Stony Brook

When we search for a pen or a paper to jot down a note, the targets in these tasks are not specific visual patterns but rather categorically defined classes of objects. Although search is clearly guided by the visual features of specifically defined targets, it is not known whether search is similarly guided by the visual features defining an object class. We addressed this question by having subjects do two versions of an identical teddy-bear search task; one with a visually non-specific categorically defined target (e.g., "find the teddy-bear") and the other with a specifically defined visual target (i.e., subjects were shown a target preview). Guidance was defined by the proportion of initial saccades directed to the target and by the cumulative probability of target fixation. As expected, we found evidence for target-specific guidance in both of these measures. More importantly, we also found evidence for guidance to categorically defined targets. Although categorical guidance was not as pronounced as target-specific guidance, subjects searching for the teddy-bear object class preferentially directed their initial saccades to teddy-bear targets and fixated these targets sooner than what would be expected from chance. In follow-up experiments we varied the repetition of specific targets and distractors in a categorical teddy-bear search task to determine how the availability of specific visual templates affects categorical search behavior. The data from

these experiments suggest that subjects were forming non-specific visual templates for object classes and using these class-defining features to guide their categorical search.

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E26 *555* Noise unveils spatial frequency and orientation selectivity during visual search

Abtine Tavassoli[1] (atavasso@ece.utexas.edu), Ian van der Linde[2], Alan C Bovik[1], Lawrence K Cormack[3]; [1]Department of Electrical and Computer Engineering, University of Texas at Austin, USA, [2]Department of Computing, Anglia Ruskin University, UK, [3]Department of Psychology, University of Texas at Austin, USA

Spatial frequency and orientation are features whose significance in visual selectivity is supported by physiological and psychophysical evidence. In this study, a fast classification image framework (Tavassoli et al., *in press*) distinguishing foveal and non-foveal search processes was employed to examine human observer strategies in 8 separate visual search experiments using Gabor targets (2 and 8cpd spatial frequencies at 0, 20, 70, and 90deg orientations, with 0deg corresponding to vertical bars). Eye movements were recorded during every trial as observers searched for one target randomly embedded in one tile of a grid of 1/*f* noise tiles. A variant of signal detection theory was then used to classify noise tiles. Estimates of spatial frequency and orientation tuning were obtained by spectral domain Gabor fitting using the noise spectra. Results showed that observers' saccade destination selection and final tile choice were based on available phase information for low but not high spatial frequency targets. Center/surround frequency responses were observed in which the frequency of the sought target was excited and nearby frequencies inhibited, suggesting a strategy different from an ideal observer. Discrepancies between the foveal and non-foveal orientation tuning revealed lower accuracy for peripheral vs. foveal targets. In at least one case, confusion between orthogonal orientations (only) occurred. Our data were consistent with earlier parafoveal studies and provided additional insight into observers' dynamic decision-making, highlighting different search strategies that predominate at different target frequencies.

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E27 *556* Classification images reveal observer templates underlying the direct tilt illusion

Ian van der Linde[1] (i.v.d.linde@anglia.ac.uk), Abtine Tavassoli[2], Alan C Bovik[2], Lawrence K Cormack[3]; [1]Department of Computing, Anglia Ruskin University, [2]Department of Electrical & Computer Engineering, University of Texas at Austin, [3]Department of Psychology, University of Texas at Austin

The tilt illusion demonstrates how the sensation of orientation is misperceived in the presence of an inducing distracter. A fast classification image (CI) technique (Tavassoli et al., in press) was used to visualise the impact of the direct tilt illusion in a visual search experiment. A search target (a sine-wave grating oriented at 0 deg) was embedded in a grid of 1/f noise tiles of 1 deg visual angle each. In an eye-tracker, observers searched the grid to find the target in a series of 5s time-limited trials. Two different background distracter orientations (-15 deg and +15 deg vertically offset sine-wave gratings) and a distracter-absent control condition were run, using two human observers at 500 trials per condition. For both observers a repulsive tilt in the CIs and spectral CIs was observed relative to the orientation of the background distracter, where no significant tilt was seen in the distracter-absent control condition. Earlier studies measured the tilt illusion at various eccentricities with 2AFC/yes-no psychophysics; our study reveals that this phenomenon is similarly pervasive in a naturalistic visual search scenario. Our results indicate that peripherally viewed tiles (saccade targets) are misperceived prior to foveal scrutiny, thus our results support the hypothesis that the direct tilt illusion is low level and originates early in the visual pathway. Work is underway to quantify magnitude of the tilt illusion in this experimental setup, relative to the eccentricity of the saccade preceding each tile's fixation.

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E28 *557* Search Asymmetry and Eye Movements in Infancy

Pamela K. Gallego[1] (pgallego@yorku.ca), Scott A. Adler[1]; [1]Department of Psychology and Centre for Vision Research, York University, Toronto, Ontario, Canada.

PURPOSE. Visual search studies with adults have demonstrated an asymmetry in that search for a feature-present target amidst feature-absent distracters (R among Ps) is faster and more efficient than the reverse search (P among Rs). Research with infants has suggested that they might exhibit a search asymmetry; however, these studies assessed asymmetry in seconds or minutes, whereas in adults it is assessed in milliseconds. Consequently, whether infants have similar visual search and selective attention mechanisms as in adults is not clear. Adler and Orprecio (2006) have recently demonstrated search performance in infants on the order of millisecond, similar to adults. The present study examined search asymmetry in infants using a visual search paradigm. METHODS. Three-month-olds' saccade latencies to a target in a visual search array were measured as they randomly viewed the following four arrays: feature-present (R among Ps), feature-absent (P among Rs), homogenous Rs and homogenous Ps. All four arrays were presented in set sizes of 1, 3, 5 and 8. RESULTS. Similar to findings with adults, the target in the feature-present array popped-out from amidst the distracters and the saccade latencies were unaffected by increasing set sizes. In contrast, the saccade latencies to the target in the feature-absent array and the homogenous arrays increased with increasing set-sizes. CONCLUSIONS. These findings indicate that infants exhibit a search asymmetry similar to that found with adults. This suggests that the same selective attention mechanisms are functioning in infants and adults. Supported by NSERC 503860 to SAA.

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E29 *558* Latency and accuracy of search eye movements across the macaque visual field

Bernard Gee[2,3] (bgee@cvs.rochester.edu), William Merigan[1,2,3]; [1]University of Rochester Eye Institute, [2]Department of Ophthalmology, [3]Center for Visual Science

We measured saccadic eye movements of macaques while they performed visual search monocularly across the central 30 deg of the visual field. Monkeys made eye movements to choose the target that matched a prior sample stimulus among 0 to 7 distractors. Positional jitter was used to make target and distractor locations unpredictable from trial to trial. Target and distractors were gray discs presented on a white background and targets could be either lighter or darker than the distractors.When distractors were present, the decreased target identification accuracy that was observed was accompanied by very little increase in search times. When there was only a single distractor, its location relative to the target altered search performance, with optimal detection when there was an intermediate distance between target and distractors. Search latency and landing accuracy showed little variation with eccentricity, but percent correct target identification decreased with eccentricity. For both monkeys, performance was slightly better in the nasal inferior visual field. Asymmetric performance was observed (greater percent correct identification but not different search times) when targets were of higher contrast than distractors, and search times for error trials were longer than for correct trials.Our results show how search performance changes with both stimulus conditions and location in the visual field.

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E30 *559* **Optimal feature gain modulation during visual search**

Vidhya Navalpakkam[1] (navalpak@usc.edu), Laurent Itti[1,2]; [1]Dept. of Computer Science, University of Southern California, [2]Neuroscience Program, University of Southern California

Despite substantial neurobiological and behavioral evidence thatknowledge modulates feature processing and facilitates visual search,currently, there is no mathematical theory to capture such top-downinfluences. We propose an optimal theory of how prior statisticalknowledge of target and distractor features modulates the responsegains of neurons encoding low-level visual features, such that search speed ismaximized. Through numerical simulations, we show that this theorysuccessfully explains many reported behavioral andelectrophysiological observations including top-down effects such asthe role of priming, role of uncertainty, target enhancement anddistractor suppression, as well as bottom-up effects such as pop-out,role of target-distractor discriminability, distractor heterogeneity,linear separabilty and others. Further, the theory makes surprisingpredictions whereby finding a target may sometimes require suppression oftarget features, or enhancement of non-target features. We validatethese counter-intuitive predictions through new psychophysicsexperiments. Four naive subjects performed a difficult search for 55degree oriented target among 50 degree distractors. The gains thus set up weretested by randomly inserting probe trials, in which we briefly flashed(200ms) four items representing the distractor (50 degree), the target(55 degree), relevant as predicted by the theory (60 degree), andsteep (80 degree) cues. Although subjects searched for a 55 degreetarget, as predicted by the theory, there were significantly highernumber of reports on the 60 degree item (paired t-test with $p < 0.05$). These results provide direct experimental evidence that humansmay deploy optimal feature gain modulation strategies.

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E31 *560* **Models of Eye Movement Strategies: Optimal Searcher vs. Optimal Saccadic Targeting**

Wade A. Schoonveld[1] (schoonveld@psych.ucsb.edu), Miguel P. Eckstein[1]; [1]University of California, Santa Barbara

Many models of eye movements during search maximize the probability of saccadic targeting by selecting the location with the highest posterior probability of containing the target (Beutter et al., 2003; Torralba, 2003, Journal of the Optical Society of America A). Recently, a different model was proposed that uses knowledge of the varying visibility of the target/distractors across the retina to optimally plan sequences of saccades maximizing localization performance (optimal searcher, Najemnik & Geisler, 2005, Nature). Here, we compare the two models' distributions of 1st saccade endpoints to those of three human observers during a search for a bright Gaussian target among four dim distractors (Caspi et al., 2004). The contrast of the target as well as the distractors was varied over time, every 25 ms, by adding samples of random Gaussian noise (single frame SNR = 1.4). Display elements were placed equidistant around the circumference of a circle with a radius of 6.4 deg. The 1st saccade endpoints of human observers and the ideal saccadic targeting model clustered around the possible target locations. The pattern of 1st saccade endpoints of the ideal searcher varied with signal contrast, becoming more like the ideal target saccadic targeting model at low SNRs, and clustering around the center of the display for high SNRs. We present a quantitative approach to compare human results and model predictions by estimating the likelihood of observing the human saccade endpoints given that a particular underlying model is driving the eye movements.

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E32 *561* **A robot with active vision**

Tom Troscianko[1] (tom.troscianko@bris.ac.uk), Ben Vincent[1], Iain D Gilchrist[1], Rob Knight[2], Owen Holland[2]; [1]Department of Experimental Psychology, University of Bristol, UK, [2]Department of Computer Science, University of Essex, UK

Traditional artificial visual systems have assumed a homogeneous sampling of the visual field and have tended not to be able to cope with natural or complex viewing situations. However, the visual neurophysiology shows that visual sampling is highly non-uniform and that features extracted in early vision are combined in a salience map. The purpose of the salience map is to drive eye movements to relevant parts of the visual field, allowing high resolution analysis of the fixated region by the fovea. We have built a robotic system with an inhomogeneous retina. The visual system of the robot extracts features at different scales in different visual locations. Features such a color, spatial scale, and orientation are combined in a salience map. The salience map is altered by the task set in two distinct ways. First, the contribution of each feature map to the salience map is modulated by which features are predictive of the target. Second, locations in which the target are more likely to occur have a higher weighting. Foveal inspection of candidate locations then allows a decision about whether it is the target which is present at that location. Importantly, because of the inhomogeneous retina, salience changes radically with each fixation and the system appears to be more robust to complex scenes because detailed analysis is only occurring at one location at a time.We shall demonstrate an implementation of the system which executes saccades and searches for a target in its natural environment.

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Scene Perception

E33 *562* **Differential Encoding of Environmental Features in Spatial Representation**

George S. W. Chan[1] (changsw@mcmaster.ca), Patrick Byrne[1], Suzanna Becker[1], Hong-Jin Sun[1]; [1]McMaster University

Originally demonstrated by Wang and Spelke (2000), it has since been shown that different features of an environment may be encoded either allocentrically or egocentrically. Following this line of research, we studied subject's directional judgments of environmental features (objects and corners) from an imagined viewpoint that was either aligned or misaligned with the originally learned viewpoint. Subjects were first brought to a fixed learning position in a four-sided, irregularly shaped room and learned the locations of four corners and four different objects relative to two testing viewpoints (aligned or misaligned). They were then blindfolded, brought out of the room, and required to point in the directions of the corners and objects while imagining themselves at one of the two testing viewpoints. Three experiments were conducted: different objects placed in the middle of the room (Exp 1); different objects placed against the wall (Exp 2); and identical objects placed against the wall (Exp 3). The results showed that absolute error for both corners and objects and configurational error for corners (Exp 1, 2, and 3) and objects with the same identity (Exp 3) was higher from the misaligned viewpoint compared to the aligned viewpoint. However, the configurational error for objects with different identities was similar between viewpoints (Exp 1 and 2). The fact that configuration errors were different relative to different viewpoint under particular circumstances (e.g., environmental features) argues against a definitive allocentric representation. Thus, disregarding important variables such as viewpoint can potentially misrepresent the true nature of spatial representations.

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E34 *563* **Representing Layout: What is the time course of Boundary Extension?**

Christopher A. Dickinson[1] (cdickins@udel.edu), Daniel Bensonoff[1], Helene Intraub[1]; [1]University of Delaware

Remembering unseen layout beyond the edges of a photograph (*boundary extension;* BE) is thought to facilitate integration of successive views. In

prior research, however, the briefest retention interval tested was 1 second (Intraub et al., 1996). Might a veridical representation be retained for a few hundred ms following offset? On each trial, 3 photographs of unrelated scenes were presented for 325 ms each in rapid succession at center screen. They were followed by a masked retention interval and repetition of one picture (the first, second, or third). The repeated picture remained on the screen while the observer rated it on a 5-point scale ("same [0]", "a little closer [1]", "a lot closer [2]", "a little wider-angle [-1]",or "a lot wider-angle [-2]"). The retention interval was either 1000, 625, 250, or 100 ms (between-subjects variable: total N=144). On 1/3 of the trials the test picture appeared in the same spatial location as the stimulus. Anticipating that an early visual buffer might maintain a veridical representation, on the other trials, the test item was shifted to the left or right, requiring an eye movement - a situation more comparable to visual scanning. Surprisingly, results showed significant BE at *all* retention intervals, irrespective of serial position or spatial position at test. Beginning with the briefest interval, mean scores were .56, .44, .41, and .41. Spatial extrapolation occurred extremely rapidly for briefly glimpsed pictures, rapidly enough to facilitate integration of successive views.

E35 *564* Assessment of Images Fused using False Colouring

Timothy D Dixon[1] (Timothy.Dixon@bris.ac.uk), Eduardo F Canga[2], Tom Troscianko[1], Jan M Noyes[1], Stavri G Nikolov[2], Dave R Bull[2], C Nishan Canagarajah[2]; [1]Department of Experimental Psychology, University of Bristol, UK, [2]Centre for Communications Research, University of Bristol, UK

Image fusion involves combining multiple images of differing modalities (e.g. infrared and visible light radiation) to create a composite that contains complementary information from the inputs. Most methods of fused image assessment have involved some kind of subjective quality rating, which is then correlated with computational metrics. A different approach recently adopted (Dixon et. al, 2005; submitted) is to apply a task to the assessment process. Extending a 2AFC paradigm previously used, the current paper compares how quickly participants stated whether a soldier was left or right of a clearing of trees in frames of a fused image sequence. False colored fused images were used, created by applying the infrared image to a red color plane, and the visible light image to a green color plane (1 condition), as well as adding a uniform blue additional color plane (1 condition), and comparing these with the monochrome Dual-Tree Complex Wavelet Transform (DT-CWT) method. In addition, two levels of JPEG2000 compression were applied, as well as an uncompressed condition. Participants were also asked to make subjective quality assessments of the images. The results showed significantly faster reaction times for the two color-fusion methods over the DT-CWT method, although no significant effect of compression was found. The subjective quality ratings showed main effects of both fusion method and compression, and an interaction. The results suggest that application of color to a given fused image assessment task can be beneficial, whilst subjective quality ratings should be used with care.

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These images are available online at www.imagefusion.org.

E36 *565* Interaction of scene background, size change, direction and velocity in determining perceived motion in depth

Shaw Gillespie[1] (gillesps@uci.edu), Myron L. Braunstein[1], George J. Andersen[2]; [1]University of California, Irvine, [2]University of California, Riverside

Gibson (1950) contrasted ground theory in which distance judgments are made for objects seen against a continuous background surface with air theory in which isolated objects are seen against a homogeneous background. The present study examined the effects of three sources of distance information with objects displayed against a real world scene background or a uniform background. Observers were presented with two displays in sequence and asked to select the display in which the final position of a spherical object was closer. The object either varied in projected size or maintained a constant size and either moved downward in the projection or moved only horizontally. Objects that moved downward either maintained a constant 3-D velocity or a constant projected velocity. Size change was effective in indicating motion in depth for both background conditions, but the effect of vertical motion was different for the two background conditions. With a homogeneous background, objects moving only horizontally were judged as moving closer and the different velocity functions did not significantly affect judgments. With a scene background, judged motion in depth was smallest for objects moving only horizontally. Objects moving at a constant 3-D velocity were judged as approaching closer than objects moving at a constant projected velocity. These results show an interaction of the presence or absence of a ground surface with size and motion information, with changing size effective independently of the background but the effect of motion direction and velocity strongly dependent on the presence of a scene background.

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E37 *566* The Role of the Periphery in Directed Search for Natural Objects

Scott Gorlin[1, 2] (gorlins@mit.edu), Chetan Nandakumar[1, 2], Pawan Sinha[1]; [1]MIT Department of Brain and Cognitive Sciences, [2]These authors contributed equally to this work

The task of locating a target pattern within a scene is ubiquitous in vision. Past work on visual search typically used synthetic stimuli such as blobs and lines and has focused on a few low-level saliency cues. We build upon this work by investigating visual search for real-world objects. In particular, we examined human search efficiency by using an eye-tracker to record subjects' scan paths as they looked for designated targets in 2D arrays of randomly chosen natural objects.In order to make principled comparisons across subjects and stimuli, we have developed a metric to quantify 'search efficiency'. Using this metric, our experimental data indicate that while natural object search is typically not a parallel one, observers are considerably more efficient than an item-by-item serial search strategy. Matching of attributes, such as coarse color and orientation histograms in the periphery, drives the search, in stages, towards the target. Different attributes appear to be effective at different degrees of eccentricity. This suggests a computational approach to visual search that involves the creation of coarse maps of target likelihood in peripheral vision that are defined over simple attributes such as color and orientation. These maps then guide the next fixation in an iterative manner until the target has been precisely located. In addition to helping understand search by normal observers, this model makes interesting predictions about how search efficiency is likely to degrade in tunnel vision patients - patients with normal foveal vision but varying degrees of peripheral visual field loss.

E38 *567* Seeing the {closed+camouflage+natural=forest} for the trees: Rapid scene categorization can be mediated by conjunctions of global scene properties

Michelle R. Greene[1] (mrgreene@mit.edu), Aude Oliva[1]; [1]Massachusetts Institute of Technology, Department of Brain and Cognitive Science

The human ability to categorize novel natural scenes with minimal exposure duration is a truly remarkable and mysterious feat. How is the initial scene representation constructed to allow for rapid scene categorization given the many possible levels of scene description (objects, global layout and functional properties, semantic categories, etc.)? In the first experiment, we tested the temporal availability of seven global scene properties (e.g. volume, navigability, openness) relative to semantic categorization of eight common natural scene categories (e.g. forest, lake) by comparing presentation-time thresholds for these tasks. Results showed that, for the same images, global properties were available for report with less expo-

sure time (25 msec) than semantic categories (43 msec). Do combinations of global scene properties predict semantic categorization? In a second experiment, we compared human performances on a rapid scene categorization task to a model observer whose input was the global property descriptors for each image. The model was trained on the distributions of scene categories along global property dimensions, outputting the scene category with the maximum likelihood summed over global properties. Remarkably, the model's categorization performance matched human performance for presentation times of 30 msec (74% vs. 70% correct) as well as the patterns of availability for individual categories. Furthermore, errors made by the model observer predicted human errors for 69% of images. Taken together, these results strongly suggest that the rapid semantic categorization of natural scenes by humans can be mediated by detecting conjunctions of global scenes properties.

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E39 *568* Seeing the forest but not the trees: spared categorization and functional activation for scenes in patients with object agnosia

Jennifer K Steeves[1] (steeves@yorku.ca), Jonathan S Cant[2], Kenneth F Valyear[2], Jean-François Démonet[3], Robert W Kentridge[4], Charles A Heywood[4], Melvyn A Goodale[2]; [1]Department of Psychology & Centre for Vision Research, York University, [2]CIHR Group for Perception and Action, The University of Western Ontario, [3]INSERM, Toulouse, [4]The University of Durham

We compared scene categorization in two patients with object agnosia (SB and MS) to previously published data from patient DF, who has a profound visual form agnosia. Subjects viewed three categories each of natural (beach, forest, desert) and non-natural (city, room, market) scenes. Colour is known to facilitate natural scene identification, when colour is diagnostic (Oliva & Schyns, 2000). Scene colour and spatial frequency content were manipulated to create 4 different scene versions—normally-coloured, colour-inverted, greyscale, and black & white (texture degraded). All three patients were able to categorize scenes despite object agnosia. Patient DF performed better with normally-coloured natural scenes compared to other versions of the same scenes, reflecting her spared colour and texture processing. In contrast, SB and MS, both of whom have cerebral achromatopsia, demonstrated similar performance across all versions of natural and non-natural scenes. Further, MS showed good performance for natural but was near chance for non-natural scenes, possibly due to spatial frequency content differences between these categories. DF exhibited functional activation for scenes in the parahippocampal place area (PPA) whereas both MS and SB did not, but instead showed activation in the region of the transverse occipital sulcus (TOS), an area also known to be selective for scenes. SB also showed activation in the intraparietal sulcus. These findings provide further evidence that scene categorization is independent of object recognition and suggest that activation in either regions (PPA and TOS) of the scene processing network is sufficient for scene categorization.

E40 *569* Not all scene categories are created equal: the role of object and layout diagnosticity in scene gist understanding

Aude Oliva[1] (oliva@mit.edu), Talia Konkle[1], Michelle R Greene[1], Antonio Torralba[2]; [1]Department of Brain and Cognitive Sciences, MIT, [2]Computer Science and Artificial Intelligence Laboratory, MIT

Historically, scene understanding has focused on the understanding of individual objects and their locations. However, recent computational approaches have shown that regularities in spatial layout can mediate scene recognition. These approaches are not mutually exclusive as the layout of scenes (e.g. bedroom) is often constructed from the arrangement of large diagnostic objects (e.g. bed). In Experiment 1, we set up a pairwise comparison matrix of eight indoor categories, testing categorization performance along a range of short presentation times (20-80 msec). These data provide a measure of confusion between one indoor category to another, and suggest that categories whose objects are diagnostic of the indoor category and/or who form a regular layout (e.g. conference room) were more easily discriminable than categories whose objects were not diagnostic, and/or whose layout varied (e.g. office). How much of this performance is due to the generalized layout from these objects and how much is due to the objects themselves? In Experiment 2, we presented the images for 200 msec at varying degrees of blur, maintaining coarse layout but making individual objects unrecognizable. We found that categories whose objects form a diagnostic layout were recognized at a coarser scale than categories for which layout was not diagnostic. Altogether, the results suggest that scene gist understanding seems to be mediated by a hierarchy of regularities, in both spatial layout and in its objects. We show the extent to which statistical regularities of objects and their layout across scene categories predict human performances in rapid scene categorization tasks.

URL: http://cvcl.mit.edu

E41 *570* Why are natural scenes easy to remember, but artificial ones hard?

Claudia M. Hunter[1] (cmg56@cornell.edu), Shimon Edelman[1]; [1]Cornell University

A convergent set of findings suggests that the phenomenal impression of a scene's structure contains representations of some of the viewed objects, set at relatively precise spatial locations in the visual field. The representation is thought to be limited to 4-5 objects by the capacity of visual short-term memory (Hunter, Warlaumont, and Edelman, 2005; Irwin and Zelinsky, 2002). Yet, our ability to rapidly extract the gist of real-world scenes or decide which objects are congruent with scene context argues for much greater capacity (Davenport and Potter, 2004; Rousselet, Joubert, and Fabre-Thorpe, 2005). What accounts for the disparity in these findings? We attempt to bridge the gap between scene research using naturalistic photographs and that using artificial scenes of parameterized stimuli by investigating what aspects of scenes increase subjects' ability to remember spatial positions of objects. Subjects were shown scenes composed of photographs of diatoms randomly located against 1) no background; 2) a background of rippled sand; or 3) sand with two fixed "landmarks," for 6 s, with one scene intervening between sample and test. Subjects indicated whether or not a designated object was in the same location as in any previous scene. Trial blocks with landmarks showed significantly better performance than blocks with sand but no landmarks; both were better than blocks with no background. Scene backgrounds and landmarks may work to activate brain areas that represent spatial geometry (Epstein, 2005), helping to "anchor" object locations and thereby boosting visual memory capacity.

E42 *571* Constructing Depth Information in Briefly Presented Scenes

Talia Konkle[1] (tkonkle@mit.edu), Elisa McDaniel[1,2], Michelle R. Greene[1], Aude Oliva[1]; [1]Brain and Cognitive Sciences, MIT, [2]Neuroscience, Wellesley College

With only a glance at a novel scene, we can recognize its meaning and estimate its mean volume. Here, we studied how depth layout perception of natural scenes unfolds within this glance: how does three-dimensional content emerge from the two-dimensional input of the visual image? One hypothesis is that depth layout is constructed locally: points close on the two-dimensional image will be more easily distinguishable in depth than points separated by a larger pixel distance. An alternative hypothesis is that depth layout is constructed over the global scene: points lying on the foreground and background surfaces will be distinguishable in depth earlier than surfaces at intermediary distances, independent of their proximity in the two-dimensional image. The method consisted in superimposing two colored target dots on gray level pictures of natural scenes, while participants responded which dot was on the shallowest surface. The location of the two dots was pre-cued and the scene image was displayed for various durations from 40 to 240 ms, and then masked. Results suggest that depth information is available in a coarse-to-fine, scene-based representation: when the two targets have the greatest depth disparity in the scene (irrespective of their pixels distance), participants accurately select the

closer surface at shorter presentation times than when the surfaces were nearer in depth. These data support the hypothesis that the representation of depth available at a glance is based on rapidly computed global depth information, rather than local, image-based information.

E43 *572* Amodal completion when perceiving and remembering RSVP pictures

Ming Meng[1] (mmeng@mit.edu), Mary C. Potter[1]; [1]Department of Brain and Cognitive Sciences, MIT

Objects in a scene are often partially occluded without causing the viewer any problem: the occluded parts are apparently represented via amodel completion. To evaluate human ability to perceive and remember partially occluded pictures, we showed sequences of pictures using rapid serial visual presentation (RSVP) for durations of 53ms, 107ms, 213ms or 426ms/picture. The pictures were 1296 color photographs (size = 300×200 pixels) with widely varied content. Partially occluded pictures were covered by 90 red disks (size = 16×16 pixels each) at random positions, covering 30% of the picture area. Whether a given sequence was presented normally or partially occluded was counterbalanced between participants. In one condition participants attempted to detect a named target (e.g., " businessmen at table") which was present on 2/3 of the trials; in a second condition, participants were given a yes-no memory test of one item; the correct answer was "yes" on 2/3 of the trials. In the detection condition the occluded pictures were almost as successfully detected as the normal pictures, even at the shortest duration. In contrast, in the memory condition performance was markedly worse with partially occluded pictures than normal pictures, particularly at the two shorter durations. The results suggest that amodal completion can occur rapidly when the observer has gist information about a picture, but occurs more slowly when the viewer has no prior conceptual information. The effects of inverting normal and partially occluded pictures will also be discussed.

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E44 *573* Effects of Set-Size on Scene Recognition Following Locomotion

Michael A Motes[1] (motes@psychology.rutgers.edu), Cory Finlay[1], Maria Kozhevnikov[1]; [1]Rutgers University

Cognitive processes associated with locomotion have been hypothesized to automatically spatially update navigators' egocentric representations of objects in an environment. However, we have conducted a series of experiments that question the generality of this spatial updating hypothesis. We examined the effects of varying scene set-size on scene recognition RT and accuracy following locomotion. Across three experiments, observers viewed different scenes on each trial and made scene recognition judgments (i.e., identified which object in the scene had been moved) from the encoded view, after moving around the scene, from 36-180 degrees, or after the scene was rotated, from 36-180 degrees. The scenes consisted of 4, 6, 8, or 10 objects in Experiments 1 and 2 and of 4, 5, or 6 objects in Experiment 3. Across experiments, regardless of set-size and regardless of whether observers moved around the scene or whether the scene was rotated, RT increased and accuracy decreased with angular distance between encoded and judged views. Thus, the data show that locomotion impaired scene recognition. Furthermore, observers were generally faster and more accurate at judging smaller scenes, but with the exception of the 10-object scenes, the linear relationships between RT and angular distance and between accuracy and angular distance did not vary with scene set-size. Thus, the performance advantage with smaller set-sizes was not due to locomotion facilitating the transformation of smaller versus larger scenes. Together, these data in comparison with data from other studies raise questions about when locomotion leads to automatically updated representations of scenes.

E45 *574* Illumination discrimination under varying complexity of shape and light sources

Susan F. te Pas[1] (s.f.tepas@fss.uu.nl), Sylvia C. Pont[2]; [1]Utrecht University - Helmholtz Institute - Psychonomics, [2]Utrecht University - Helmholtz Institute - Physics of Man

Introduction: The appearance of objects in natural scenes is determined by their reflectance, their surface roughness, their shape and by the nature of the illumination. Results of previous experiments suggested that illumination perception depends mainly on simple cues such as the location of the shadow edge. In the present study we investigate whether varying the complexity of illumination and shape influences the perception of illumination. **Method:** We use a set of stimuli taken from the Amsterdam Library of Object Images (Geusebroek et al., International Journal of Computer Vision, 2005), containing photographs of complex shapes under a varying number and configuration of light sources.**Results:** We find that perception of material, shape and illumination are basically confounded. Low spatial frequency manifestations of the illumination, such as average direction of the illumination and maybe an ambient term, can be discriminated, but high spatial frequency features, such as the number of light sources are almost impossible to distinguish. Introducing more complex shapes to the scene made the identification of such features of the light field even more difficult.**Conclusions:** Shape, illumination, reflectance are perceptually confounded, and illumination discrimination is mainly based on low spatial frequency manifestations.

E46 *575* Direct comparison of preferences for dramatically different stimulus types reveals higher observer agreement for images with semantic content

Edward A. Vessel[1] (vessel@cns.nyu.edu), Nava Rubin[1]; [1]Center for Neural Science, New York University

Previous studies of preference for real-world scenes found a high degree of agreement for ratings across observers (Vessel & Biederman, 2002 J. of Vision 2(7) 492a). Vessel & Rubin (2005, ECVP) tested the degree to which this agreement is attributable to familiarity with the themes and/or semantic content of scenes by measuring observer agreement for preferences of a set of abstract, novel color images. Observers performed forced-choice, "one-back" paired comparisons between images and preference values were estimated for the full stimulus set from these paired comparisons (a sorting algorithm guided presentation order to optimize the estimation procedure). We found very low agreement across observers, but robust within observer reproducibility. Using the identical task with half abstract and half real-world images (grouped into six categories each) we tested whether this difference remains when the two stimulus types are directly compared within a session. We found higher agreement across subjects for real-world scenes (r = 0.24) than for abstract images (r = 0.12). Subjects slightly favored the scenes over the abstract images, and produced a slightly larger range (nonsignificant) of preferences for real-world scenes. Preferences for the image categories were uncorrelated across subjects for abstract categories (r = -0.1), but well correlated for real-world categories (r = 0.43). Intermixed paired comparisons allow for direct comparison of preferences for dramatically different stimulus types. We replicated our previous finding of higher agreement for real-world scenes than abstract images, and found that this difference cannot be attributed to differences in stimulus range or within-subject variability.

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E47 *576* The Role of Motion in Natural Scene Processing Revealed by Visual Search

Quoc C Vuong[1] (quoc.vuong@tuebingen.mpg.de), Ian M Thornton[2]; [1]Max Planck Institute for Biological Cybernetics, [2]University of Wales Swansea

There is a large amount of movements in the environment but only some are relevant to an observer, as these indicate objects of interest (e.g., prey or predator). In the present study, we used a visual search paradigm to

investigate the role of motion in the perception of natural scenes. Observers were presented with a circular array of 2, 4, 6 or 8 natural scene movies. These scenes were selected from three categories: human actions, animal movements and machine movements. The objects in these different categories differed in their shape and movement patterns. The observers' task was to search for a target category among distractors from another category. In Experiment 1, observers searched for human targets among machine distractors on one block and machine targets among human distractors on another block (or vice versa). In Experiment 2, we used animals and machines. Lastly, in Experiment 3, we used humans and animals. Across all experiments, search times were affected by set size. Importantly, we found that observers were faster at searching for humans and animals among machines than they were at searching for machines among these distractor categories (Experiments 1 and 2), suggesting that biological motion facilitated search. However, there was no difference in search times for humans and animals (Experiment 3), suggesting that human and animal movements are treated equivalently by the visual system. Overall, the present results point to the importance of a high-level interpretation of motion (e.g., as biological versus mechanical motion) in processing natural scenes.

E48 *577* Examining Spatial Properties From Multiple Views

Ying-Hua Wang[1] (sunhong@mcmaster.ca), Qi Wang[1], Qiang Liu[1], George S. W. Chan[2], Hong-Jin Sun[2]; [1]Southwest University, China, [2]McMaster University

Object position and identity has been dissociated using spatial memory tasks involving the reproduction of object layouts. We explored this dissociation through a spatial task involving changes in viewpoint. In two experiments, subjects (Ss) were presented with an array of objects positioned on a circular table that either remained stationary or was rotated. In Exp 1, two sets of objects were used: identical cylindrical objects or different cylindrical objects. Further, the number of objects presented was varied from four to seven. For each trial, following learning, one of the objects was moved to a new position and Ss were required to identify which object had moved. Results showed that for identical objects, Ss' reaction time and error rate were similar regardless of the number of objects presented. However, for different objects, Ss' performance decreased as the number of objects increased. This suggests that Ss tend to take advantage of the global properties of the visual scene if the scene is composed of identical objects. However, if the scene is composed of objects with different identities, Ss tend to focus on local spatial properties. In Exp 2, only different objects were used. In Condition one, a single object was moved to a new position. In Condition two, one of the objects was replaced with a novel one. Subjects were required to identify which object had changed. An interaction effect was observed between spatial properties (position and identity) and sex. This provides further support that position and identity may be differentially processed.

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E49 *578* Dichoptic difference thresholds for familiar and unfamiliar transformations of real scenes

Ali Yoonessi[1] (ali.yoonessi@mcgill.ca), Frederick A.A. Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal H3A 1A1, Canada

Aim. We have previously shown that sensitivity to photometric (colour and luminance) transformations in images of real scenes is lower for familiar compared to unfamiliar transformations. This suggests a normalization, or gain reduction, of familiar transformations. At what stage does this normalization occur? We tested whether it occurred before or after the stage of binocular combination by measuring dichoptic difference thresholds, or DDTs (the DDT is the just detectable between-eye difference in a binocularly superimposed image-pair), for photometrically-transformed real scenes, and comparing these with conventional image-difference thresholds. Methods. Stimuli were fifty calibrated color photographs of real scenes. The chromaticity and saturation of every image pixel was represented as a vector in a modified version of the MacLeod-Boynton color space, and could be translated, rotated, compressed or randomly repositioned within that color space. The dichoptic image pairs were presented via a modified Wheatstone stereoscope, while the conventional image pairs were presented with the stereoscope removed. All thresholds were measured using 2AFC. Results. DDTs, unlike the conventional image difference thresholds, were more or less constant, i.e. unaffected by familiarity. Conclusion. The result suggests that the normalization process happens after the stage of binocular combination.

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E50 *579* The neural basis of preference for natural scenes

Xiaomin Yue[1] (xyue@usc.edu), Edward A Vessel[2], Irving Biederman[1]; [1]University of Southern California, [2]New York University

What determines the preference we have for some scenes over others? Vessel & Biederman (2003) hypothesized that such preferences were mediated by a gradient of mu-opioid receptors (ligand termed "endomorphin") in the macaque ventral cortical visual pathway. These receptors are sparse in the earliest stages, e.g., V1 and V2, but dense in the later stages (e.g., parahippocampal gyrus, pHg), where perceptual information activates the products of past experience. Experiences would be preferred that maximize the rate of endomorphin release. Such inputs will tend to be those that are richly interpretable (not just complex) insofar as they would produce high activation of associative connections in areas that have the greatest density of mu-opioid receptors. PHG was defined as a region where BOLD responses evoked when viewing images depicting places were larger than those evoked when viewing images of objects (Epstein & Kanwisher, 1998). The lateral occipital complex (LOC), a critical area for object recognition, was defined as a region where objects were larger than their scrambled versions. Preference ratings were obtained by button press for each scene while subjects were in the magnet. Scenes rated as highly preferred (above the subject's median rating) were associated with a greater hemodynamic response in the PHG compared to less preferred scenes. There was no difference in LOC as a function of preference, indicating that the larger hemodynamic response in the PHG was not a feed forward effect from LOC.

E51 *580* Cortical Networks Underlying Scene Segmentation

Greg Appelbaum[1] (greg@ski.org), Vladimir Vildavski[1], Mark W. Pettet[1], Alex R. Wade[1], Anthony M. Norcia[1]; [1]Smith-Kettlewell Eye Research Institute

The segmentation of visual scenes into objects and their surrounds is a fundamental task that can be accomplished by the detection of spatial gradients in local cues such as luminance, texture, color, or temporal structure. To assess the cortical mechanisms underlying figure and background processing and to evaluate the role of boundary cues in segmentation, we constructed displays in which figure and background regions were separately 'tagged' with periodic modulations of their local texture elements. Textures were defined on orientation, phase (co-linearity), and temporal structure. Using these synthetic texture-defined objects and an electrophysiological paradigm that allows us to monitor figure-region, background-region, and border-specific activity separately in fMRI defined visual areas, we have found distinct neuronal networks for the processing of each surface and the formation of region boundaries. Figure activity was distributed over a network of ventral stream visual areas including the lateral occipital cortex. A separate network, extending from primary visual cortex through the dorsal visual pathway is observed in response to the background region. The activated sites and temporal sequence of these networks was largely invariant with respect to the cues used to define the figure. In contrast, responses related to non-linear figure-ground interaction (measured at the sum of the two tag frequencies) depended strongly on the cue type and, involved both first-tier (V1/V2/V3) and extra-striate areas. Cue-specific activity in several visual areas

converges on the both dorsal and lateral occipital cortex where cue-invariant surface representations are formed.

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E52 *581* Illusions of Space, Field Dependence and the Efficiency of Working Memory

Paul Dassonville[1] (prd@uoregon.edu), Elizabeth Walter[1], Katy A. Lunger[1]; [1]Department of Psychology & Institute of Neuroscience, University of Oregon

The cognitive construct of field-dependence/independence (FDI) reflects the general tendency of an observer to make use of contextual cues in a wide range of tasks, with field-dependent individuals more reliant on these cues than are field-independent individuals (Witkin, 1956). Traditionally, FDI is quantified by measuring the susceptibility to the Rod-and-Frame Illusion (RFI) or the proficiency at finding figures in the Embedded or Hidden Figures Task (HFT). Here, we demonstrate that FDI generalizes to another illusion of space, the Roelofs effect (however, see also Hudson et al., forthcoming in P&P). We also sought to determine whether FDI and illusion susceptibility are simply manifestations of large individual differences in the efficiency of working memory (Vogel et al. 2005), with some subjects better able to exclude the misleading effects of context from working memory. Subjects underwent a battery of tests, to obtain measurements of working memory capacity/efficiency (K), RFI and Roelofs susceptibility, HFT proficiency, and general cognitive processing speed (symbol-digit coding, SDC). A principle component analysis indicated factors associated with FDI (loaded with RFI, Roelofs and HFT), processing speed (loaded with SDC, HFT and K) and gender (loaded with gender, HFT and K). This pattern of results indicates that field-dependence/independence and illusion susceptibility cannot be explained simply as effects of the individual differences in the efficiency of working memory.

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E53 *582* Framing Aesthetic Judgments

Jonathan S. Gardner[1] (jonathansgardner@gmail.com), Stephen E. Palmer[1]; [1]Department of Psychology, University of California, Berkeley

Painters, photographers, and graphic designers regularly face the problem of how to frame the subjects of their creations in aesthetically pleasing ways. We investigated people's aesthetic responses to the position, facing direction, and size of single objects within rectangular frames using free choices in taking actual photographs and 2AFC preferences. The experiments tested the validity of rules of thumb taught in the visual arts, most of which have never been tested experimentally. One example is the "facing rule:" if the subject of the work has horizontal directionality (e.g., a sideview of a person, car, or teapot), it should point into rather than out of the frame. An experiment testing this rule examined subjects' aesthetic preferences for pictures of objects pointing into and out of the frame as a function of their position and directionality. In the directional (sideview) conditions, preferences were found for objects pointing into versus out of the frame. In both the directional and nondirectional (frontview) conditions, subjects tended to prefer objects positioned at the center of the frame. Further experiments examined preferences for the size of objects relative to the frame and its interaction with position and directionality. The results are discussed in terms of the power of the center in visual art (Arnheim, 1988). People prefer the subject to be located in the center of the frame, but if an object is not in the center, they prefer it to be oriented toward the center.http://socrates.berkeley.edu/~plab/projects.htm

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URL: http://socrates.berkeley.edu/~plab/projects.htm

E54 *583* Knowing where it goes:Different saccadic responses to dynamic versus static targets.

Holle Kirchner[1] (holle.kirchner@cerco.ups-tlse.fr), Quoc Vuong[2], Simon J. Thorpe[1], Ian M. Thornton[3]; [1]Centre de Recherche Cerveau et Cognition, CNRS Toulouse, France, [2]MPI for biological Cybernetics, Tuebingen, Germany, [3]Department of Psychology, University of Wales Swansea, UK

Ultra-rapid categorization studies analyze human responses to briefly flashed, static natural scenes. Recently, we reported that reaction times can be extremely fast if subjects are asked to move their eyes to the side where an animal had appeared. Accuracy was remarkably good with the fastest reliable saccades occurring in only 120 ms after stimulus onset [Kirchner & Thorpe, Vision Res, (2005)]. In the present study we determined the processing speed of static vs. dynamic displays. In blocked conditions, human subjects were asked to detect either animal or machine targets. On each trial, an examplar of each image category was presented simultaneously on the left and right of fixation for 80 ms. In half of the trials both images were static and in the other half of the trials both were dynamic (i.e., four consecutive images). Subjects made a saccade towards (or button press on) the side containing the target. While both response modes resulted in good accuracy, only saccades showed an advantage of dynamic over static trials. The saccade latency distributions indicated a clear dissociation in that dynamic displays resulted in much more continuous information accrual and a broad distribution as compared to a bimodal distribution in the static trials. A control study with simple form stimuli (squares vs. circles) served to preclude a low-level explanation of the result. We conclude that form processing can be improved by stimulus motion, and furthermore, that this information can be directly used to control directed behavior.

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Eye Movements and Cognition

E55 *584* Saccades in ambiguous figures

Kai Hamburger[1] (Kai.Hamburger@psychol.uni-giessen.de), Brian J. White[1], Denise D.J. de Grave[1]; [1]Department for General Psychology, Justus Liebig University Giessen, Otto-Behaghel-Strasse 10F, 35394 Giessen, Germany

Several studies have investigated saccadic eye movements in illusions and most of these have examined simple geometric-optical illusions like the Mueller-Lyer or Judd illusion. In contrast, eye movements in ambiguous figures have rarely been studied (the Necker cube; Einhäuser et al., 2004). In the context of saccadic eye movements Yarbus (1967) showed that saccadic end positions in "natural scenes" can be influenced by prior instruction. Here, we investigated whether the prior instruction to perceive one or the other interpretation of an ambiguous figure affects saccadic end positions. One of four classic ambiguous figures (old woman/ young lady, face/ vase, saxophone player/ woman, and seal/ donkey) was presented randomly 6.5 degrees to the left or to the right of a central fixation point. Prior to the onset of the fixation point subjects (n=11) were instructed to look at one of two possible percepts. Subjects looked at different features of the image when asked to perceive one or the other interpretation (e.g. in the old woman subjects looked at the nose/mouth region and at the cheek and the eye of the young lady). We found a significant difference ($p < .05$) in landing positions of the first and second saccades depending on the instruction in all four ambiguous figures. We conclude that early saccadic eye movements (first and second saccade) towards ambiguous figures can be strongly influenced by top-down processes (here prior instruction).

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E56 *585* **Learning gaze allocation priorities in complex environments**

Jelena Jovancevic[1] (jjovancevic@cvs.rochester.edu), Brian Sullivan[1], Mary Hayhoe[1]; [1]University of Rochester, Center for Visual Science

In dynamic environments, gaze patterns are often driven by competing task goals, such as avoiding obstacles, controlling direction, etc. (Hayhoe and Ballard, TICS, 2005). How do observers determine gaze priorities, especially in uncertain environments? We investigated whether the history of experience with events in the environment influences the distribution of gaze. Subjects walked in a virtual environment where the probability of salient events could be manipulated. Subjects walked along a path with virtual pedestrians that could be triggered to walk on a collision path. Two groups of subjects were given experience (18 trials) either in a normal environment without colliding pedestrians, or in an environment with frequent potential collisions (approximately 1 per trial). Gaze distribution was measured for three objects types in the environment: normal pedestrians, colliders and other (i.e. fixations on the path or surroundings). The proportion of fixations that were on normal pedestrians was 23% without prior experience with colliding pedestrians, but rose to 31% if subjects had previous experience in a condition where there were frequent pedestrians on a collision path. Similarly, when colliders were present, subjects devoted fewer fixations to normal pedestrians if they had prior experience without colliders (29% vs. 35%). This result suggests that subjects use their experience with relevant events to adjust gaze priorities in situations when there are multiple task goals. This is consistent with predictions of computational models of attentional allocation while walking (Rothkopf and Ballard, VSS, 2005).

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E57 *586* **Predictive Eye Movements in Squash**

Kelly Chajka[1] (kchajka@cvs.rochester.edu), Mary Hayhoe[1], Brian Sullivan[1], Jeff Pelz[2], Neil Mennie[3], Jason Droll[4]; [1]University of Rochester: Center for Visual Science, [2]Rochester Institute of Technology, [3] Justus-Liebig-University Giesen, [4]University of California, Santa Barbara

Natural behavior must deal with inherent delays in visual feedback. This problem is particularly acute in dynamic environments such as playing sports. One solution is to learn environmental dynamics to predict future states, similar to proposals for predicting sensory consequences of movements (e.g. Wolpert et al., 1998). We present evidence for predictive control of eye movements of two skilled squash players. Eye movements were recorded simultaneously from both subjects using two RIT lightweight wearable eye-trackers (Babcock & Pelz, 2004). Gaze was analyzed when subjects observed the ball after the opponent hit it (receiving), and after the subject hit the ball back to the other player (returning). When receiving, Player 1 fixated the front wall 110ms before the ball arrived with 8° of error on average. Player 2 fixated 200ms before arrival, with 13° of error. When returning, fixations began 31 (Player 1) and 57 ms (Player 2) after the bounce on the front wall. Players pursued the ball for 64% (Player 1) or 41% (Player 2) of its path from wall to the floor. Player 1 was able to pursue the ball up to speeds of 190°/s and at reduced gain up to 230°/s, while Player 2 pursued up to 117°/s, and to 160°/s with reduced gain. We conclude that the ability to make high-precision anticipatory fixations, and to pursue at such high speeds, is evidence for predictive mechanisms due to learnt models of the ball's dynamic properties. In addition, the degree of prediction depends on the subject's behavioral goals.

E58 *587* **Eye Movements Incorporate Knowledge of Part Structure**

Laura W. Renninger[1] (laura@ski.org), Preeti Verghese[1], James Coughlan[1]; [1]The Smith-Kettlewell Eye Research Institute

PURPOSEHumans have evolved an efficient eye movement system for sampling the visual world. Last year we introduced a shape learning task and modeling approach for probing the algorithms that underlie eye movements (Renninger, Verghese & Coughlan, 2005). In that work, we discerned that despite the unfamiliarity of the shapes used in the task, observers spontaneously perceived each shape as having multiple "parts". To what extent do part representations play a role in eye movement planning?METHODSObservers actively studied novel shapes as their eye movements were measured. After this learning interval, the shape was displayed with a highly similar shape and the observer selected which one they studied. We compare eye movement traces with prediction maps from several theoretical models, using a rigorous SDT approach. We include a model that makes fixations to the informative "parts" of the shape. In a separate experiment, perceived parts were marked by observers using a manual segmentation tool. Information is defined as the uncertainty (entropy) of edge orientation distributions along the bounding contour of the shape or shape part.RESULTS & CONCLUSIONSDespite their good performance in the discrimination task, observers were not optimal when planning eye movements to the shape. Saliency was also a poor strategy for describing where fixations will occur. Strategies that look at "informative parts" or at locations that "reduce local orientation uncertainty" are the best predictors of fixation locations in this task. We conclude that observers are using a hybrid of strategies when planning eye movements.

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URL: http://www.ski.org/Verghese_Lab/laura/

E59 *588* **Instructing express saccades to shift in the face of large distractors**

David Shiu[1] (jedelmanma@yahoo.com), Jay Edelman[1]; [1]Dept. of Biology, City College of New York

Instructions (INS) to make a saccade to one side of a suddenly appearing visual stimulus array can affect the vector of express saccades (RTs: 80-110ms) with no sacrifice in RT (VSS 05). Here, we examined whether INS affected saccade vector when the stimulus array was placed at varying positions inside a much larger and more salient object. RTs and spatial effect of INS were measured in 6 tasks: Tasks 1-3) Frame present - 2 small squares (1°x1°) were separated horiz. (6°) inside a 16° x 6° frame (1° thick). Ss were instructed to saccade to the 1) left square 2) right square or 3) the stimulus display as whole. In each task, the frame appeared 0°,+/-3° horiz. w.r.t. the 2 squares. Ss were instructed to ignore the frame. Tasks 4-6) Like tasks 1-3, but no frame. INS were indicated by a central arrow prior to target onset. The 2 squares appeared at a random location on the screen. A 150-200ms gap was used to lower RT. The EMs of two Ss were recorded at 500Hz using an Eyelink II eyetracker. Saccade endpoint deviation in tasks 4-6 was regressed against instruction and of frame position. The effect of INS was found to be more than 2x that of frame position, despite the fact that the frame has an area 20x that of the 2 squares. Both instruction and frame presence had little effect on RT (<10ms). Thus, irrelevant visual objects of high salience can be rapidly filtered out by the saccadic system.

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E60 *589* **"Blind" search --- successful saccades to the unknown target location up to 1000 ms after removal of visual search stimulus**

Li Zhaoping[1] (z.li@ucl.ac.uk), N. Guyader[1]; [1]Department of Psychology, University College London

In our experiments of visual search for a not particularly salient target, the subjects' eye movements were tracked. After a random time interval of search, all 660 visual items, including the target and the distractors, were covered by identical masks, each covering an original search item which consequently became imperceptible even in after images. In about 80% of the trials, the masks were displayed before the subjects had saccaded to the target location. The subjects had to make a forced choice decision, by a button press, regarding whether the target was in the right or left half of the search display. Most of these decisions were made after the mask onset.

We observed that the subjects continued to make eye movements on the mask display for a duration up to a few seconds before responding. In about 20% of the trials in which eyes had not reached the target before masking, the post-mask saccades arrived correctly (within 2 degrees in a display of 46x34 degrees of visual angle) on the location of the target, sometimes after more than one post-mask saccades. We measured the target localization performance as a function of post-mask saccade latency, defined as the time difference between the eyes landing onto the target location and the mask onset. We found that the performance is significantly higher than chance for the latencies up to 1000 milliseconds. In comparison, in the trials in which eyes never reached the target location, the performance is at chance level.

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E61 *590* The Gap Effect revisted; seven wrong explanations and two possibly right ones

Adam J Reeves[1] (reeves@neu.edu), Zhenlan Jin[1]; [1] Dept. Psych., Northeastern University, Boston MA 02115, [2] Dept. Psych., Northeastern University, Boston MA 02115

We investigated several explanations for the 'gap effect' (saccades to flashed targets are faster if there is a temporal gap from fixation offset to target onset than if there is no gap.) One target appeared on each trial randomly at one of 4 locations (top, bottom, left, right; 10 deg eccentricity). Three trained observers pressed a manual key at target onset (MRTtarg), or pressed a key at fixation offset (MRTfix), or made a single saccade to the target (latency = SRT). The fixation spot was continuous (no gap), or (200 ms gap) was blanked, or dimmed, or brightened, or turned into 4 foveal or 4 extrafoveal spots. Mean SRTs were 232 (no gap), and 183, 192, 208, 202, 199 ms (corresponding gap conditions), generating gap effects of 49, 40, 24, 30, and 33 ms. MRTfix was proportional to MRTtarg (r =0.98). MRTtargs were 274 (no gap), and 196, 223, 216, 198 and 206 ms (gaps). As potential explanations, we (like others) exclude, from data analysis, (1) supression of microsaccades, (2) early triggering of pre-programmed saccades, and (3) express saccades; also, (4) speed-accuracy trade-offs --faster saccades were less accurate within, but not across, conditions, (5) foveal capture of attention, (6) changes in the shapes of the SRT distributions, and (7) salience of the fixation target, in that mean MRTs and mean SRTs were independent across conditions. We conclude the gap effect reflects (8) an overall warning effect and (9) the disengagement of saccade-specific central attention.

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E62 *591* Testing an Object File Theory of Object Correspondence across Saccades

Ashleigh M. Richard[1] (ashleigh-richard@uiowa.edu), Andrew Hollingworth[1], Steven J. Luck[1]; [1]The University of Iowa

How does the visual system establish correspondence between objects visible on separate fixations? Object file theory (Kahneman et al., 1992) proposes that objects are represented as a spatial index, with object property information bound to the index. In this view, object correspondence across disruptions such as saccades is established by position consistency (spatiotemporal continuity) without reference to an object's visual properties. However, Hollingworth et al. (submitted) recently found that object correspondence across saccades can be driven by memory for an object's shape or color. In the present study, we placed position and object property information at odds to investigate the primary determinant of object correspondence across saccades. The method was a gaze correction paradigm. Participants generated a saccade to one of two objects that differed in shape or color. On some trials, the stimulus array shifted during the saccade, causing the eyes to land between the two objects. Participants executed a corrective saccade either to the object in the appropriate relative spatial position or to the object with the appropriate surface property. On a critical subset of trials, the two objects switched positions, placing correction based on position and correction based on surface properties at odds. Participants were faster and more accurate to correct gaze based on position. However, inconsistent surface properties slowed correction latency. These results provide support for a weak version of object file theory, in which object correspondence across saccades is primarily governed by spatial continuity, but object property information is also functional in establishing correspondence.

E63 *592* Psychophysical evidence that top-down input effects error directions in a choice-response saccade task

Paul D. Thiem[1] (pdthiem@ski.org), Edward L. Keller[1], Kyoung-Min Lee[1]; [1]Smith-Kettlewell Eye Research Institute

We have studied the neural correlates in frontal eye fields and superior colliculus for saccadic behavior in monkey, employing a choice response task. Saccades to visually similar color-coded targets were elicited by the color change of a foveal fixation mark. Here we describe the saccadic choice behavior in these animals as a function of the number of alternative targets in the array and the spatial discordance between actual and cue locations in the array. Arbitrary color-location associations are built up during training and held in long term memory. On each trial the correct location of the saccade target is signaled by the central cue. During the experiment the locations of the colored stimuli are rotated to new locations, while the same color cues from training are delivered centrally. In the limiting case where the array is a single alternative target (1NA condition), no entry into associative memory was needed; regardless of the color-association discordance, performance was at or near ceiling. However, saccade latencies were significantly longer than those where a delayed saccade was made to a single, neutrally colored target, as if the animals continued to decode the central color cue. In the 4NA condition performance with no rotation of the array was > 95%. Performance degraded smoothly and symmetrically for both ipsilaterally and contralaterally rotated discordances. Error direction varied as a function of color-location discordance. The pattern of errors suggests these learned associations have broad spatial tuning, but the tuning does not extend across angular separations of 90°.

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E64 *593* Looking away from death: The influence of subliminal priming on eye movement decisions

Avi Caspi[1] (avi.caspi@psych.ucsb.edu), Gilad Hirschberger[1], Tsachi Ein-Dor[1], Ari Z. Zivotofsky[1]; [1]Gonda Brain Research Center, Bar Ilan University, Ramat Gan, Israel

Terror management theory (TMT) posits that the denial of personal mortality is a central motivation underlying many human behaviors. According to TMT, reminders of death induce proximity-seeking with culturally-similar others. Recent studies have also shown that death reminders lead to emotional withdrawal from others who may remind people of their fragile, mortal nature, such as people with physical disabilities. The current research examined whether subliminal death primes influence eye movement decisions. In three experiments participants were subliminally primed with the word "death" or with a control word, and then viewed a matrix of 4 images while their eye position was monitored using a video-based eye tracker. Experiment 1 indicated that primes of death increased the viewing time of a picture of a religious person, but did not affect the viewing time of pictures with non-identified persons. Experiment 2 indicated that primes of death decreased the time participants looked at pictures of severely injured persons, and also decreased the time they looked at neutral pictures that were presented alongside the injury pictures. Experiment 3 indicated that primes of death did not affect the viewing time of neutral pictures when they were not presented together with injury pictures. These results indicate that subliminal primes of death influence eye movement decisions. Moreover, subliminal death primes may serve as a "knob" that may shift one's gaze towards or away from visual stimuli that are relevant to terror management defenses.

E65 *594* **An optimal experimental design model of information acquisition on a classic concept learning task**

Jonathan D Nelson[1] (jnelson@salk.edu), Garrison W Cottrell[2]; [1]Computational Neurobiology Laboratory, Salk Institute, La Jolla, CA, [2]Computer Science and Engineering Dept., UCSD

It has been unclear whether optimal experimental design accounts of data selection may offer insight into evidence acquisition tasks in which the learner's beliefs change greatly during the course of learning. Data from Rehder and Hoffman's (2003, 2005) eye movement version of Shepard, Hovland, and Jenkins's (1961) classic concept learning task provide an opportunity to address these issues. We introduce a principled probabilistic concept-learning model that describes the development of subjects' beliefs on that task. We use that learning model, together with a sampling function inspired by theory of optimal experimental design, to predict subjects' eye movements on the active learning version of that task. Results show that the same rational sampling function can predict eye movements early in learning, when uncertainty is high, as well as late in learning when the learner is certain of the true category. Several issues for future work, and the relationship of eye movement to non-eye movement means of information acquisition, are discussed.

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URL: http://www.jonathandnelson.com/

E66 *595* **Modeling Eye-Hand Movement Sequences in Natural Tasks**

Weilie Yi[1] (wyi@cs.rochester.edu), Dana Ballard[1,2], Mary Hayhoe[1,2]; [1]Department of Computer Science, University of Rochester, [2]Department of Brain and Cognitive Sciences, University of Rochester

We show that a Markov model captures the variance in eye and hand movement sequences in a natural task such as making a sandwich. Observing the different ways subjects perform the task allows the automatic decomposition into subtasks. The different ways of doing the task can then be described as alternate possible sequences of primitive operations, including eye movements and hand movements. Each such sequence fully characterizes a sandwich-making behavior. The transitional probabilities between subtasks are then computed from human data. The resultant model can produce new variations, which can be executed by a graphical human model in virtual reality with eye movements, body movements and object manipulation capability.The model can explain almost all eye fixations observed in the course of sandwich-making, including anticipatory fixations to objects that are to be manipulated in the future. We explain such anticipatory fixations as initiated to update visual memory of objects relevant to future subtasks. The memory update facilitates upcoming visual search and visual guidance of hand movements. In this model, memory uncertainty initiates look-aheads probabilistically with other task specific parameters. Experiments with human subjects making sandwiches show that the Markov model of subtask planning fits human data almost exactly. The mean number of anticipatory fixations in 10 trials averaged over 3 subjects was 3.10 with a ó of 1.13 whereas the mean for the computer simulation was 3.09 with a ó of 1.08. Thus anticipatory fixations can be seen as given advance notice of a visuo-motor plan.

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E67 *596* **MOTOR CONTROL OF EYE MOVEMENTS IN HUMANS: A Brain Imaging and Behaviour Study**

Melanie R Burke[1] (m.r.burke@manchester.ac.uk), Graham R Barnes[1]; [1]Faculty of Life Sciences, University of Manchester, Manchester, U.K.

Smooth pursuit (SP) and saccadic (SAC) eye movements share the ability to anticipate or predict object motion, which is a fundamental feature of animal behaviour. We have compared predictive and non-predictive SP and SAC responses using temporally and spatially equivalent paradigms, whilst simultaneously monitoring brain activity using fMRI. The visual stimulus comprised a double gap-step-ramp task (SP) and a double gap-step task (SAC) to either predictable (PRD) or randomized (RND) target motion/location. 12 subjects performed eye movement trials in the standard laboratory, prior to a recording session inside the fMRI scanner (1.5T, Philips Intera). Eye movements were monitored using infra-red limbus tracking systems in both the laboratory (Skalar IRIS, CRS Ltd) and scanning environments (MR-eyetracker, CRS Ltd). Laboratory based eye movement data revealed the latency difference between RND and PRD conditions in SP is less pronounced and distinct than in SAC. Performing contrasts on resultant functional brain images for PRD and RND conditions revealed elevated BOLD responses in a network of brain areas including left putamen/insula, left precuneus and left supramarginal gyrus. We additionally found differential activation for dorsolateral prefrontal cortex (BA 45/9) in both the SAC and SP trials. Many areas involved in predictive SP and SAC eye movements reveal an overlap in brain activation, demonstrating that the mechanisms involved in motor prediction may be generated by common circuitry.

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Eye Movements: Saccades and Fixations

E68 *597* **Storing visual object features and locations across saccades**

Steven L Prime[1,2] (sprime@yorku.ca), J. Douglas Crawford[1,2]; [1]York University, [2]Centre for Vision Research

In a series of studies, we tested how many object features and locations could be retained across saccades in 6 human subjects. Visual targets were either circular gabor patches or luminance disks. The Saccade Task consisted of briefly presenting a random number of targets (as many as 15). Each target's spatial position and orientation or luminance was varied randomly. Then, subjects saccaded to a different location and were briefly presented with a probe. The probe's orientation or luminance was systematically varied relative to the pre-saccadic target at the same location (the 80% detection amount determined from preliminary one-target trials). Subjects reported how the probe's visual feature differed from the original target. We compared the performance in this task to a Fixation Task which was identical except subjects maintained eye-fixation throughout the trial. The magnetic search coil technique was used for precise monitoring of eye movements. Results showed that up to 6 targets the subjects' accuracy in the Saccade Task was the same as in the Fixation Task. For trials with more than 6 targets, performance in both tasks declined but the Saccade Task declined at a faster rate than the Fixation Task. This decline was not observed when the test target was attentionally cued – showing that these were not low-level effects. Moreover, subjects' performance was poorer with larger saccade amplitudes than smaller saccades. These findings suggest that limits of transsaccadic memory depend on the number of objects it can retain and the size of the saccade.

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E69 *598* **From Eye-tracking Data to Information: Lessons from Dynamic Scenes**

Ran Carmi[1] (carmi@usc.edu), Laurent Itti[1]; [1]Neuroscience Program, University of Southern Califronia, Los Angeles

A common simplifying assumption for dealing with vast amounts of raw eye-tracking data is to focus on spatial rather than temporal analyses. This assumption is supported by studies with still images, which showed that spatial rather than temporal correlations provide the only source of infor-

mation in eye-tracking data. Here we establish the extent to which this assumption is violated during inspection of dynamic scenes.We collected 50 video clips depicting a heterogeneous collection of natural scenes. These clips were cut into clip segments, which were re-assembled into 50 scene-shuffled clips (MTV-style). Human observers inspected either continuous or scene-shuffled clips, and inter-observer agreement in gaze position was quantified across conditions and over time. On average, the instantaneous eye-positions of 4 human observers were clustered within a rectangle covering 8.51% and 6.04% of the display area in the continuous and scene-shuffled conditions, respectively. These values increased to 11.48% ($p<0.01$) and 9.36% ($p<0.01$) when eye-positions were sampled from the same eye traces in random order. The average cluster area increased further to 35.88% ($p<0.01$) when 4 eye-positions were chosen at random from a uniform distribution of spatial locations. Moreover, preserving time information led to previously unreported patterns of inter-observer agreement. These results demonstrate that increasing stimulus dynamics triggers eye-movement patterns that diverge increasingly from previous accounts based on still images. The limited scalability of conclusions based on still images is likely to be further accentuated by future enhancements in the realism of laboratory stimuli, such as larger field of view and reduced central bias.

E70 *599* Path length and number of saccades affect saccade accuracy

Elisabeth M. Fine[1,2] (fine@vision.eri.harvard.edu), Sergey Yurgenson[3], Cathleen M. Moore[4]; [1]Schepens Eye Research Institute, [2]Harvard Medical School, [3]SY Consulting, [4]Pennsylvania State University

Background: The last saccade in a series was less accurate when the series was longer, especially when the spacing between targets was wider (Fine et al., 2005; ECEM). Number of saccades and distance to the farthest target were confounded. It is unclear whether error accumulated with each saccade or because the distance to the farthest target was greater as series length and spacing increased. Methods: We recorded the eye movements of 18 observers using a dual-Purkinje-image eye tracker. Observers were told at the start of each trial to make either one saccade to the farthest target (3.75 or 7.5 deg from fixation) or a series of saccades to each target in a linear display. In the latter case, the number of saccades matched the number of targets (1, 3, or 5, positioned semi-randomly). The average space between targets was greater with the farther target. Results: Overall, observers were less accurate with the farther target. There was a significant interaction between distance to farthest target and number of saccades. For the 3.75 deg target, number of saccades did not matter; for the 7.5 deg target observers were more accurate when they made a series of saccades than when they made one saccade. Conclusions: Saccades are less accurate the farther the endpoint is from fixation, regardless of the number of saccades made to reach it. This suggests that when planning a series of saccades, the total distance from fixation plays an important role in the calculation of saccade metrics.

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E71 *600* Saccadic Targeting Variability revealed by High Magnification Retinal Imaging

Girish Kumar[1] (gkumar@uh.edu), Scott B. Stevenson[1], Austin Roorda[2]; [1]University of Houston, College of Optometry, [2]University of California, Berkeley, School of Optometry

Purpose: Measure eye movements while imaging the retina using the Adaptive Optics Scanning Laser Ophthalmoscope (AOSLO), allowing accurate measurement of the variation of saccadic landing points to targets with small eccentricities.Methods: Two subjects were imaged using the AOSLO with a 660 nm laser and a 1 degree field of view. Subjects were instructed to follow a 2 min of arc square that was jittered randomly among nine possible locations within the 1 degree field. Eye movements were extracted by cross-correlating sequential video frames and the retinal position of the fixation square was determined just before and just after each saccade. Variability in the retinal landing point of a target after a saccade and the magnitude of the retinal position error before a saccade were calculated.Results: The starting and landing points of 78 and 104 saccades were measured for two subjects. The standard deviation of the landing points was 8.19 minutes of arc and 11.25 minutes of arc. Saccades to targets outside this zone were almost all corrective. Once a target landed within this zone, fixation often remained relatively steady.Conclusions: Small saccades place targets within a zone that is smaller than the diameter of the foveola where the cone density is maximum, but is much larger than the diameter of a single cone in this zone.

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E72 *601* Statistical Analysis and Selection of Visual Fixations

Umesh Rajashekar[1] (umesh@ece.utexas.edu), Ian van der Linde[2], Alan C. Bovik[1], Lawrence K. Cormack[1]; [1]Center for Perceptual Systems, The University of Texas at Austin, USA, [2]Anglia Ruskin University, UK

An understanding of how the human visual system selects and sequences image regions for scrutiny is not only important to better understand biological vision, it is also the fundamental component of any foveated, active artificial vision system. Analysis of the statistics of visual stimuli at observers' point-of-gaze can provide insights into the mechanisms of fixation selection. We recorded the eye movements of 29 observers as they viewed 101 calibrated natural images for 5s each, and attempted to quantify the differences in the statistics of features of image patches centered on human and randomly selected fixations. We studied the statistics of three low-level image features: local patch contrast (RMS), center-surround outputs of patch luminance and contrast, and discovered that the image patches around human fixations had, on average, higher values of each of these features than the image patches selected at random. Center surround contrast showed the greatest difference between human and random fixations, followed by center surround luminance, and contrast. A foveated analysis, in which we accounted for the falloff in visual resolution with increasing eccentricity, resulted in even greater differences between human and random fixations for contrast statistics than previously reported results that did not incorporate foveation. An eccentricity-based analysis of the patches revealed that the influence of these image features was not uniform across different saccade magnitudes. A simple algorithm that selected image regions as likely candidates for fixation based upon a linear combination of these features produced high correlations with fixations recorded from observers.

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E73 *602* A model of supplementary eye field (SEF) involvement in saccade generation

Shun-nan Yang[1] (syang3@ski.org), Stephen Heinen[1]; [1]Smith-Kettlewell Eye Research Institute

Here we present a recurrent neural network model based on evidence that neuronal activity in the SEF encodes saccade location and initiation timing during learned saccade sequences (Isoda & Tanji, 2004). In our model, the learned saccade sequence is retrieved from "memory traces" that encode the locations of the targets and triggering times of each saccade. During retrieval, the neural activity at a given spatial location increases, and is modulated by the memorized target locations through successive iterations until it crosses an exponentially decreasing threshold and triggers the saccade. Time-related parameters in the memory determine the rise of neural activity corresponding to each target location. By changing the weights applied to each target location and initiation timing, the model was able to replicate the findings that microstimulation applied the supplementary eye field can alter saccade selection to temporally offset targets (Histed & Miller, 2005) and can modulate saccade latency (Yang & Heinen, 2004). The model also predicts that higher variance in saccade endpoint should occur for later saccades in a sequence, and that there should be a

greater likelihood of sequencing errors when two saccade targets occur in spatial and temporal proximity. The simulation results suggest that multiple saccade targets can be encoded in a single SEF network to be retrieved and executed in order and at the proper time.

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E74 *603* Saccade-related direction-selective activation in visual cortex

Joy J. Geng[1] (j.geng@ucl.ac.uk), Christian C. Ruff[1,2], Jon Driver[1,2]; [1]Institute of Cognitive Neuroscience, University College London, [2]Wellcome Department of Imaging Neuroscience, University College London

We investigated the effect of directional saccades on visual cortex using fMRI. A location in either the upper right or upper left visual quadrant was cued as the saccade target on each trial. After an empty delay period, an auditory cue signaled whether to make the saccade, 'go'; or to remain fixated, 'no-go'. Activation was found in the lingual gyrus contralateral to the cued saccade direction. While this applied for both 'go' and 'no-go' trials, the direction-specific effects were larger in the 'go' condition. These results suggest that preparing a saccade to a remembered location produces activation in visual cortex specific to the location of the anticipated saccade, with execution of the saccade leading to stronger activation. Individual retinotopic mapping suggests quadrant-specific activations affecting the earliest stages of visual cortex.

E75 *604* Cortical Activation during Triple-Step Memory-guided Saccadic Eye Movements as measured by fMRI

Mark W. Greenlee[1] (mark.greenlee@psychologie.uni-regensburg.de), Gabriele Frank[1], Oliver Baumann[1]; [1]Insititute for Experimental Psychology, University of Regensburg

Blood oxygenation level dependent (BOLD) contrast was measured using event-related fMRI in subjects while they performed visually guided (VGS) and memory guided (MGS) triple-step saccades to three eccentric targets presented sequentially left or right of central fixation. Saccadic eye movements were recorded with a fiber-optic limbus-tracking technique in the MR scanner. Responses during VGS were compared to those evoked during MGS, in which the subject performed saccades to each of three remembered locations. To explore the role of dorsolateral prefrontal cortex (DLPFC) in the manipulation of the contents of working memory, the sequence of saccade targets in the MGS task was either constant or was manipulated in a color-sequence recoding phase. Saccade-related BOLD responses in prefrontal, premotor, parietal and occipital areas depend on the type of task performed. More pronounced activation in DLPFC was found only during the color-recoding phase of each trial for that condition and not during the maintenance of spatial locations. This finding suggests that DLPFC is primarily involved in the manipulation, and to a lesser extent, the maintenance of the contents of working memory. The results support the process-specific model of DLPFC, where the manipulation and reorganization of the contents of working memory is emphasized. Maintenance of the contents of visual working memory appears to be supported by neural populations in the parietal and occipital cortex.

Acknowledgment: Bayerische Forschungsstiftung

URL: http://www.psychologie.uni-regensburg.de/Greenlee/forschung/forschung.en.html

E76 *605* A recurrent neural network for trans-saccadic spatial updating produces receptive field remapping and suppressed moving hills

Gerald P Keith[1,2] (eagleaty@yorku.ca), Gunnar Blohm[2], J Douglas Crawford[1,2,3]; [1]Psychology, [2]Centre for Vision Research, [3]Biology, York University, Toronto, ON, Canada

It is currently believed that remembered visual target locations are stored in eye frame and updated across eye movements. Neurons in brain areas associated with saccade generation have shown transient receptive field remapping prior to and during saccades. The question remains as to whether these receptive fields spread or jump (Wurtz & Sommer 2005). We used a simple 3-layer neural network with recurrent connections between units in the hidden layer to examine the temporal dynamics of updating using the full 3-D geometry of eye rotations. We found that the network was able to perform the required updating task, and that it did so by remapping receptive fields of both output and hidden layer units. While the network was trained to generate a hill of activation in the output layer before and after the saccade, no constraint on the behavior of the network during the saccade was made. The network developed a moving hill of activation in the output layer during the saccade, but with suppressed activation magnitudes. This suppressed moving hill reconciles previously conflicting findings of moving and jumping hills. The mechanisms observed appear to be a viable model for how trans-saccadic spatial updating is done in the brain.

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E77 *606* Perisaccadic mislocalization of spatial locations and saccade initiation

Antonella Kis[1] (atorok9@yahoo.com), Matthias Niemeier[1,2]

Previous experiments have shown that the location of stimuli briefly flashed around the time of the saccade are perceived either as compressed towards the saccade target or as shifted in saccade direction. The mechanisms underlying these misperceptions remain unresolved. It can be assumed that perceiving brief flashes is a challenging task in part because it requires accurate integration of sensory and motor information in time. For example, the task is complicated by the brain's uncertainty about when a saccade is initiated. In the present study we systematically manipulated saccade onset times by presenting saccade targets either at a location that was highly predictable or at a location, on the opposite side, that occurred less frequently. We found that saccade reaction times were more scattered for the unpredictable target location than for the predictable one. Also, our data suggest that the degree of misperception is more pronounced for the unpredictable saccade direction. These results are consistent with the idea that perisaccadic perception of space is a challenging task that is affected by the brain's limited ability to process the timing of sensory and motor signals.

Acknowledgment: CFI, NSERC

E78 *607* The effect of presaccadic and postsaccadic visual information on saccade endpoint error and velocity

Paul K Mitchell[1] (meson66@hotmail.com), Jay A Edelman[2]; [1]Program in Cognitive Neuroscience, CUNY, [2]Dept. of Biology, City College of New York

We measured how the saccadic system's ability to get on target depends upon the visual information available before and after the saccade. We were particularly interested in whether postsaccadic visual information was sufficient to program subsequent saccades orthometrically. Using variants of visual and memory-guided saccade tasks we measured saccade endpoint error and peak velocity. Tasks varied with regard to the information available presaccadically: 1) visually-guided (VG); 2) memory-guided (MG) – target appeared for 250ms then disappeared 750 ms before saccade; 3) target invisible before saccade (NVG). Tasks also varied with regard to whether targets appeared postsaccadically: 1) visible immediately postsaccade (Tvis); 2) invisible postsaccade (Tnot). Tnot trial blocks began with 5 Tvis trials. Stimuli were presented using a CRT projector (Barco) on a large (54"x71") screen in a darkened environment. A thin white frame was visible at the screen's edge. EMs of 3 Ss were recorded at 500Hz using an EyelinkII eye tracker. Saccade amplitude ranged from 30-40°. NVG endpoint error was surprisingly small. In the Tvis condition errors were: VG-1.34°, MG-1.60°, NVG-2.00°. In the Tnot condition NVG error increased but was

still quite small. Errors in the Tnot condition were VG-1.00°, MG-1.47°, NVG-2.27°. VG peak velocity was larger than that of MG and NVG (VG-485°/sec, MG-426°/sec, NVG-413°/sec). Target visibility after the saccade had little effect on peak velocity. Our results suggest that information obtained after a saccade is sufficient to maintain saccade accuracy and precision, even across several movements in which the target is invisible both pre and postsaccadically.

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E79 *608* Stimulation of human intraparietal cortex disrupts spatial updating of visual locations across saccades

Adam P Morris[1] (morrisa@unimelb.edu.au), Christopher D Chambers[1], Jason B Mattingley[1]; [1]Cognitive Neuroscience Laboratory, School of Behavioural Science, University of Melbourne, Victoria, Australia

Mechanisms of spatial updating maintain accurate representations of visual space across eye movements. In monkeys, salient locations are retained across saccades by transferring activity among spatially-tuned neurons within the intraparietal sulcus (IPS). Little is known, however, about similar mechanisms in the human brain. We examined the role of two subregions of the IPS in spatial updating in human observers using transcranial magnetic stimulation (TMS) to transiently disrupt cortical activity while participants performed double-step saccades. Participants made successive saccades to targets such that the retinal location of the second target had to be updated using information about the first saccade. We stimulated three right hemisphere sites: anterior and posterior IPS (IPSa and IPSp), and primary somatosensory cortex. TMS was delivered at the onset or offset of the first saccade. Performance of the second saccade, which is an index of spatial updating, was affected only for TMS over IPSp, and only for trials in which the first saccade was directed to the left. Specifically, second-saccades showed a trajectory-bias toward the mid-sagittal axis and an increase in amplitude regardless of the timing of TMS. Both of these effects are consistent with an over-estimation of eye displacement caused by the first saccade. In addition, TMS applied at the offset of the first saccade increased variable error of the second saccade. Our findings suggest that neurons in the IPSp integrate visual and saccade-related information to calculate metrics for spatial updating, and implement the coordinate transformation at the completion of the saccade.

E80 *609* Differences in perisaccadic retinotopic and spatiotopic localization in the parietal and occipital cortices in the absence of visual input.

Jochem W Rieger[1] (jochem.rieger@nat.uni-magdeburg.de), Ivan Bodis-Wollner[2,3], Mircea Ariel Schoenfeld[1], Hans-Jochen Heinze[1]; [1]Department of Neurology II, Otto-von-Guericke University Magdeburg, Germany, [2]State University of New York, Health Science Center at Brooklyn NY, USA, [3]Hanse Wissenschaftskolleg, Delmenhorst, Germany

Purpose: We aimed to delineate parietal and occipital cortical activity in humans for self-initiated saccades decoupled from concurrent visual input. In particular we wished to define the topographical distribution in reference to retinotopic and spatiotopic coordinate systems.

Methods: Prior to every scan the subjects were presented with a fixation cross that was horizontally displaced in an outline face between nose, left and right eye. During the fMRI-scans subjects (2 males and 2 females) performed voluntary saccades in total darkness to the previously trained positions in the imagined face. Eye movements were recorded with EOG. The latency and the direction of the saccades served to define the event related fMRI-model. The BOLD-responses to the same saccades were contrasted in reference to retinotopic space (saccades directed leftwards vs. rightwards to the current fixation) and egocentric space (saccades within left vs. right head/body centered space). The two spaces are identical for centrifugal but not for centripetal saccades.

Results: Retinopically defined perisaccadic activity was consistent in the contralateral (to saccade direction) parietal cortex. The activation in V1 was ipsilateral and in two locations: at the fovea and at extrafoveal representations.

Conclusions: Previous fMRI data show that V1 does not code for imagined saccades (Bodis-Wollner et al., 1997). Our study shows that V1 activity codes for processes associated with fixational and with eye movement processes when self-initiated saccades are decoupled from visual input. V1 activity is referenced to body centered coordinates, while the parietal cortex, consistent with other studies, codes the activity in retinotopic coordinates.

E81 *610* Patients with tunnel vision frequently saccade to outside their visual fields in visual search

Gang Luo[1,2] (gangluo@eri.harvard.edu), Eli Peli[1,2]; [1]Schepens Eye Research Institute, [2]Departement of Ophthalmology, Harvard Medical School

Peripheral visual information is normally used for planning of saccadic eye movements in visual search. Patients with tunnel vision have severely restricted peripheral visual fields (VF) due to retinitis pigmentosa, choroideremia, etc. It is of interest to investigate how loss of peripheral vision would affect the saccadic eye movements of the patients. 9 subjects with tunnel vision (VF: 8°-16°) performed visual search for "pop-out" targets sequentially presented outside their VF, within a 66°×54° area, in 4 sessions combining two cue conditions and 2 types of background, with or without auditory cues provided by 8 buzzers that indicated the approximate direction of targets, and over a blank background or a complex background (one of 16 street scene pictures). We found that the amplitudes of 30% of the saccades were larger than the subject's VF. The frequency of saccades was exponentially distributed with amplitude (for those > 4°), and was very similar to the distribution reported for normally-sighted subjects walking through a college campus (Bahill 1975 Invest. Ophthalmol.). Use of auditory cues or complex backgrounds did not affect the distribution (P>0.46). No effect of VF size on saccadic eye movements was found.These results suggest that many saccades of subjects were not elicited by visual information. While lacking peripheral vision, subjects probably performed search based on an internal representation of space in mind, by which they voluntarily saccade to locations outside their VF. One of the questions remained to be answered is if this strategy is optimal for people with tunnel vision.

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E82 *611* Asymmetric responses to temporal versus nasal hemifield stimulation in the human superior colliculus.

Richard Sylvester[1,2] (r.sylvester@fil.ion.ucl.ac.uk), John Dylan Haynes[3], Jon Driver[1,2], Geraint Rees[1,2]; [1]Wellcome Department of Imaging Neuroscience, Institute of Neurology, University College London, [2]Institute of Cognitive Neuroscience, University College London, [3]Max-Planck-Institute, Leipzig

Normal subjects show a temporal hemifield advantage in visual orientating tasks, with a reduction in saccade latency when orienting to cues presented in the temporal (versus nasal) hemifield. Hemianopic patients with geniculostriate lesions show this effect for cues presented in their blind field, while newborns (who have yet to develop functioning geniculostriate pathways) show an exaggerated effect. These lines of evidence suggest that the temporal hemifield advantage is mediated via extrageniculate pathways, specifically the retinotectal pathway involving the superior colliculus. We therefore examined temporal/nasal field asymmetries in the human visual system using fMRI at high spatial resolution (voxel size - 1.5mm3) accompanied by conventional retinotopic mapping in eight right-eye dominant subjects who viewed monocular checkerboard stimuli. The superior colliculi consistently showed significantly greater activity for temporal compared to nasal field stimulation, while LGN and V1 showed no temporal/nasal asymmetry. This provides direct evidence that the extrageniculate pathway in humans has a bias towards the temporal visual field, and may represent the neural basis for the temporal field advantage seen in visual orientating tasks.

Poster Session F

Sunday, May 7, 2006

Attention: Neural Mechanisms and Models (612-625), Search II (626-638), Cortical Organization (639-650), Motion: Aftereffects, Ambiguity and Illusions (651-664), Spatial Vision: Natural Image Statistics (665-676), Motion Perception: 2D (678-695)

Poster Session:12:00 - 3:00 pm ***Municipal Auditorium***
Author presents: 1:00 - 2:00 pm

Attention: Neural Mechanisms and Models

F1 *612* A Computational Model for the Distribution of Spatial Attention

Arvin Hsu[1] (athsu@uci.edu), Ian Scofield[1], George Sperling[1]; [1]University of California, Irvine

We describe a model for estimating the spatial distribution of visual attention for detecting a target embedded in arbitrarily shaped to-be-attended areas within a field of distracters and non-attended false targets. Expanded from the linear systems model of Gobbel, Tseng, and Sperling (Vision Research, 2004, 44: 1273-1296), the model comprises a spatial frequency modulation transfer function (MTF), an acuity strength map, local compensation for crowding, and a signal-detection decision mechanism. Computation sequence: The pattern of to-be-attended areas undergoes a continuous Fourier transform in order to create an attentional map in the spatial frequency domain that is multiplied by the MTF (attenuating middle and high spatial frequencies), and then inverse Fourier transformed, returning the map to retinal coordinates. The resulting strength map is multiplied by an acuity function, a linear spatial bias function, and a crowding function based on the number of nearest neighbors. This embellished strength map multiplies the input stimuli which consists of a 12x12 array of targets and distractors. Gaussian noise is then added to all locations; the highest valued location is designated as the target. Bootstrap methods are used to derive maximum likelihood estimates (MLE) of model parameters from a set of regular simple stimuli, and then applied to complex 8-block and 16-block patterns of to-be-attended areas (and to the inverse attention patterns). The model rendered parameter-free predictions of search performance in the 72/144 attended locations of the two 8-block and two 16-block patterns; observed data were then evaluated for closeness of MLE fit to model predictions.

Acknowledgment: This work was supported by the US Air Force Office of Scientific Research, Life Sciences, under grant no. FA9550-04-1-0225.

URL: http://aris.ss.uci.edu/HIPLab/Attention/Model1/

F2 *613* Complex Spatial Distributions of Attention

Ian Scofield[1] (iscofiel@uci.edu), Arvin Hsu[1], George Sperling[1]; [1]Department of Cognitive Sciences, University of California, Irvine 92687-5100 USA

We investigate the ability of highly trained subjects to conform spatial attention into arbitrary complex patterns in a search task. Subjects search a 12x12 jittered disk array for a target disk that is 50% larger in diameter than the distractor disks. The target occurs in a random one of 72 to-be-attended locations. In Experiment 1, the to-be-attended locations are defined by a pseudorandom arrangement of 8 3x3 blocks, in Experiment 2 by 18 2x2 blocks. Ten false targets are randomly placed in unattended locations to force the subject to confine attention to the to-be-attended locations. An attention instruction is a spatial diagram in which to-be-attended areas are green, to-be-ignored areas are reddish-brown. To begin each trial, an attention instruction is shown, it fades out, and is followed by a 150 msec exposure of the 12x12 search array. In each experiment, on successive trials, the instruction pattern alternates randomly with its negative.For two subjects, the percents correct were 45%, 57% for 8-block patterns, 25%, 43% correct for 18-block patterns. Subjects conformed their distributions of attention partially but not perfectly to the block patterns. In addition to the attentional limitations, search accuracy depends on exposure duration, target-distractor difference, the number of false targets, eccentricity, and crowding. All these factors were estimated from search experiments with simple attentional distributions, and used to generate parameter free predictions of the data. The results suggest that as attention attempts to conform to more-and-more complex patterns, complexity itself becomes a limiting factor.

Acknowledgment: Air Force Office of Scientific Research, Life Science, Grant FA9950-04-1-0225

614 Abstract withdrawn.

F3 *615* Transcranial magnetic stimulation of striate cortex induces illusory percepts of past and future events

Jacob Jolij[1,2] (jacob.jolij@epfl.nl), Victor A.F. Lamme[1]; [1]Department of Psychology, University of Amsterdam, [2]Laboratory of Psychophysics, BMI, EPFL

Transcranial magnetic stimulation (TMS) of the occipital pole is known to suppress perception of visual targets, when applied 100 ms after the target. TMS can also induce a brief phosphene. Here we report a novel TMS induced phenomenon: an illusory repetition of visual events happening either shortly before or shortly after magnetic stimulation. These illusory percepts are not phosphenes: they have the same features as the original stimulus, effectively function as primes, and their perceived features are modulated by visual context. The timing of the phenomenon strongly suggests that the brain tries to interpret the neural activity induced by magnetic stimulation, and uses visual information presented shortly before or after TMS to construct a visual percept. This active construction of conscious perception is affected by events happening up to 450 ms afterwards, strongly suggesting that visual awareness is an extremely sluggish process. We believe the phenomenon we present here offers new possibilities to study the neural mechanisms of conscious visual perception and its timecourse.

F4 *616* Pushing to and pulling away from salience: Evidence from rTMS for opposite biases in selection for the left and right posterior parietal cortex

Carmel Mevorach[1] (c.mevorach@bham.ac.uk), Glyn W. Humphreys[1], Lilach Shalev[2]; [1]Behavioural Brain Sciences Centre, School of Psychology, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK, [2]Department for Education & Psychology, Open University Israel, Tel Aviv, Israel

When the visual scene contains both the target of the current behavioural goal and competing distractors, visual attention must be engaged to resolve the emerging conflict by focusing on the target and suppressing the distractors. Here we examined the neural structures involved in these selective processes by applying offline repetitive Transcranial Magnetic Stimulation (rTMS) over right and left posterior parietal cortex (PPC) immediately before participants were asked to perform a Global-Local task using compound letters. The saliency of the information available at each level of the stimulus was varied orthogonally with whether local or global information had to be selected for the task. There was a double dissociation between the effects of rTMS to right and left PPC. When the more salient aspect of the stimulus had to be ignored, rTMS over the left PPC had a detrimental effect on performance. Conversely, rTMS over the right PPC made it more difficult to select the more salient aspect of the compound figure when it was relevant for the task. The data suggest critical roles for the left and right PPC in biasing attention away from and towards salient aspects of stimuli.

F5 *617* Non-invasive induction and cancellation of visuo-spatial neglect by repetitive Transcranial Magnetic Stimulation (rTMS)

A. Valero-Cabre[1,2] (avalero@bu.edu), A. Pascual-Leone[2], BR Payne[1]; [1]Lab. for Cerebral Dynamics, Plasticity and Rehabilitation, Boston University School of Medicine, [2]Center for Non-Invasive Brain Stimulation. Harvard Medical School-BIDMC

Repetitive Magnetic Stimulation (rTMS) has shown to modify the metabolism of specific cortical regions, thus altering activity along extended brain networks. In both, intact, and injured cats with unilateral parietal ablations, we applied rTMS trains on the visuoparietal (VP) cortex, which is crucial for visuo-spatial attention. All animals were intensively trained (<10% errors) in a set of visuo-spatial tasks consisting in the detection and localization of moving or static targets. In two of them, a TMS coil was centered on the VP cortex and 1200 pulses of 1 Hz rTMS were unilaterally delivered. rTMS significantly increased the number of errors in orienting responses towards static but not moving targets, only when presented at the contrastimulated visual hemifield (38±4%; and 48±3%; $p<0.05$ vs. baseline). Performance went back to baseline error levels 45 minutes after the end of the stimulation (4±2; 6±1%). In the 2 other animals, the right or left parietal and primary visual cortices were surgically removed, generating a complete visuo-spatial neglect syndrome in the contralesional field (100±0% errors; $p<0.05$). Daily stimulation with 1 Hz rTMS on the intact VP region resulted in a progressive reduction of detection-orienting mistakes to moving but not static stimuli (34±5% and 28±4% errors; $p<0.05$). We conclude that rTMS can interact with attentional brain networks in both ways; transiently disrupting visuo-spatial processing in normal subjects, and also canceling spatial neglect after lesions of the same area. It constitutes, thus, a non-invasive 'surgery-less' method to manipulate brain activity and promote recovery after injuries.

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F6 *618* A computational model of task-dependent influences on eye position

Robert J Peters[1] (rjpeters@usc.edu), Laurent Itti[1,2]; [1]Department of Computer Science, University of Southern California, [2]Department of Neuroscience, University of Southern California

Computational models of bottom-up attention can perform significantly above chance at predicting eye positions of observers passively viewing static or dynamic images. Nevertheless, much of eye movement behavior (50% or more) is unexplained by purely bottom-up models, and is typically attributed to top-down, inter-observer, task-dependent, or random effects. Other studies have qualitatively described such high-level effects in naturalistic interactive visual tasks (e.g., while driving, how often do people fixate other cars, or the road, or road signs); yet the underlying neurocomputational mechanisms remain unknown. Here, we introduce a simple computational model of task-related eye position influences in interactive tasks with dynamic stimuli. This model extracts from each frame a low-dimensional feature signature ("gist"), compares that with a database of eye position training frames, and produces an eye position prediction map. Finally, we combine the task-related and bottom-up maps, and compare the combined maps with observers' actual eye positions across 216000 frames from 24 five-minute videogame-playing sessions. For analysis, each map was rescaled to have zero mean and unit standard deviation; the average predicted value at human eye position locations was 0.61 ± 0.1 in the purely bottom-up maps, and 2.42 ± 0.07 in the combined maps (a random model gives an average value of 0). Thus, this straightforward model of task-dependent effects offers some of the strongest purely computational general-purpose eye movement predictions to date, going significantly beyond what is explained by purely bottom-up effects; yet it relies only on simple visual features, without requiring any high-level semantic scene description.

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F7 *619* Feature attention in motion perception - a computational account

Pierre Bayerl[1] (pierre.bayerl@uni-ulm.de), Heiko Neumann[1]; [1]Dept. of Neural Information Processing, University of Ulm, Germany

Introduction. Experimental studies on feature attention in visual motion perception revealed effects at the neural and behavioral level of observation. However, it remains unclear how such results from different studies relate. In this work we build upon a neural model of cortical motion perception (Bayerl, Neumann. *Neural Computation*, 2004) to explain distinct experimental observations within a single theoretical framework. **Model.** The model consists of a layered architecture simulating the function of primate areas V1 and MT. Model neurons in each area are coupled via feedforward integration, lateral competition and feedback modulation. To model feature attention the model dynamics is influenced, or biased, by an excitatory top-down attention signal indicating attended motion features. We use our model to link a physiological study of feature attention in cortical motion processing (Martinez-Trujillo, Treue. *Current Biology*, 2004) to a psychophysical experiment of motion perception (Felisberti, Zanker. *Vision Research*, 2005). **Results.** Via computer simulations, the model accounts for physiological data on feature attention and generates behavioral data in a decision experiment that is consistent with psychophysical observations. Furthermore, our investigations predict a decreased performance in motion detection tasks when the wrong direction of motion in attended. In sum, the model explains experimental findings from behavioral as well as physiological investigations. The key underlying function relates to the biased competition framework by utilizing soft-gating modulatory feedback combined with shunting competition for activity normalization. The model itself is able to account for experimental findings as well as to process real-world sequences.

F8 *620* Beyond the Spotlight: An Attentional Landscape Model of Visuospatial Attention

Ritobrato Datta[1,2] (rdatta@mcw.edu), Edgar A. DeYoe[2,1]; [1]Dept. Biophysics, Medical College of Wisconsin, Milwaukee, Wi, [2]Dept. Radiology, Medical College of Wisconsin, Milwaukee, Wi

In this human fMRI study we describe the complete topography of attention-related cortical activation throughout the visual field and compare it with previous models. We cataloged separate fMRI-based maps of attentional topography in V1 when subjects covertly attended to each target location in an array (22 degrees max radius) of 3 concentric rings of 6 targets each. On each run, auditory cues directed the subject to attend to one specific target or to a central segment in a randomized block design. We

combined the attentional maps for each of the 18 target locations for each subject into a unique composite display to identify common principles of attentional organization for different target locations. In general, attention modulated cortical activity throughout the visual field, not just at the cued location. Attentional activation was highest at the attended target but spread to other segments in a manner depending on eccentricity. For targets in the inner (1-5 degrees) and middle (5-12 degrees) rings, attention spread mainly outward to other segments along the same clock angle. For targets in the outer ring, attentional gradient was more diffuse, spreading to nearby segments of the same eccentricity and inward to the middle ring segments. We propose an "Attentional Landscape" model that is more complex than a 'spotlight' or simple 'gradient' model but includes aspects of both and accounts for some seemingly conflicting reports in the literature. The model suggests that peripheral and central attention may differ in spatial precision, perhaps reflecting distinct functional roles (monitoring vs. scrutiny).

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F9 *621* Flicker Elicits EEG Responses in Two Distinct Cortical Networks Depending on Attention and Flicker Frequency

Jian Ding[1] (jding@uci.edu), Ramesh Srinivasan[1], George Sperling[1]; [1]Dept of Cognitive Science, University of California, Irvine

Frequency-tagging is an experimental design for EEG or MEG in which two or more stimuli are presented simultaneously but flickered at different frequencies. Steady-state responses (SSVEP) elicited by the flicker are detected at each stimulus frequency by Fourier analysis of EEG responses. We studied attentional modulation of EEG flicker responses using 15 "tag" frequencies ranging from 2.5-20 Hz. The stimuli were confined to two color-coded concentric annuli. On each annulus, a sequence of search arrays (concentric disks with, possibly a target triangle) was superimposed. The two sequences were updated independently; one updated at a fixed frequency (flicker) and the other updated at random intervals to generate a white noise temporal-frequency distribution. On each trial, observers were instructed to attend one of the two annuli and to detect target triangles that appeared occasionally. Results. The choice of whether the annulus with flicker is attended or not, whether the unattended annulus (the competing annulus) was inner or outer, and flicker frequency all influence SSVEP amplitude and cortical distribution. There are two cortical response configurations (networks) with different sensitivities to attention. At low flicker frequencies in the delta band (2-4 Hz), and in the upper-alpha band (10-11 Hz), an occipital-frontal network appears to phase-lock to the flicker when attending to the flicker, increasing the steady-state response. When attention is directed away from the flicker in the lower-alpha (8-10 Hz) band and towards a competing stimulus in the fovea, a global resonance, including parietal cortex and posterior-frontal cortex, responds preferentially to the unattended flicker.

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F10 *622* ADAPTIVE CORTICAL PLASTICITY UNDERLYING RECOVERY FROM CEREBRAL DAMAGE INDUCED VISUAL NEGLECT

Stephen G. Lomber[1] (lomber@utdallas.edu), Bertram R. Payne[2], Amee J. Hall[1], Shveta Malhotra[1], Jeffrey G. Mellott[1]; [1]Behavioral and Brain Sciences, University of Texas at Dallas, [2]Boston University School of Medicine

In humans, damage to cortex at the temporo-parieto-occipital junction in the right hemisphere often results in profound neglect of contralateral visual space. In cats, similar deficits are identified following reversible deactivation of cortex forming the banks of the posterior middle suprasylvian (pMS) sulcus. Cooling deactivation of none of the flanking cortices results in contralateral neglect. Neglect is also caused by permanent lesions of pMS sulcal cortex. However, these deficits are only profound for the first few days following the lesion and the deficits quickly attenuate to normal levels over the first two weeks post-lesion. In this study we tested the hypothesis that flanking cortex would assume the attentional functions normally mediated by pMS sulcal cortex. Cats were trained to perform a visual localization task, pMS sulcal cortex in the right hemisphere was ablated using ibotenic acid, and cooling loops were placed over four flanking cortices: anterior middle suprasylvian (aMS) sulcus, middle suprasylvian (MS) gyrus, the middle ectosylvian (ME) gyrus, and the dorsal posterior suprasylvian (dPS) gyrus. Neglect was profound for three days post-op. The deficit then attenuated and was absent by the end of the 2nd week. One month post-surgery, we found that cooling deactivation of aMS sulcal cortex, but not aMS sulcal cortex nor the MS or dPS gyri, resulted in a profound contralateral visual neglect. Therefore, we conclude that functions of visual attention normally mediated by pMS sulcal cortex relocate to aMS sulcal cortex following permanent damage to pMS sulcal cortex.

Acknowledgment: Supported by NSF and NINDS.

F11 *623* Effects of Dorsal and Ventral Visual Pathway Lesions on Visual Vigilance

Carissa L Philippi[1] (carissa-philippi@uiowa.edu), JonDavid Sparks[2], Maureen A Marron[1], Matthew Rizzo[1]; [1]Department of Neurology, College of Medicine, University of Iowa, [2]College of Public Health, University of Iowa

Spatial attention depends on a network of structures along the occipito-parietal pathways. This study examined anatomical substrates of visual vigilance in 19 patients with MR/CT verified occipital-temporal pathway lesions (11-L hemisphere, 8-R hemisphere) and 17 occipito-parietal pathway lesions (8-L hemisphere, 9-R hemisphere). We also tested 145 neurologically normal controls. Subjects completed the Starry Night task. Each trial required immediate response to the appearance or disappearance, at unpredictable locations and intervals, of a single element in a multi-element random dot display. We eliminated trials presented in the regions of visual field loss to avoid confounding vigilance impairments with sensory deficits, and adjusted vigilance scores for age, visual acuity and contrast sensitivity. Results showed that the dorsal and ventral pathway lesion groups each scored worse than the non-lesion subjects on all vigilance measures (all ps < .008). Within these groups, right hemisphere cases showed worse vigilance scores than left hemisphere cases (all ps < .04). Unilateral lesions in visual association cortex impaired vigilance scores in both hemifields. However, visual vigilance deficits did not differ significantly between the dorsal and ventral pathway lesion groups, suggesting that dorsal and ventral visual association cortices, particularly in the right hemisphere, are important for maintaining visual vigilance, compatible with the reported advantages of the right hemisphere in visual spatial processing. Unilateral lesions produce bilateral deficits (Rizzo & Robin, 1996). Surprisingly, there was no evidence to support an advantage of the dorsal over ventral visual association cortices for maintaining visual vigilance.

F12 *624* Effects of spatial and non-spatial attentional load on posterior parietal cortex

Won Mok Shim[1] (wshim@fas.harvard.edu), George A Alvarez[2], Timothy J Vickery[1], Yuhong Jiang[1]; [1]Harvard University, [2]Masachusetts Institute of Technology

Purpose: The capacity limitation of human attention is best exemplified in attentive tracking of moving objects: our tracking ability declines when more objects are tracked, or when each object moves at a faster speed. Previous behavioral studies showed a trade-off between the number of objects tracked and the speed of each object, suggesting that a single type of attention is loaded. Using fMRI we examined whether common or separate neural substrates underlie spatial and non-spatial load. Methods: We parametrically manipulated two types of attentional load using an attentive tracking task. A rotating pinwheel was presented at each of four visual quadrants simultaneously. Observers tracked the cued spoke of a pinwheel(s) with attention while maintaining central fixation. We manipulated spatial load by cuing observers to monitor 1 or 2 pinwheels, and non-spatial load by varying the rotation speed of each wheel. Results: Tracking accuracy deteriorated as each wheel rotated more rapidly, with a sharper decline when more wheels were tracked. Posterior parietal cortex, how-

ever, was sensitive only to spatial load. Its activation was higher when subjects tracked 2 rather than 1 wheel, but showed no systematic change at different rotation speeds (from 100-400deg/s). In addition, although tracking accuracy was higher in bilateral tracking than unilateral tracking of two wheels, posterior parietal activity was equivalent between these two conditions. Conclusion: These results suggest that spatial and non-spatial attentional load are represented differently in the brain, with the posterior parietal cortex more sensitive to spatial attentional load than to non-spatial attentional load.

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F13 *625* The Influence of Attention on Motion Selective Channels: An Equivalent Noise Approach

Sam Ling[1] (ling@nyu.edu), Taosheng Liu[1,2], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Background: Two mechanisms have been proposed to explain how attention affects signal processing: Gain (Signal Enhancement) and Tuning (External Noise Exclusion). In the present study we use Equivalent Noise Analysis in conjunction with the Perceptual Template Model (Lu & Dosher, 1998) to assess how sustained (endogenous) attention affects the gain and tuning of motion selective channels. **Methods:** In each trial, observers were shown four moving dot cinematograms (100 ms), presented iso-eccentrically. The motion directions of individual dots were drawn from Gaussian distributions around a direction either upward-left or upward-right. External noise was manipulated by varying the coherence of the dot fields, which was defined as the width of the Gaussian distribution. In the Attended condition a small line at fixation pointed to one of the stimulus locations 350 ms prior to the stimuli presentation, instructing observers to attend the upcoming target location. In the Neutral condition, the same line appeared simultaneously with the stimuli. Observers performed a 2AFC direction discrimination task for the field of dots at the cued location, reporting its global motion direction. To obtain Equivalent Noise functions, we measured direction thresholds for different levels of dot coherence (external noise). **Results:** For all observers, attention reduced thresholds at high motion coherence levels (low external noise), but had no impact on low coherence (high external noise). These findings are consistent with a model where attention only increases the gain of the motion selective channel (Signal Enhancement), with no influence on tuning (External Noise Exclusion).

Search II

F14 *626* When is search for a static target efficient?

Yair Pinto[1] (yairpi@yahoo.com), Christian N. L. Olivers[1], Jan Theeuwes[1]; [1]Vrije University Amsterdam

Intuitively, dynamic visual stimuli, such as moving objects or flashing lights, attract attention. Visual search tasks have revealed that dynamic targets among static distractors can indeed efficiently guide attention. The present study shows that the reverse case, a static target among dynamic distractors, allows for relatively efficient selection in certain but not all cases. A static target was relatively efficiently found among distractors that featured apparent motion, corroborating earlier findings. The important new finding was that static targets were equally easily found among distractors that blinked on and off continuously, even when each individual item blinked at a random rate. However, search for a static target was less efficient when distractors abruptly varied in luminance, but did not completely disappear. We suggest that the division into the parvocellular pathway dealing with static visual information on the one hand, and the magnocellular pathway common to motion and new object onset detection on the other, allows for efficient filtering of dynamic and static information.

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F15 *627* Spatial partitioning during visual search of a dyad

Astros Chatziastros[1] (astros@tuebingen.mpg.de), Heinrich H. Bülthoff[1]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany

It has been shown recently that people can use visual feedback about the current gaze direction of a second searcher to effectively partition the search space (Zelinsky et al., VSS abstract 2005, p. 193). We investigated whether a partitioning of space during dual visual search can occur without explicit feedback and verbal communication.Pairs of participants were seated side-by-side and searched for a target letter ("T") among a set of distractor letters ("L"), projected on a large projection screen (2.20 x 1.80 m), indicating target present or absent on their individual keyboard. The instructions were varied: In experiment 1 (N=20) neither collaboration nor competition was emphasized (neutral instruction condition, NIC). In experiment 2, participants (N=22) were instructed to collaborate in order to obtain an announced gratification for the best group performance (collaborative instruction condition, CIC). In both experiments participants wore hearing protections and communication was prohibited.In NIC, participants responded fastest when the target appeared at the opposite side of the screen's center. In CIC, however, reaction times were faster when target letters were presented on the same side of the participant, resulting in a linear relationship between horizontal target eccentricity and the prevalence of the faster response at a particular seating side. We conclude that attention became spatially biased in horizontal direction during dual visual search, as a result of the physical juxtaposition of the participants. These findings can be interpreted as evidence for an implicit spatial partitioning of search space which can occur even without explicit feedback and verbal communication.

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F16 *628* Performance on a structured visual search task depends much more on perceptual span than fixation duration

Matthew H Phillips[1] (phillips@sci.ccny.cuny.edu), Jay A Edelman[1]; [1]City College of CUNY

This study investigated information processing in visual search, by examining how eye movement patterns changed during search as a function of changes in the stimulus array and in performance variability. 3 Ss (2 naive) searched regular, dense linear arrays of Landolt-C-like boxes for one of 4 targets and reported its orientation (4AFC). A video eyetracker (EyeLinkII) recorded eye movements at 500Hz. We manipulated the orientation (Ss scanned left, right, up and down), width (1 or 3 columns), and target/distracter similarity (high, medium, low) of the search array across trials. We measured search speed (rows scanned per sec), perceptual span (number of items scanned divided by number of fixations) and fixation duration. All manipulations of the search array substantially influenced search speed as well as perceptual span, changing them by 15-55%. Fixation durations changed much less (5-15%). In particular, changing from easy to hard distracters decreased span by 29%, and changing from 1 column of easy distracters to 3 columns of hard distracters decreased span by 41%, but fixation durations increased by only 9% in both cases. There was also an extremely robust and consistent correlation between span and search speed within and across conditions (typical r = .8-.9). The correlation between fixation duration and search speed was much weaker and often not significant. Thus, the visual system appears to use a relatively set amount of time to process information at each fixation. Increasingly difficult searches rely on increased foveal proximity of stimuli, not longer exposure to them.

F17 *629* **What makes search for negative faces efficient? Distinguishing between pre-attentive and post-attentive processes**

Daniel Smilek[1] (dsmilek@uwaterloo.ca), Alexandra Frischen[2], Michael G. Reynolds[1], Cory C. Gerritsen[2], John D. Eastwood[2]; [1]University of Waterloo, [2]York University

Visual search for negative target faces among neutral distractor faces is more efficient than search for positive faces. The present experiments introduced a new search technique to dissociate between contributions of pre-attentive guidance and post-attentive template matching processes to this difference in search efficiency. In Experiment 1, participants searched for negative or positive target faces presented among varying numbers of neutral faces. Search was performed under standard viewing conditions (Exp 1a) or a new restricted viewing condition where items were occluded by black placeholders, and a given item was revealed only when a participant moved the mouse pointer over the black square (Exp 1b). Search slopes for identifying negative faces were shallower than slopes for positive faces, indicating more efficient search, but only in the standard search task. When guidance by unattended items was prevented in the new task, search was much less efficient and search slopes did not differ for the positive and negative target faces. Experiment 2 (easy pop-out search) and Experiment 3 (difficult conjunction search) yielded considerably flatter and steeper slopes, respectively, showing that the lack of a slope difference in Experiment 1b was not due to floor- or ceiling effects associated with the unique motor demands of the new method. Together, these findings support the notion that emotional information is processed pre-attentively and influences the allocation of focal attention. Furthermore, they demonstrate the utility of our new search technique for selectively investigating various influences on visual search, such as pre-attentive guidance, template matching, and perceptual grouping.

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F18 *630* **Can parafoveal processing explain skipping behaviour in interactive menu search?**

Mariana M Silva[1] (mariana.silva@ucl.ac.uk), Anna L Cox[1]; [1]University College London Interaction Centre

Research has shown that when searching for information in a web-based menu people do not always scan every item (e.g. Pierce, Parkinson & Sisson 1992; Brumby and Howes, 2003, 2004). Furthermore, this behaviour has been attributed to the pattern of relevance of the items in the menu with regards to a pre-specified task goal. We report an experiment to test whether the number of items skipped depends on the semantic quality of the alternative items and found that as more alternatives compete with the target for selection, less items are skipped. This behaviour was emphasised when the target was positioned towards the top of the menu. This suggests that when alternative items are perceived as unlikely to lead to task completion, people develop a scanning strategy that allows for more cost-effective searches. This is in accordance with a priori predictions made by a computational model for single-page menu search based on rational analysis (Cox and Young, 2004). The results of a forced-choice recognition task demonstrated that parafoveal processing of items occurred during scanning of the menu which could account for the lack of fixations on items.However, in a second experiment, parafoveal processing was eliminated by increasing inter-item distance, and in this case, fewer items were skipped, suggesting that parafoveal processing accounts for part of the skipping behaviour. An extension of the initial rational model is proposed to explain the results.

URL: http://www.cs.ucl.ac.uk/staff/Anna.Cox/index_files/interactive_search_project.htm

F19 *631* **Right hemisphere dominance in attentional processing and spatiotopic representation of visual stimuli during serial search tasks**

Reza Rajimehr[1,3] (reza@nmr.mgh.harvard.edu), Seyed-Reza Afraz[2,3]; [1]NMR Athinoula A. Martinos Center, Massachusetts General Hospital (MGH), Charlestown, MA, [2]Vision Sciences Laboratory, Department of Psychology, Harvard University, Cambridge, MA, [3]School of Cognitive Sciences (SCS), Institute for Studies in Theoretical Physics and Mathematics (IPM), Tehran, Iran

The visual system uses a dynamic process of actively searching the visual environment to select perceptually-relevant events. Previous studies suggest that right hemisphere is mainly involved in visual search tasks; however, little is known about 'how' this hemispheric asymmetry occurs. We hypothesized that a part of visual information should be transferred from left hemisphere (LH) to right hemisphere (RH) for detailed attentional processing during serial search. The first experiment was designed to psychophysically probe this conjecture. In this experiment, a conjunction search array (presented to the left or right visual hemifield) was followed by another search array (presented on the same or opposite side). Presentation of the first array to LH and the second array to RH resulted in longer reaction times (compared to RH-LH order) when the temporal separation between the two arrays was short. This finding shows a central role for right hemisphere in attentional representations of both left and right hemifields. In the second experiment, a conjunction search array was presented in two temporal epochs. Subjects made a saccade between the two epochs while the array was maintained in the same spatial location (spatiotopic condition). In the control condition, the location of array was changed while subjects had constant fixation. Reaction times were faster in the spatiotopic condition mostly when the stimulus of the first epoch was presented to RH. This asymmetry demonstrates that right hemisphere also plays a dominant role in spatiotopic representations during dynamic serial search.

F20 *632* **Configural superiority: RT, accuracy, and an ideal observer approach**

Ami Eidels[1] (aeidels@indiana.edu), James T. Townsend[1]; [1]Indiana University, Bloomington

In visual-search tasks, adding context can dramatically hamper or facilitate the latencies for detecting a target-item. An appealing demonstration of the latter was provided by Pomerantz, Sager, and Stoever (1977). Participants were presented with a display containing four diagonal lines and were then asked to indicate the location of the odd line – which differed from the other three by its orientation. In a second condition, a fixed context (carrying no task-relevant information) was added to each of the lines: an L shape that created a closed figure of a triangle when combined with the odd line, but not with the other diagonals. The localization of the odd item in the 'with-context' condition was much faster than in the original condition (Configural Superiority Effect, CSE). Presumably, novel properties such as closure may emerge when we combine distinct features (lines) into a unified configuration (a triangle). Recently, we have applied Townsend and Nozawa's Systems Factorial Technology to study the processing of these stimuli, using a slightly different search task. Topologically dissimilar alternatives, although not concurrently presented, led to faster processing. Most visual-search tasks with timed responses involve the presentation of super-threshold stimuli that result in error-free performance. In the current study we test if the advantage of configural figures exists for accuracy as well. To impair performance, we added random Gaussian noise to each display. Our preliminary data show CSE for speeded detection, but a reversed accuracy effect for noisy displays. 'Ideal observer' analysis was conducted for the no- and with-context conditions.

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F21 *633* **Visual search in familiar contexts – effects of learning or adaptation?**

Kyle C McDermott[1] (mcdermo6@unr.nevada.edu), Jeffrey B Mulligan[2], George Bebis[1], Michael A Webster[1]; [1]University of Nevada Reno, [2]NASA Ames Research Center

Search times for detecting a novel color on a background of varying colors

are faster when observers are previously exposed to the background colors. We examined whether this improvement reflects changes in color salience resulting from adaptation to the background vs. changes in search strategies or learning for familiar backgrounds. The target was an ellipse at a random location on backgrounds of overlapping ellipses. Target colors varied across trials over a wide range. The luminance and color of background elements varied randomly by sampling from different color distributions. In the first condition, we used selective distributions with colors confined to the LM or S cardinal axes. Subjects first viewed sequences of LM or S backgrounds for 2 min and then searched for targets on an LM or S background. Searches were monitored with a CRS eyetracker and terminated when the targets were fixated for 0.5 sec. Targets were located more quickly on the pre-exposed backgrounds. However, eye movements patterns (e.g. fixation durations and saccade lengths) did not differ across the two backgrounds, suggesting that sampling strategies remained similar. In a second condition, we measured search on a nonselective color distribution drawn from a circle of hues at fixed contrast. Prior exposure to this background did not facilitate search for novel contrasts relative to an achromatic adapting background, suggesting that subjects were not simply learning the background distributions. Instead, results for both conditions are consistent with a selective adaptation effect that enhances the salience of novel stimuli by discounting the background.

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F22 *634* Effects of priming visual relatedness and expectancy on visual search performance

Kenneth Hailston[1] (kwh70@bellsouth.net), Elizabeth T. Davis[1]; [1]Georgia Institute of Technology

Identifying and locating a target can be difficult when uncertainty exists about what to look for or even where to look. Cognitive research in matching and classification tasks (Neely, 1977; Posner & Snyder, 1975) have shown that uncertainty is reduced both by semantic priming, which is fast-acting but decays rapidly, and by expectancy, which has a slower onset but persists much longer.The current study extended their cognitive approach to a visual search paradigm in the perceptual-cognitive domain. We manipulated visual-relatedness between prime and target so that they were either identical (same) or different. We manipulated expectancy by varying the proportion of validly primed trials. The inter-stimulus interval (ISI) between offset of prime and onset of search display also was varied. Our goals were two-fold: (a) Does visual priming affect a brief sensory store that decays rapidly (e.g., Sperling, 1960) or a longer-lasting store, such as a visuo-sketchpad (Baddeley, 1993) or visual-implicit memory (Schacter & Cooper, 1993)? (b) Do the onsets of expectancy and priming occur simultaneously or does one precede the other?Twelve college-age subjects were tested and, at the beginning of the session, were informed of the prime's validity (20%, 50%, or 80%). They had to identify and locate the target within a brief visual search display of four objects.Response accuracy data indicated that the effects of visual priming decayed very rapidly, implying a sensory store mechanism rather than a visuo-spatial sketchpad or visual implicit memory. Moreover, visual priming effects occurred before the onset of expectancy.

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F23 *635* Examining the influence of saliency during visual search.

Yi-Fang D. Tsai[1] (ytsai1@gmu.edu), Matthew S. Peterson[1]; [1]George Mason University, USA

Saliency map models of attentional guidance predict that attention should be allocated to items in descending order of saliency (Theeuwes, 2004; Turatto et al., 2004). If the most salient item is not the target, does attention go to the second-most salient item? To examine this question, participants were tested using a visual search task involving a target and seven distractor items arranged in a circle around the periphery of the display. Stimuli were gray discs containing sinusoidal gratings that could only be identified when directly fixated. The target was a disc with a grating orientation of 45 degrees to the left or the right, and the distractors were discs with horizontal or vertical gratings. Two of the discs were either brighter or darker than the remaining discs and coincided with the target at chance level. Compared to the remaining six discs, one (first-most salient) of these two differed in luminance more than the other (second-most salient). According to saliency map-based models of visual search (Wolfe, 1994; Itti & Koch, 1999), the most salient items are attended to first, items with the second-highest salience are attended to second, and so forth. Response times to target detection were fastest when the target was in the most salient item, slower when the target was in the next-most salient item, and slowest when the target was in the remaining items. This effect held regardless of whether the salient items were brighter or darker than the other items in the display.

F24 *636* Stimulus-driven mechanism of search asymmetry revealed by classification image analysis of singleton search

Jun Saiki[1,2] (saiki@cv.jinkan.kyoto-u.ac.jp); [1]Graduate School of Human and Environmental Studies, Kyoto University, [2]PRESTO, Japan Science and Technology Agency

In previous work (Saiki, VSS05), the classification image (CI) technique applied to search asymmetry between O and Q revealed the use of the same vertical bar feature in both search tasks, and strong stimulus-dependent nonlinearity since noise with Q stimulus alone leads to errors. Analyses of CI showed that the bar feature in Q stimulus had larger negative modulation in the O-target condition, probably because multiple Q stimuli are in the search display. Although these findings reject a hypothesis of using different target-defining features, asymmetry in feature strength may reflect top-down control of feature tuning, because the target stimulus was predefined. To address this issue, I used a singleton search task. Three observers viewed displays with 1 target and 3 distractors, either O (1.9 degree diameter ring) or Q (O plus 0.9 degree vertical bar), embedded in white Gaussian noise, each located at 3.8 degree eccentricity. O and Q targets were randomly mixed across trials, thus target identity was unpredictable. Observers first localized the target, and then judged its identity. CIs were constructed from trials with correct target identification and incorrect localization. The pattern of results was the same as that with target-defined search, suggesting that asymmetry was not due to top-down control of feature tuning. Model-based analyses revealed that CIs can be fully accounted for by nonlinear signal transduction and multiplicative noise proportional to output pooled across search items. Taken together, search asymmetry between O and Q may be purely stimulus-driven mechanism.

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F25 *637* Features and suppression: what perceptual features afford suppression in the distractor previewing effect?

Xiaoang Irene Wan[1] (xwan@uiuc.edu), Alejandro Lleras[1]; [1]University of Illinois at Urbana-Champaign

Previous studies on "oddball" visual search have shown that the relative match/mismatch between the features in an oddball-absent trial and those in the subsequent oddball-present trial greatly influences reaction times (RT) to oddball-present displays, an effect known as the distractor previewing effect (DPE). For example, in a color-oddball task, RTs to a red diamond presented among two green diamonds are (1) decreased if three green diamonds were previewed in the preceding trial and (2) increased if three red diamonds were previewed in the preceding trial, compared to a non-previewed color baseline (e.g., gray). Importantly, in DPE tasks, participants respond to a second feature of the target (e.g., shape), totally uncorrelated to the oddball feature (color in this example). We refer to these two types of features as the "response feature" and "defining feature" of the target, respectively. Here we investigated what combinations

of response and defining features lead to the DPE. In separate experiments, we used the following response and defining features: topological oddballs (open vs close surfaces), two levels of color discrimination (red vs. green and yellowish-red vs blueish-red), and two levels of closed-shape discriminations (triangles vs. circles and diamonds missing-right vs missing-left corners). Our results showed a generalization of the DPE to visual searches in which the defining features of the target allow for efficient surface segmentation of oddball-present displays. Implications for models of visual search and pop-out search are discussed.

F26 *638* Aging and inhibitory tagging during visual search

Nora D Gayzur[1] (nora.gayzur@ndsu.edu), Alyson Saville[1], Linda K Langley[1]; [1]North Dakota State University Dept. of Psychology Center for Visual Neuroscience

The purpose of this study was to examine the role of inhibition in age-related changes in visual search. Visual search involves finding goal-relevant target objects within a cluttered array of distracting items. Inhibitory deficit theory proposes that visual search performance declines with age due to reduced ability to inhibit attention to distracting information. Using Klein's (1988) inhibitory tagging paradigm, 42 younger adults (ages 18-35 yrs) and 42 older adults (ages 60-80 yrs) completed both a visual search and probe detection task. Probes were presented within the search array at the location of a distractor (on probe) or at an empty location (off probe). We found that inhibition was reflected in slower responses to on probes than to off probes, especially following an inefficient search task (find an O among Q's); on-off probe differences were reduced following an efficient search task (find a Q among O's). Although older adults showed poorer search performance than young adults, particularly during inefficient search, contrary to predictions, they showed the same ability to inhibit re-inspection of distractors. Thus, we found no evidence of an age-related inhibitory deficit associated with visual search performance.

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Cortical Organization

F27 *639* Distinguishing visual field map clusters: a new paradigm

Serge O Dumoulin[1] (serge.dumoulin@stanford.edu), Alyssa A Brewer[1], Michal Ben-Shachar[1], Robert F Dougherty[1], Brian A Wandell[1]; [1]Dept of Psychology, Stanford University, Stanford, CA, USA

Introduction: Conventional visual field mapping contrasts stimuli at a series of visual field locations. Visual field map estimates identify the most effective stimulus position at each cortical location. Conventional methods (a) do not include a blank period, so that it is impossible to know whether all stimuli cause some response, and (b) summarize responses by a single variable that indicates only the most effective stimulus location. We introduce a new stimulus protocol and time-series modeling that provide additional information about cortical visual field sensitivity. Methods: Conventional expanding ring and rotating wedge contrast stimuli were modified by inserting a time period with zero contrast (mean-luminance). The new paradigm allows us to compare contrast responses at multiple locations with a zero contrast stimulus and estimate a better spatial model of the local cortical visual field responsivity from the response time course. Besides conventional Fourier analysis, the response components were estimated using a general linear model.Results: Cortex within V1-V3 is predominantly sensitive to stimulus location. Lateral and ventral occipital cortex respond to stimuli from a much larger part of the visual field, but is also sensitive to stimulus location. The transition between V1 and LO maps is particularly distinctive, allowing segregation of the confluent foveal regions that are otherwise hard to discern.Discussion: The new paradigm and response modeling provide a more quantitative description of the visual field map properties. The cortical selectivity differs across visual field clusters, permitting accurate segmentation of visual field maps that are hard to distinguish with other methods.

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F28 *640* Neuronal resources for perceptual judgment localized in the human brain

Joong Nam Yang[1] (yangjo@upstate.edu), Daniel Ts'o[1], Nikolaus Szeverenyi[2]; [1]Dept. of Neurosurgery, SUNY Upstate Medical University, [2]Dept. of Radiology, SUNY Upstate Medical University

PURPOSE: Is there a common area in the human brain that is involved in perceptual decision-making regardless of visual attributes or perceptualmodalities? To answer this question, we combined a psychophysical paradigm of difference scaling with fMRI. METHODS: We used the method of difference judgment for perceptual decision. Two small colored rectangles with different widths (less than 1 degree/visual angle) were presented on each side of a fixation point in one interval, and second set in the next interval. Subjects responded with a button press to indicate which set had the greater difference in color, area, speed or orientation. We extended this paradigm to auditory stimuli; subjects performed difference judgment on two intervals of tone durations. RESULTS: Passive viewing of stimuli led to retinotopically-appropriate BOLD responses in the para-foveal regions for color, form, and in MT and STS for motion. With active perceptual judgment, areas in V4/V8 complex were additionally activated for color and form. Surprisingly, however, for each of the four visual attributes, the lateral/ posterior region of the parietal lobe that includes IPS was consistently activated. For auditory stimuli, passive listening led toactivation in the auditory cortex, while difference judgment also produced additional activation in IPS. Absence of the button press did not change the results. CONCLUSIONS: (1) Perceptual judgment is distributed in neuronal representation, and (2) The lateral/posterior areas of the parietal lobe in the distributed representation are consistently activated during both visual and auditory judgments.

F29 *641* Harmonic components of SSVEPs simultaneously generate both broad bilateral and focal contralateral responses.

Yee Joon Kim[1] (paticca-vajra@northwestern.edu), Marcia Grabowecky[1], Ken A. Paller[1], Satoru Suzuki[1]; [1]Department of Psychology, Northwestern University

When an observer views a rapidly flickered stimulus (8-30 Hz), the resulting steady-state visual evoked potential (SSVEP) includes Fourier components at the flicker frequency (1f) and at twice the flicker frequency (2f), as well as higher harmonics. We recorded SSVEP responses from 64 scalp electrodes using lateralized stimuli (circular gratings presented to the left and/or right visual hemifields). We found a surprising topographic difference between 1f and higher harmonic responses in the posterior regions of the scalp. Whereas 2f (and higher harmonic) responses were localized to contralateral scalp locations, 1f responses were broadly bilateral. These localized versus broadly distributed responses were not tied to any specific flicker frequencies. Rather, scalp distribution varied in accordance with 1f versus higher harmonic responses. For example, 2f responses to a 12.5-Hz stimulus flicker and 1f responses to 25-Hz stimulus flicker both produced SSVEPs at 25 Hz, but 2f responses were localized to the contralateral hemisphere whereas 1f responses were bilateral. Because we obtained localized 2f responses and broadly distributed 1f responses simultaneously, their topographic differences could not be due to artifacts such as eye movements. Based on the fact that 2f responses are robust across a variety of stimuli and are more strongly modulated by top-down influences such as voluntary attention, we speculate that higher harmonic responses reflect processes that are tuned by feedback interactions. In contrast, 1f responses might reflect broad bottom-up activation of visual cortical areas.

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F30 642 A possible human homologue of the macaque V6A

Sabrina Pitzalis[1] (s.pitzalis@hsantalucia.it), Martin I. Sereno[2], Giorgia Committeri[3], Gaspare Galati[1,3], Patrizia Fattori[4], Claudio Galletti[4]; [1]Fondazione Santa Lucia, IRCCS, Rome, Italy, [2]Department of Cognitive Science, University of California, San Diego, La Jolla, CA, USA, [3]Department of Clinical Sciences and Biomedical Imaging, University G. d'Annunzio, Chieti, Italy, [4]Department of Human and General Physiology, University of Bologna, Bologna, Italy.

We have recently mapped the retinotopic organization of the area V6 in the human parieto-occipital sulcus thanks to a wide-field retinotopic stimulation, up to 168 degrees (Pitzalis et al., 2004). In monkey, dorsal and anterior to V6 there is the visuomotor area V6A. Monkey V6A is retinotopically less organized than V6, showing only a rough tendency for the eccentricity to increase dorso-ventrally in both the anterior bank of POS and the precuneate cortex (Galletti et al. 1996, 1999a). Visuomotor neurons in V6A have been found to respond more during reaches than during saccades to visual targets. Here we used phase-encoded fMRI, cortical flattening and wide-filed retinotopic mapping to detect the presence in the human POS of a visual area having retinotopic properties similar to those of the macaque area V6A. We also combined event-related fMRI with cortical surface reconstruction, in order to isolate movement-related activity for reaching and saccades in relation to the individual sulcal anatomy. We found an area in the POS located just anteriorly to V6 and medial to V3A which has an inconsistent polar angle representation but a clear trend in the eccentricity maps. In agreement with functional data on monkey V6A, this region of the human brain shows a marginal effect of cue location (contralateral side slightly preferred) and a transient activity during reaching trials stronger than during saccade trials. We propose that this region may be the putative homologous of area V6A.

F31 643 Mapping of posterior parietal areas in fMRI using task relevance and response modalities

Dorothe A. Poggel[1,2] (dapoggel@bu.edu), Dae-Shik Kim[1], Louis J. Toth[1]; [1]Center for Biomedical Imaging, Boston University School of Medicine, Department of Anatomy and Neurobiology, 715 Albany Street, Boston, MA 02118, USA, [2]Center for Innovative Visual Rehabilitation, Boston VA Medical Center, 150 South Huntington Ave., Boston, MA 02130, USA

Lateral intraparietal area (LIP) is activated in monkeys performing delayed saccade tasks requiring attention to stimulus location or color (*Toth & Assad, 2002*). A human LIP-analogue was identified with fMRI for delayed saccades to spatial instructions (*Sereno et al., 2001*). Our goal was to explore whether the same human parietal cortex regions can also be differentially activated by task-instructions and response modality.We measured BOLD fMRI in 11 subjects (5 male, average age 29 years) with a 3T Philips Intera MR scanner (FEEPI, TR=2500msec, 35 slices, 3mm, TE=35msec, FOV 230x230, 128x128 matrix). Before each block of 16 trials, subjects were instructed to respond to the location (left/right) or color (red/green) of a randomized sequence of cues. Subjects responded by pressing a left or right button. A subset of the sample was re-tested with the same paradigm but responding by delayed saccades. Data were analyzed with BrainVoyager software using GLM and event-related analysis.Color vs. spatial instructions activated different, neighboring subregions of posterior parietal cortex. For the button-press response, activated areas were located in an area consistent with being homologous to macaque medial intraparietal area (MIP), part of the parietal reach region (PRR). For delayed saccades, separate activation of more lateral parietal areas (homologous to LIP) was observed for color vs. space instructions. Importantly, both areas showed large positional variability between subjects. Our results suggest that human posterior parietal cortex contains responses modulated by task instruction, with response modality being the prime organizing principle, i.e. a hierarchical architecture of functional maps.

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F32 644 Representation of observed hand actions in macaque Superior Temporal Sulcus.

Koen Nelissen[1] (koen.nelissen@med.kuleuven.ac.be), Giuseppe Luppino[2], Wim Vanduffel[1,3], Giacomo Rizzolatti[2], Guy Orban[1]; [1]Labo voor Neuro- & Psychofysiologie, K. U. Leuven Medical School, Leuven, Belgium, [2]Dipartimento di Neuroscienze, Sezione di Fisiologia, Università di Parma, Parma, Italy, [3]MGH/MIT/HMS, Athinoula A. Martino's Center for Biomedical Imaging, Charlestown, MA, USA

Cells responding to the observation of goal-directed hand actions have been recorded in the anterior portion of the superior temporal sulcus (STS) of the macaque (Perrett et al., 1989). From here, information about the characteristics of the action is sent via parietal lobe to frontal cortex involved in motor planning (Rizzolatti and Craighero, 2004). However, the extent and location of the STS regions responding to vision of hand actions remains unclear. Four macaques were scanned while they fixated videos showing object-directed and mimicked hand grasping actions (Nelissen et al., 2005). Static frames and scrambled videos were used as controls. In previous experiments, six different STS motion sensitive regions were functionally defined (Nelissen et al., Soc. Neurosci. Abstr., 2003), including MT/V5, ventral and dorsal MST, FST, a motion responsive region anterior to FST, termed lower superior temporal (LST) region and the middle portion of STP (STPm).Observation of hand grasping actions activates lower bank (MT/V5) and fundus (FST) in the caudal part of the STS. Anterior to FST, responses were found both in the lower (LST) and upper bank (middle STP). Finally, in the rostral portion of the STS, activations were restricted mainly to the lower bank. This activation pattern by observation of hand actions was similar for isolated hand videos and person acting videos. These data suggest that multiple motion pathways may arise from MT/V5: while MST is involved in control of locomotion and pursuit, a second pathway processing actions projects from MT/V5 to more ventral and rostral STS regions.

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F33 645 Visual field representation in the lateral occipital complex.

Mary-Ellen Large[1] (mlarge2@uwo.ca), Anil Kuchinad[2], Adrian Aldcroft[2], Jody Culham[1], Tutis Vilis[2]; [1]Department of Psychology, University of Western Ontario, [2]Department of Physiology & Pharmacology, University of Western Ontario

A current debate concerns the topographic organization of object-sensitive cortical regions in the ventral visual cortex. Using high-resolution fMRI we found that, although the lateral occipital area (LO) showed a contralateral preference, the representation of the upper and lower visual fields largely overlapped. To determine whether neurons in LO code the entire contralateral hemifield, two fMRI adaptation experiments were performed. In the first experiment alternating blocks of identical or different faces were displaced either along the horizontal or vertical meridian. If the same LO neurons code upper and lower hemifields, we predicted more adaptation for vertical translations than horizontal translations (8 deg). Although adaptation occurred for all repetitions of the same face, more adaptation occurred for faces displaced along the vertical axis compared to the horizontal axis. These data were supported by a second slow-event related experiment in which we measured adaptation to a second identical face presented either to the left of or below the first face. Although both LO and FFA showed a preference for stimuli in the contralateral vs. ipsilateral field, only LO showed greater adaptation to within-hemifield than between-hemifield pairs. The results suggest that both LO and FFA have some degree of position invariance, however, the invariance in LO is greater within a hemifield than between hemifields. The implication is that both FFA and LO contain large receptive fields that are biased toward the contralateral hemifield, but within LO the receptive fields may be elliptical about the vertical axis.

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F34 646 Laterality Effects in the LOC

Mark D Lescroart[1] (lescroar@usc.edu), Xiaomin Yue[1], Kenneth Hayworth[1], Irving Biederman[1]; [1]University of Southern California

The lateral occipital complex (LOC), an area critical for object recognition (James et al., 2003), is defined by fMRI criteria as the region in which there exists a difference in the activation produced by intact and scrambled pictures of objects (Malach et al, 1995). To assess coarse retinotopy in the LOC, subjects viewed sequences of either intact or scrambled images presented in quadrants of the visual field while they maintained central fixation. The eccentricity and sizes of the images were designed to produce neural activity that would be confined to a single quadrant, based on single-unit receptive field tuning in macaque TEO (Ungerleider, 1991). Although there was significant activation (above baseline) from ipsilateral presentations, activation in the LOC in the hemisphere contralateral to the side of presentation was significantly greater than in the ipsilateral LOC. The differences in loci of activation between upper and lower visual fields were much less pronounced. The laterality effect was more marked in the lateral occipital cortex (LO) than in the posterior fusiform (pFs), a result consistent with the general finding of an increase in the complexity of the representation along the anterior-posterior axis of the LOC. Assuming a decrease in retinotopy from posterior to anterior along the ventral stream pathway, the LOC's homology with macaque stages would appear to be anterior to TEO (because of the absence of upper vs. lower field differences) and posterior to TE (assuming that activation in TE is invariant to side of presentation).

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F35 647 Contrast responses and retinotopic organization in Blindsight: an fMRI study

Petya D. Radoeva[1] (petya@mail.med.upenn.edu), David H. Brainard[1], Geoffrey K. Aguirre[1]; [1]University of Pennsylvania

It has been debated whether residual vision in blindsight/Riddoch's phenomenon is mediated by subcortical projections to extrastriate areas or whether there are contributions from spared V1 cortex. Here we tested patient MC who sustained a left PCA stroke at the age of 16. Her initial right homonymous hemianopia later recovered to a scotoma with macular sparing. Behavioral studies have demonstrated a statokinetic dissociation within her scotomatous field. In the current 3T fMRI study, we examined neural contrast response functions and retinotopic organization in her normal and affected hemispheres. Expanding/contracting concentric rings of eight different levels of contrast (ranging from 1% to 100%) were presented within the scotoma, or in the healthy visual field. In the healthy hemisphere, activation was observed in areas V1, V2/V3, hV4, and MT, and the contrast response functions were comparable to those of Liu and Wandell, 2005. In the affected hemisphere, there was robust activation in areas V2v/V3v, hV4, and MT, and more subtle activation within area V1. All of these areas retained contrast sensitivity at high levels of contrast, but had reduced sensitivity for low contrast levels. Retinotopic mapping revealed spatially organized signals within V1, adjacent to her lesion. Eccentricity representation within V1 included her scotomatous field in which the stimuli from the contrast experiment were presented. The current study demonstrates that it is possible to observe retinotopic organization, and contrast sensitivity, in spared V1 cortex for stimuli presented in the scotoma of a patient who clinically presents with Riddoch's phenomenon.

F36 648 The fidelity of the retinotopic cortical map in amblyopia measured with BOLD-fMRI

Xingfeng Li[1] (xing.li@mcgill.ca), Serge Dumoulin[2], Behzad Mansouri[1], Robert Hess[1]; [1]McGill Vision Research Unit,Department of Ophthalmology,McGill University,Montreal,QC,Canada, [2]Department of Psychology, Stanford University ,CA

Purposes: To study the locations of early visual areas in amblyopia and the fidelity of their retinotopic maps using fMRI.Methods: fMR images were acquired with a Siemens Sonata 1.5T. The stimuli consisted of abruptly randomly changing (8Hz) sharp-edged checkerboard stimuli of 80% contrast presented to either the normal or amblyopic eye of 11 amblyopic subjects and 6 normal controls. A phase-encoded design was used in which the attention of the subjects was controlled using a target detection task. All the known retinotopic visual areas were delineated by the normal and fellow amblyopic eye in V1 to V4. Correlation between the fixing eye boundaries and amblyopic eye boundaries as well as the boundaries between dominant and nondominant eyes in normal controls were compared. Distortion and variability in amblyopic eyes measured using a novel psychophysical mapping task were correlated to the phase variance in different cortical regions of our subject group. Results: Boundaries in amblyopic subjects defined in term of fMRI retinotopic mapping using fixing eye and amblyopic eye show differences compared with normal controls. This could not be explained simply by the reduced signal-to-noise ratio of the amblyopic cortex. We did not find a strong correlation between the larger phase variances typical of amblyopic visual areas and distortion or variability measured psychophysically.Conclusion: The fidelity of the retinotopic map is not as good in amblyopic eyes. Supported by CIHR grant MOP53346 to RFH.

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F37 649 A disrupted retinotopic map in amblyopia

Behzad mansouri[1] (behzad.mansouri@mcgill.ca), Robert Hess[1]; [1]McGill Vision Research unit, Ophthalmology Department, McGill University, Montreal, Qc, Canada

Purpose: The amblyopic visual system exhibits both positional uncertainty and distortion. Animals whose visual input in early life has been disrupted also exhibit severe deficits in positional coding (Gingras 2005). We studied the quality of the retinotopic map by measuring the perceived position of stimuli presented to various parts of the amblyopic visual field.Methods: Using a polarization method, we have tested 15 amblyopes and 5 normals. The stimuli were Gaussian blobs, which were presented within a circle of 30 degrees diameter. Each blob was seen only by the amblyopic eye. Moving a mouse and a marker seen only by the fellow-fixing eye, each subject had to localize the position of this previously presented target. This was repeated 50 times in each of 32 field positions. Refraction and alignment of the eyes were corrected before data collection.Results: Our results confirm previous findings that there are significant degrees of distortion in the maps of the central visual field in amblyopic subjects (Fronius 1989). However, the variability was not correlated with the measured distortion in amblyopic maps. The distortion/variability index was significantly larger in amblyopic maps, showing that the higher distortion in amblyopia could not be simply explained by higher variability in localization. Also, regional analysis of the data showed that the distortion occurred heterogeneously in different parts of the visual field. Conclusions: Our results show that amblyopes are not only uncertain as to where objects are but also they experience stable distortions that may only affect circumscribed regions of the visual field.

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F38 650 Cortical visual field representations in patients with albinism and female carriers of ocular albinism assessed with multifocal visual evoked potentials

Michael B. Hoffmann[1] (michael.hoffmann@medizin.uni-magdeburg.de), Birgit Lorenz[2], Markus Preising[2], Petra Seufert[1,3]; [1]Visual Processing Lab, Magdeburg University, [2]Ophthalmogenetics, Regensburg University, [3]Sektion für funktionelle Sehforschung

Purpose: In human albinism part of the temporal retina projects abnormally to the contralateral hemisphere. We tested whether this abnormality can be identified with multifocal visual evoked potentials (mfVEPs) and

whether it is evident in carriers of ocular albinism (OA1).Methods: In 12 controls, 11 patients with albinism, and 5 female carriers of OA1 monocular pattern-reversal mfVEPs were recorded for 60 locations comprising a visual field of 44° diameter (VERIS 4.8; EDI). For each eye and each stimulus location inter-hemispheric difference potentials were calculated and correlated with each other to assess the lateralisation of the responses: positive and negative correlations indicate lateralisation on same or opposite hemispheres, respectively. Misrouted optic nerves are expected to yield negative interocular correlations. Silent visual field locations were excluded from the analysis using a signal-to-noise threshold. Our analysis also allowed for the assessment of the sensitivity and specificity of the detection of projection abnormalities.Results: Sizable mfVEPs were obtained in all controls, carriers and the 3 albino patients with negligible nystagmus and visual acuity > 0.25. 97% and 98% of the visual field locations were identified as normal in controls and carriers, respectively. While this indicates a specificity of 97%, the sensitivity of the procedure was estimated to be 76%. Finally, in albinism 50% of the responses were abnormally represented. Conclusion: In the absence of nystagmus mfVEPs are a powerful tool to identify, in a spatially resolved manner, abnormal visual field representations. No local representation abnormalities were evident in the female carriers of OA1 tested.

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Motion: Aftereffects, Ambiguity and Illusions

F39 *651* Geometric Context Influences Ambiguous Apparent Motion.

Allan C. Dobbins[1] (adobbins@uab.edu), Alexander Zotov[1]; [1]Vision Science Research Center, Dept. BME, UAB, Birmingham, AL, USA

How sensitive is the matching process in long-range apparent motion to contextual influences? The M points in N frames computational models make little accommodation for more general scene analysis constraints. Alternatively, if apparent motion perception is to be understood as generating a model of a scene transformation due to changing object/object and object/observer relationships, then other factors might affect one's interpretation.We examined the ability of contours to influence the interpretation of dynamic dot quartet motion. In the first two experiments, we measured the frequency of seeing horizontal vs. vertical quartet motion in the presence of flanking real or Kanizsa rectangles arranged outside the sides or top/bottom of the quartet. Most observers exhibited a significant change in quartet interpretation with the motion more frequently appearing to be along the contours. The biasing effect was greater for real contours than for cognitive contours. In some control conditions, the Pacman disks were oriented so that no virtual figure was seen, and no biasing effect was observed. In these experiments the observed along-the-contour bias was very sensitive to proximity. In contrast, a central "blocking" rectangle is also effective in biasing quartet motion, but in a way that is not proximity-dependent.A third experiment measured the influence of a central virtual blocker crossing either horizontal or vertical quartet paths. Virtual blockers were effective in all experienced observers, but only in some naive observers. Therefore the effect may depend on the observer being actively aware of the virtual contours and objects.

F40 *652* The Bicycle Illusion: A new look at acuity, form, and motion interactions in conscious experience

Michael D. Dodd[1] (mike@psych.ubc.ca), Michael E. J. Masson[2], James T. Enns[1]; [1]University of British Columbia, [2]University of Victoria

A bicycle rolling on a level surface alongside a fence of horizontally sagging chains appears to move up and down with the chains at certain viewing distances. In this bicycle illusion the relative vertical position of the bike follows the path of the chains. The illusion is different from motion capture because here a static form (fence) influences the perception of a moving form (bicycle), rather than the other way around. It is also distinguished from motion contrast because the moving bike follows the inducing chains rather than repelling from them. We took this sidewalk visual science into the lab by moving a disc horizontally on the screen and on top of two sinusoidal wavy lines. Our discoveries include: 1. The direction of the illusion is acuity dependent: at far viewing distances the disc appears to wiggle vertically in phase with the wavy lines (assimilation illusion) whereas at nearer viewing distances it appears to wiggle in counterphase to the lines (contrast illusion). 2. The assimilation illusion depends on the relative acuity of the static lines and the moving disc: the illusion is strengthened when the luminance contrast of the disc is reduced relative to the luminance contrast of the lines. 3. The contrast illusion is less dependent on the relative contrast of the disc and the lines. The bicycle illusion is therefore a novel preparation for studying the interactions between acuity, form and motion in conscious visual perception.

F41 *653* The Freezing Rotation Illusion

Max R Dürsteler[1] (max.duersteler@usz.ch); [1]Dept. of Neurology, University Hospital Zurich, CH-8091 Zurich, Switzerland

In 1996 Mesland and Wertheim described a new motion illusion: when a monitor with a constantly moving sinusoidal grating was swayed near stationary observers, they perceived the grating as freezing or decelerating on the moving screen. The phenomena of "motion freezing" also arises with rotating patterns (Dürsteler, 2005). In order to measure the illusion effects I borrowed an experimental design from Gestalt psychology (K. Duncker, 1929). A central disk could be rotated independently from the surround. The "freezing rotation illusion" arises when the surround is rotating sinusoidally back and forth around a physically continuously and slowly rotating center. First I measured the effect of surround rotation on center rotation perception. In half of the trials the surround was turning opposite to the center, in the other half, the surround was rotating in the same direction as the center. The observers had to estimate the rotational velocity of the center. Its perceived velocity was smaller in trials where centre and surround were rotating in the same than in the opposite direction. In the second series of experiments I measured the effect of center rotation on surround rotation perception. There was no noticeable effect of the center rotation on the surround rotational velocity perception. *References:*Duncker K. Über induzierte Bewegung. Psychol Forschung 12:180-259.1929Mesland B.S., Wertheim A.H. A puzzling percept of stimulus stabilization. Vision Res. 36:3325-3328. 1996Dürsteler M.R. Eine neuartige Bewegungstäuschung: Duncker Illusion und "Motion Capture" im Widerstreit. Ophta 3:19-26. 2005http://web.unispital.ch/neurologie/vest/MotionIllusion/

URL: http://web.unispital.ch/neurologie/vest/MotionIllusion/

F42 *654* Opposite biases for the perceived direction of first- and second-order lines

Ross Goutcher[1,2] (ross.goutcher@gcal.ac.uk), Gunter Loffler[1]; [1]Glasgow Caledonian University, [2]University of St Andrews

Image features (e.g. line terminators) play an important role in the computation of 2D motion. It has been suggested that such features are processed by specialised detectors (end-stopped cells). However, the motion of line terminators may also be processed by a combination of first- and second-order motion information (Loffler & Orbach, 1999). According to this model, first-order signals are biased in the direction orthogonal to the line orientation, whereas second-order signals are biased in the direction of the line orientation. Are these biases evident in the perception of moving lines?Observers were presented with an array of tilted line segments (each measuring 0.5 by 2.2 degrees, with orientation ±20 degrees to the vertical and 30% – 90% contrast) moving along one of several linear trajectories (±60 degrees to the horizontal). Lines were defined by either first- or second-order information (i.e. luminance or contrast modulated dynamic 2D noise). Observers' task was to state whether the trajectory of the lines was above or below horizontal. Perceived horizontal motion, the trajectory where 'above' and 'below' responses are equally probable, was inferred

from psychometric functions.For first-order lines, perceived horizontal motion was biased in the direction orthogonal to the line orientation (average bias = –31.6 degrees). For second-order lines the bias was in the opposite direction, towards the line orientation (average bias = 27.2 degrees), as per model predictions. Our results suggest a novel role for second-order processing: it may be crucial for the coding of veridical two-dimensional feature motion.

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F43 *655* Motion after-effects from two-stroke apparent motion

George Mather[1] (g.mather@susx.ac.uk); [1]Department of Psychology, University of Sussex, Brighton, UK.

Two-stroke apparent movement was first reported at ECVP last year - repeated presentation of a two-frame pattern displacement followed by a brief inter-stimulus interval (ISI) can create an impression of continuous forward motion. The illusion is based on previous reports of reversed apparent motion in two-frame stimuli containing a brief ISI, and can be explained by a biphasic temporal impulse response preceding motion energy detection (Shioiri & Cavanagh, Vision Research, 30, 757-768, 1990; Strout, Pantle & Mills, Vision Research, 34, 3223-3240, 1994; Takeuchi & De Valois, Vision Research, 37, 745-755, 1997).Two-stroke apparent motion of a sine-wave grating was used as an adapting stimulus in a motion after-effect (MAE) experiment. Naive subjects reported clear MAEs following a short period of adaptation, consistent with unidirectional activation of motion energy sensors. Experiments measured the effect of spatial frequency and ISI duration. MAE duration was longest for ISI durations of 30-40 msec, consistent with earlier research on two-frame apparent motion.

URL: http://www.lifesci.sussex.ac.uk/home/George_Mather/TwoStrokeFlash.htm

F44 *656* Independent coding of object motion and position revealed by distinct perceptual time courses

Paul F. Bulakowski[1] (pbulakowski@ucdavis.edu), Kami Koldewyn[2,3], David Whitney[1,2,3]; [1]The Department of Psychology, [2]The Center for Neuroscience, [3]The Center for Mind and Brain, University of California, Davis, USA.

We perceive a coherent visual world, despite the fact that visual processing is largely parallel and modular. There are, however, cases in which this binding is broken, causing asynchronous perception of an object's features (e.g. color and motion) or conflicting judgments of its properties (e.g. motion and position). Despite these examples of misbinding, it remains unclear whether different properties of an object are coded independently. Here we used contingent motion aftereffects (MAE) (Arnold, et al., *Current Biology*, 2001) to psychophysically measure processing differences both between and within features of the same object. Subjects adapted to a rotating grating whose direction of rotation (alternating clockwise and counterclockwise) was paired synchronously or asynchronously with changes in spatial frequency (either low or high spatial frequency). Following adaptation, subjects judged either the perceived MAE or the perceived position shift of the test grating. If the attributes of an object are processed with the same time course, then direction reversals that are synchronously paired with the spatial frequency changes should produce the strongest spatial-frequency contingent aftereffect. For judgments of the MAE, however, we found that a physical asynchrony must be introduced between attributes to maximize the contingent MAE; the motion reversals had to lag the spatial frequency changes by approximately 90ms. On the other hand, for judgments of the test grating's position (i.e., the phase), no asynchrony was revealed. The distinct time courses for judgments of motion and position- following precisely the same physical adaptation- suggests that they are coded by separate neural populations.

F45 *657* Artificial image oscillation enhances the rotating snakes illusion

Ikuya Murakami[1] (ikuya@fechner.c.u-tokyo.ac.jp), Akiyoshi Kitaoka[2], Hiroshi Ashida[3]; [1]Department of Life Sciences, University of Tokyo, [2]Department of Psychology, Ritsumeikan University, [3]Graduate School of Letters, Kyoto University

A stationary pattern with asymmetrical luminance gradients can appear to move. We hypothesized that this effect, also known as the "rotating snakes" illusion, is driven by retinal image jitters due to eye movements. Recently we have reported a positive inter-subject correlation between fixation instability and illusion strength (Murakami et al., SfN 2004). Here we show evidence for their causal link by comparing the amplitude of artificial image oscillation and illusion strength. The stimulus contained asymmetrical luminance gradients characterized by the sum of the first and third harmonic sinusoids in specific phase relationship. A radial grating of this waveform was presented on the monitor. By actually rotating the stimulus about the central fixation spot, the physical rotation velocity just to cancel illusory rotation was determined. In addition, the stimulus as a whole was randomly jittering in position, simulating image oscillation due to small eye movements. It was found that the cancellation velocity at the point of subjective stationarity increased as the simulated fixation instability increased. Thus, the influence of retinal-image instability on illusion strength we previously found in inter-subject data was also observed within a single observer. We also tested whether the illusion occurs in a stabilized retinal image. In a total darkness, a printed illusory figure was flashed by strobe illumination. The subject subsequently experienced the afterimage of the figure, but reported no illusory rotation. Based on these findings, we conclude that the rotating snakes illusion is caused by retinal image motions due to eye movements.

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F46 *658* The Rotating Circle Illusion

B. Pinna[1] (baingio@uniss.it), M. Boi[2]; [1]University of Sassary Dept of Sciences of Languages, [2]University of Cagliari Dept of Psychology

A novel motion illusion is shown consisting of a white circle moving across or behind black parallel lines on a grey background. When the gaze is kept on the centre of the circle, the circle appears to rotate even if it is, in fact, translating. The apparent motion can only be perceived in peripheral vision. Phenomenology of the illusion: (i) the rotation persists when then circle and/or the background are composed of textured patterns (e.g. irregularly scattered dot) or by making the circle more and more similar to a square or an ellipse; (ii) the effect is increased when the circle is in front of the background, transparent, illusory or has the same contrast as the background elements whereas it is reduced when the circle is filled or by moving the textured background while keeping the circle stationary; (iii) attentive focusing on the bottom or on the top part of the circle induces a rotation respectively synergistic or opposite to the translational movement; (iv) the rotation is perceived in the entire circle even though the background intersects only a portion of it.The illusion is related to the one reported by Cormack, Blake and Hiris (1992) but, unlike this one, here the shape influences the very type of perceived motion depending on: the motion of the intersections between circle and background elements, a figural integration of the motion vectors along the moving shape, a long range filling in process of the induced rotation spreading across regions where no intersections occur.

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F47 *659* An arrow allows illusory line motion to get together

Yuki Yamada[1] (yy@psycho.hes.kyushu-u.ac.jp), Takahiro Kawabe[1], Kayo Miura[1]; [1]Kyushu University

A briefly presented bar is perceived as extended from a pre-cued position,

a phenomenon known as illusory line motion. The present study demonstrated a different sort of illusory motion derived purely from top-down processing. After the brief presentation of a red arrow cue (leftward, rightward, or control stimulus) above the central fixation cross on the white screen, a black horizontal bar with approximately 24° in length was presented below the arrow cue. A horizontal center of the arrow cue was aligned with that of the bar. The durations for the arrow and the bar were 100 and 50 msec, respectively. The observer's task was to judge the direction in which the bar was perceived as extended (right or left, in a 2AFC paradigm). One of six ISIs (0, 100, 400, 700, 1000, and 1500 msec) was employed between the arrow cue and the bar on each trial. The results revealed that with a very short ISI observers perceived the illusory motion in the direction suggested by the arrow cue even though there was no motion signal in the horizontal direction. Meanwhile, with the increase in ISI, the probability of illusory motion in the arrow direction decreased. This kind of illusory motion is attributable to attentional shift; spatial attention might firstly engage at the arrow position and gradually shift along the arrow direction, and this produces latency difference between the position around the arrow cue and the edge of the bar in the side the cue indicated.

F48 *660* Mutually contradictory percepts in motion processing

Dylan R Nieman[1] (nieman@caltech.edu), Bhavin R Sheth[2,3], Shinsuke Shimojo[1,4]; [1]Division of Biology, California Institute of Technology, Pasadena, CA, USA, [2]Electrical and Computer Engineering, University of Houston, Houston, TX, USA, [3]Center for Neuroengineering and Cognitive Sciences, University of Houston, Houston, TX, USA, [4]ERATO Project, Atsugi, Japan

Studies of thinking and reasoning processes have shown that people can maintain multiple, fundamentally incompatible beliefs, particularly if attention is not drawn to the incompatibility. Recent work suggests the same may be true for multiple low-level visual percepts: Whitney and Cavanagh (2000) inferred that while a target's perceived position is shifted by an inducer, there is no accompanying percept of target motion. A more explicit perceptual paradox can be shown if the motion and position percepts of a target stimulus are each tested and found to be inconsistent under conditions without an inducer. Observers (n=12) watched a small, circular target move diagonally at constant speed (21.2 deg/s) on a screen for 200 ms, then make an abrupt 90 degree turn and continue at the same speed for 200 ms. Observers fixated a small dot outside the target's path and judged the position of the turn-point relative to nearby horizontal or vertical hash marks. The two-dimensional position of the turn was systematically mislocalized to a position outside the object's motion trajectory. Our control data indicates that known effects like Frohlich, flash-lag, representational momentum, and onset repulsion are unable to explain the shift. Specific probing of the target's trajectory suggests that observers maintain no less than three percepts that are mutually inconsistent: the position of the pre-turn path, the position of the post-turn path, and the position of the turn-point itself. Our findings support the idea that lower-level sensory processing can be mutually contradictory, suggesting some module-like structure.

F49 *661* Controlled processes in apparent motion

Nicolaas Prins[1] (nprins@olemiss.edu); [1]Dept Psychology, University of Mississippi, Oxford, MS

Arguably, the most important determinant of correspondence matches in long-range apparent motion is the relative proximity of the potential matches. That is, all else equal, correspondence matches are preferred between 'nearest neighbors' in retinal coordinates. However, a vast body of research has indicated that similarities between motion tokens on dimensions other than retinal position affect correspondence matches as well, though to a lesser degree. It is investigated here whether the effects of relative color, depth, or spatial-frequency content of motion tokens display characteristics typical of 'controlled', attentional processes. In experiment 1, observers were presented with a static display containing all motion tokens for a variable period of time before the motion sequence started. It was found that varying relative color, depth and spatial frequency content of the motion tokens indeed creates a bias to match tokens that are alike. However, it is shown that this bias develops over time. In the second experiment, observers were asked to remember a particular configuration of the colors or spatial frequency contents of motion tokens while judging motion in another configuration of motion tokens. It was found again that relative color or spatial frequency content of motion tokens in the actual motion frames biases correspondence matching. However, the to-be-remembered configuration of tokens affected correspondence matching also, but in an idiosyncratic manner. These findings suggest that relative color, depth, and frequency content of motion tokens affect correspondence matching through a relatively high-level, controlled process.

F50 *662* Spinning Ellipses: Dotted contours reveal the spatial resolution for the tracking of unambiguously moving features

Gideon P. Caplovitz[1] (gcap@Dartmouth.edu), Peter U. Tse[1]; [1]Dartmouth College

An ellipse rotating at a fixed angular velocity appears to rotate faster as its aspect ratio increases. (Caplovitz et al, 2005;VSS, SFN). We have hypothesized that regions of high curvature act as form-based, trackable features (TFs). When trackable feature are weak, the corresponding motion signals are weak, generating the illusion. Here we examined the perceived angular velocity of rotating ellipses defined by equally spaced dots. The local motion of each dot along the contour is unambiguous. If the dots can serve as TFs, the illusory percept that is observed with continuous contours should not be observed. Methods: Subjects performed 2AFC speed discrimination judgments on pairs of rotating dotted ellipses. 12,24 and 32 dots were used to define ellipses. Control experiments adjusted the size of the dots and the overall sizes of the ellipses. Results: The illusory percept was observed for the 24 and 32 dot ellipses and not for the 12 dot condition. The size of the dots did not affect the perception of angular velocity. Changing the size of the ellipses, and thereby the spacing of the dots, in the 24 dot condition determined whether or not the illusory percept was observed. Conclusion: the spacing and not the number or size of the dots is the critical variable in determining whether the unambiguous local motion of individual dots is used to generate the percept of angular velocity. If the dots are too closely-spaced, the visual system appears to process them as continuous contours, generating the illusion.

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F51 *663* Illusory conjunction between continuous and discrete changes in the absence of motion

Rick H Cai[1] (rcai@wisc.edu); [1]Dept. of Psychology, University of Wisconsin, Madison

Previously, we demonstrated an illusion in which a bar gradually changes its height as it moves, and somewhere along its trajectory, it also changes to a different color for one frame. The new color is assigned not only to a new spatial location, but also to a different sized bar (an illusory conjunction of color and shape). We proposed a model based on the principle that the brain represents continuous changes differently from abrupt changes, leading to an asynchrony in the processing of the two (Cai & Schlag, VSS, 01). Here we tested two predictions from the this model. First, according to the model, the illusion should not be limited to linear motion and height change. We used a hollow ring that expanded from the center. As the expanding ring reached a certain size, it changed to a different color for one frame. The new color was perceived as belonging to a ring of greater size. Second, we created a display in which dots were scattered randomly within a rectangular area. The density of the dots increased with time. There was no net motion energy within the rectangular area. As the density reached a certain level, all the dots changed color for one frame. The odd color was perceived as belonging to a field of dots of higher density then the actual case. This demonstrates that, consistent with the model prediction, illusory conjunction occurs between continuous and discrete changes, even if such changes involve no motion.

F52 *664* Speed Adaptation as Kalman filtering

Jose F Barraza[1] (jbarraza@herrera.unt.edu.ar), Norberto M Grzywacz[2]; [1]Departamento de Luminotecnia, Luz y Vision, Universidad Nacional de Tucuman and CONICET. Av. Independencia 1800, 4002BLR Tucuman, Argentina, [2]Center for Vision Science and Technology and Department of Biomedical Engineering, University of Southern California, Los Angeles, CA.

Purpose. If the purpose of adaptation is to fit sensory systems to different environments, it may be understood as an optimization process. What the optimum is depends on the statistics of these environments. Therefore, the system should update its parameters as the environment changes. A Kalman-filtering strategy performs those estimations optimally by combining current estimations of the environment with those from the past. We investigate whether the visual system uses this strategy for speed adaptation. Methods. We performed a matching speed experiment by using drifting sinusoidal gratings to evaluate the time course of speed adaptation. Simulations of these experiments were generated by an implementation of the model developed by Grzywacz and de Juan (Network: Comput. Neural Syst. 14:465-482, 2003). Results. Experimental results are in agreement with modeling predictions. When subjects adapt to a low speed and it suddenly increases, the time course of adaptation presents two phases, namely, a rapid decrease of perceived speed followed by a slower phase. In contrast, when speed changes from fast to slow, adaptation presents a single phase. However, this asymmetry disappears both experimentally and in simulations when the adapting stimulus is noisy. In both transitions, adaptation now occurs in a single phase. Conclusions. That speed adaptation follows a Kalman-strategy suggests that the brain is constantly optimizing its speed estimates. Grzywacz and de Juan reached a similar conclusion for contrast adaptation, suggesting that Kalman adaptation may be a general feature in the brain.

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Spatial Vision: Natural Image Statistics

F53 *665* Chromatic Differences within Surfaces and Across Surface Boundaries

J. Anthony Wilson[1,2] (janthonywilson@gmail.com), A. David Ing[1], Wilson S. Geisler[1]; [1]Center for Perceptual Systems and Psychology, University of Texas, Austin TX 78712, [2]Department of Psychology, University of Pennsylvania, Philadelphia PA 19104

Humans tend to group nearby image patches that are similar in color and segregate nearby image patches that are dissimilar in color. However, little is known about the predictive power of this chromatic information in natural scenes. Thus, we have analyzed close up images of foliage obtained with a calibrated 36-bit camera, which provides estimates of the relative L, M and S cone responses with error SDs of 0.15%, 0.1% and 1%, respectively, for natural spectra. More than 2000 leaves were hand segmented from over 60 images representing a wide range of foliage. Image patches were sampled from each leaf object. For each patch, other patches were sampled within and outside the leaf. The cone responses for each patch were transformed into a logarithmic space (Ruderman et al. JOSA A, 15, 2036). Probability distributions for response differences (based on all objects) were estimated, conditional on distance between patches and on whether or not patches fall within the same leaf. The grouping/segregation information was quantified for each patch size and distance by the signal-to-noise ratio (d') for deciding whether or not a pair of patches was drawn from the same leaf. For small patches, d' fell from values greater than 2.0 at smaller distances to values near 1.0 at larger distances. Thus, for foliage (a large fraction of the natural world) there is substantial chromatic information for region grouping. Further, the decline in d' with distance suggests that region grouping would benefit from a chromatic region-growing mechanism.

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F54 *666* Ideal Observer Analysis of Detection in Natural Scenes

Jiri Najemnik[1] (najemnik@mail.cps.utexas.edu), Wilson S. Geisler[1]; [1]Center for Perceptual Systems and Psychology, University of Texas, Austin TX 78712

As part of a long term goal to understand visual search in natural scenes, we are currently investigating factors that limit target detection in natural backgrounds. Here we investigate how the statistical properties of natural images affect the behavior of a rational detector. We use a large number of natural image patches (~300000) to train a PCA-based, k-nearest neighbor (NN) algorithm, where the task is to classify stimulus patches as either a natural patch + gabor target or a natural patch alone. We have some indirect evidence that this algorithm achieves near-optimal performance. First, the NN algorithm reaches near-optimal performance when detecting targets embedded in 1/f noise patches, and second, the detection accuracy of both the natural and 1/f noise NN classifiers asymptotes when the number of patches reaches 100000. In agreement with ideal-observer theory, we find that for gabor targets in 1/f noise (with no signal uncertainty), d' is a linear function of target contrast (Weibull slope parameter of 1.4). On the other hand, for gabor targets in natural scenes we find a change in psychometric function shape—d' shows a slight decelerating non-linearity as a function of target contrast (Weibull slope parameter of 1.0-1.2), which is opposite to the effect of target uncertainty. We are currently using a similar NN simulation technique to evaluate the effects of retinal filtering (eccentricity effects) and target uncertainty on the shape of the psychometric function for optimal detection in natural images.

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F55 *667* Classification of natural scenes: critical features revisited

Jan Drewes[1] (Jan.Drewes@psychol.uni-giessen.de), Felix A. Wichmann[2], Karl R. Gegenfurtner[1]; [1]University of Giessen, Giessen, Germany, [2]Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Human observers are capable of detecting animals within novel natural scenes with remarkable speed and accuracy. Despite the seeming complexity of such decisions it has been hypothesized that a simple global image feature, the relative abundance of high spatial frequencies at certain orientations, could underly such fast image classification (A. Torralba & A. Oliva, Network: Comput. Neural Syst., 2003).We successfully used linear discriminant analysis to classify a set of 11.000 images into "animal" and "non-animal" images based on their individual amplitude spectra only (Drewes, Wichmann, Gegenfurtner VSS 2005). We proceeded to sort the images based on the performance of our classifier, retaining only the best and worst classified 400 images ("best animals", "best distractors" and "worst animals", "worst distractors").We used a Go/No-go paradigm to evaluate human performance on this subset of our images. Both reaction time and proportion of correctly classified images showed a significant effect of classification difficulty. Images more easily classified by our algorithm were also classified faster and better by humans, as predicted by the Torralba & Oliva hypothesis.We then equated the amplitude spectra of the 400 images, which, by design, reduced algorithmic performance to chance whereas human performance was only slightly reduced (cf. Wichmann, Rosas, Gegenfurtner, VSS 2005). Most importantly, the same images as before were still classified better and faster, suggesting that even in the original condition features other than specifics of the amplitude spectrum made particular images easy to classify, clearly at odds with the Torralba & Oliva hypothesis.

F56 *668* What makes two images look different from each other?

P. George Lovell[1] (p.g.lovell@bristol.ac.uk), David J Tolhurst[2], Caterina

Ripamonti[2], Michelle To[2], Tom Troscianko[1]; [1]Department of Experimental Psychology, University of Bristol, [2]Deparment of Physiology, University of Cambridge

"Visual difference predictors" (VDPs) are models which attempt to predict the extent to which people judge two natural scene images to be different from each other. A VDP generally samples scenes with arrays of localized, spatial-frequency and orientation-selective filters; where filters detect significant contrast differences a larger overall difference is assigned. Our VDP predicts differences based on differences within luminance, red-green and blue-yellow channels.We now examine VDPs for supra-threshold differences. Do observer ratings of some kinds of image differences systematically deviate from the model, perhaps when the differences are considered "unimportant" (e.g. cast shadows, texture element displacement)?We devised a large set of stimuli from digitized color photographs of many classes of scene; the supra-threshold differences between pairs could be natural (e.g. object moves) or computer-generated (e.g. blurred or desaturated). A subset originated from a single reference scene (e.g. cow grazing in field) which was then transformed in many ways (e.g. cow moves/changes size; background moves; lighting changes). Images pairs in this subset were chosen so that they were equally discriminable to the low-level model. The perceptual differences between image pairs were determined with subjective magnitude ratings.The supra-threshold predictions of our low-level VDP model are good for most image pairs, but with consistent failures for some kinds of image differences (e.g. in the periphery of the images). Instances where the VDP model over-predicts differences may reveal that differences were available to low-level vision, but they were discarded somewhere between the low-level processing and the observer's response.

F57 *669* Visual features and information theory

Giovanni Punzi[1,2] (giovanni.punzi@pi.infn.it), Maria Michela Del Viva[3,4]; [1]Universita' di Pisa, Dipartimento di Fisica, Pisa, Italy, [2]Istituto Nazionale di Fisica Nucleare, Pisa, Italy, [3]Universita' di Firenze, Dipartimento di Psicologia, Firenze, Italy, [4]Istituto di Neuroscienze CNR, Pisa, Italy

We present an information-theory approach to the selection of salient characteristics in an image. We conjecture that the choice of the specific features perceived as salient can be explained on the basis of the amount of usable information they provide for coding the entire image, and the amount of computing resources required in the visual system. If this conjecture is true, the vision primitives may be the product of a natural selection process amongst all conceivable visual patterns, based on information content and computational cost. These ideas were tested in a practical implementation with samples of natural images.

F58 *670* Contour sparseness and the interactions in the visual processing of local phase alignment of natural scene contours

Bruce C. Hansen[1] (bruce.hansen@mcgill.ca), Robert F. Hess[1]; [1]McGill Vision Research Unit, Department of Ophthalmology, McGill University, Montréal, Québec, Canada

The phase spectra of natural scene imagery play a central role regarding where contours occur, thereby defining the spatial relationship between those features in the formation of image structure. Thus, we were interested in 1) measuring the relative amount of local spatial phase alignment needed by humans to extract contours from an image, and 2) determine if those measurements depended on the contour "sparseness" at different spatial frequencies (*SF*). We examined this with a match-to-sample task that used either natural scene images or noise images possessing naturalistic contours, grouped with respect to their level of sparseness. Phase alignment in the stimuli was controlled by band-pass filtering the phase spectra, where phase angles falling within the filter's pass-band were preserved, and everything else randomized. Filter widths were varied (0.3 octave steps) about one of three central *SF*s (3, 6, 12cpd). On any given trial, following a 250ms presentation of a partially phase-randomized image, participants were simultaneously shown (2sec) four images and asked which one corresponded to the previously viewed, partially phase-randomized image. Results indicated that 1) the bandwidth of local spatial phase alignment needed to match image contours depended on the relative sparseness of the original image; 2) for contours falling within the 6cpd central *SF* filter, less phase alignment was needed as compared to the other central *SF*s; 3) contour sparseness outside of a given filter's central *SF* was not found to interfere with the amount of phase alignment needed to match image contours.

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F59 *671* Predicting perturbation of object contours by background in natural images

Mark J. Brady[1] (mark.brady@ndsu.edu); [1]North Dakota State University

Purpose: Because object contours are composed of local contrast elements, perturbation of the local contrast elements will result in perturbation of an object's contour. Local contrast is generally measured using contrast sensitive filters. Contrast filters can measure both preferred orientation and contrast magnitude. Contrast filters, applied along object boundaries, take input from both the object image and the background image. Changes in the background, thus, cause changes in the filter response. This perturbation can be measured and described statistically. The goal of this study is to predict the structure of contour perturbation statistics, using background summary statistics and develop the corresponding theory.Methods: Images of natural and artificial objects were photographed and hand-segmented from their natural backgrounds. Composite images were made by digitally superimposing and translating the image of an objectacross various natural image backgrounds.Perturbation statistics were represented using 2D histograms of orientation and magnitude responses. Histograms were organized into a taxonomy, according to their prominent features. Features included single or double histogram modes. Background summary statistics were studied in order to determine if they could help predict the locations of the modes within the histogram. Results: It was found that the mode of the histogram of the background pixel intensities could predict the position of the 2D histogram modes. Prediction of mode location was highly accurate. It was also possible to predict the number of modes.Conclusions: It is possible to predict important features of contour perturbation, using summary statistics of the background.

F60 *672* Learning the selectivity of V4 neurons using a nonlinear multi-stage network

Christoph Zetzsche[1] (zetzsche@informatik.uni-bremen.de), Ulrich Nuding[2], Kerstin Schill[1]; [1]Cognitive Neuroinformatics, University of Bremen, [2]Bernstein Center f. Computational Neuroscience, Univ. of Munich

We investigate a nonlinear two-stage network optimized to reducestatistical dependencies in natural images. This network serves as a model for the neural informationprocessing in the higher visual areas of primates (visual cortices V2,V4). It is analyzedwith regard to nonlinear selectivity and invariance properties. We show thatthe proposed network principle leads to units that are highly selective with respect tothe input signal space and to units that are invariant with respect to certain stimulusclasses. A special property of the system is the emergence of nonlinear frequencyinteractions, which are necessary for exploiting the higher-order statistical structureof natural images. We extend the concept to multi-layer systems and present somesimulation results.

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F61 *673* The Effect of the Static Nonlinearity on the Efficient Coding of the VisualInput.

Mohammad S. Dastjerdi[1] (dastjerdi@ccs.fau.edu), Dawei W. Dong[2]; [1]Center for Complex Syetems & Brain Sciences , Florida Atlnatic University

It is proposed that the early visual system exploits the statistical structures of the visual environment in order to represent the visual input efficiently. In previous studies, it has been shown that the efficient representations of natural images are localized and oriented filters similar to the receptive fields of simple cells in the visual cortex. However, the orientation selective receptive fields do not emerge before visual cortex, and a simple cell receives inputs from both ON and OFF ganglion cells. Because the ON and OFF ganglion cells process visual input in a nonlinear way, one cannot simply study the efficient coding as a linear process. In the current research, the effect of static nonlinearity on the efficient coding of the visual input is investigated. Natural time varying images are preprocessed with a biologically inspired center-surround filter (CSF). Similar to the earlier studies, the efficient representations of the direct CSF output are localized and oriented filters. However, the efficient coding of the rectified CSF output (ON/OFF channels) does not result in those filters. Instead, the filters have center surround structures similar to those of ganglion cells and most of the improvement in efficiency results from the rectification. Furthermore, the efficiency can be improved much more by using a temporal filter similar to the temporal receptive field of lateral geniculate nucleus (LGN) cells. In conclusion, the results suggest that using biologically inspired spatial/temporal filter of retina/LGN with static nonlinearity gives more efficient representation than linear processing.

F62 *674* **Ecological validity determines the impact of second-order information on perceptual performance.**

Aaron P. Johnson[1] (aaron.johnson1@staff.mcgill.ca), Nicolaas Prins[2], Frederick A.A. Kingdom[1], Curtis L. Jr. Baker[1]; [1]McGill Vision Research Unit, Dept. Opthalmology, Montreal, Quebec, Canada., [2]Dept. Psychology, University of Mississippi, Oxford, Mississippi, USA.

The human visual system is sensitive to modulations in the first-order (luminance) and second-order (contrast and texture) information within the natural world. Although there is psychophysical and neurophysiological evidence that first- and second-order information are processed separately by the visual system, the two are strongly correlated within the natural world (Johnson & Baker, 2004). Here we investigated whether first- and second-order information interact in determining perception, and if so whether the interaction is dependent on their spatial correlation. Using micropattern texture stimuli with a sine-wave modulation of element orientation (2-4 cycles/image), subjects performed a 2AFC spatial frequency discrimination task. Micropattern textures were comprised of either first-order only (Gaussians), second-order only (Gabors or contrast-modulated noise), or first- and second-order micropatterns whose spatial correlation was varied from 0% to 100%. Subjects exhibited good performance using only first-order micropatterns, but they could not perform the task in the second-order only condition. However when second-order micropatterns were presented together with first-order information, the results depended on their spatial correlation: task performance was augmented maximally when their spatial correlation was 75% or more, and fell back to levels below first-order only information as correlation declined to anti-correlation conditions (0%). This result suggests that while humans are capable of performing the discrimination task with only first-order information, perceptual performance is augmented by the presence of second-order cues, but only when presented in ecologically valid combinations.

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URL: http://www.mvr.mcgill.ca/Aaron/research.htm

F63 *675* **Multifocal fMRI shows spatial interactions in human primary visual cortex**

Simo Vanni[1,2] (vanni@neuro.hut.fi), Miika Pihlaja[1,2], Andrew James[3], Linda Henriksson[1,2]; [1]Brain Research Unit, Low Temperature Laboratory, Helsinki University of Technology, [2]AMI centre, Helsinki University of Technology, [3]Centre for Visual Sciences, Australian National University

The primary visual cortex is considered to represent visual information efficiently, while aiming to reduced redundancy in the sensory code. These functions suggest attenuation of correlated signals to increase statistical independence of component responses. Here we describe spatial interactions in human V1, which show a non-linear spatial summation of BOLD signals. Nine subjects participated in visual fMRI experiment. First we compared checkerboard stimulation of a single visual field position centred in upper quadrant at 4.8° eccentricity to parallel stimulation of nine positions at and around the centre position. The multiple regions were stimulated with multifocal fMRI paradigm using orthogonal timing. The non-linearity of the compound responses was successfully modelled using a two-phase process, in which linear spatial interaction is followed by a non-linear saturation of the response. One open question is whether the non-linearity is due to non-specific saturation of BOLD or neural response, or due to efficiency principle in the sensory coding. After determining the strongest BOLD responses, we will repeat the experiment with low contrast stimuli. Our model predicts that non-specific saturation would become linear at low contrast, because the response maximum is not reached. If non-linearity persists in the low contrast condition, it can be due to a functional role. Finally, we are going to decorrelate stimuli in the neighbouring visual field positions, which should enhance the centre response, if saturation aims to reduce redundancy in neighbouring visual field positions. This would be in line with Barlow's principle of efficient coding in human V1.

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F64 *676* **Why masses are hard to detect in mammograms**

Arthur E Burgess[1] (ab2boston@gmail.com); [1]Brigham and Women's Hospital, Harvard Medical School

About 15 to 20% of malignant masses are missed in routine screening mammography. At the same time, about 80% of cases sent to biopsy are found to be normal. This is due to the complexity of normal breast tissue in the images. Mammograms have power-law spectra, P(f) = K/f^b, similar to natural scenes. The average spectral exponent, b, is approximately 3 with a range from 1.5 to 3.5. I have shown that the log-log plot (CD diagram) of contrast threshold for detection versus mass size has a slope m = (b-2)/2, with positive slopes for b greater than 2. I verified this equation by human observer experiments using filtered noise over the above exponent range. The focus of this talk is the effect of tissue composition. It is well known that masses are much harder to detect in dense tissue regions. I have a large database of normal digital mammograms and have found average exponents of 2.4 and 3,2 for fatty and dense tissue regions respectively. Human CD diagrams for the two tissue types were determined by 2AFC experiments by adding masses extracted from specimen radiographs to normal tissue backgrounds. Slopes agreed with theory. One can plot the physically determined contrast of growing masses as a function of size on the CD diagrams to determine when they will become detectable with a selected accuracy. It will be shown that under some circumstances it may not be possible to detect masses in dense tissue.

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F65 *677* Abstract withdrawn.

Motion Perception: 2D

F66 *678* **Evidence for an early, direct visual input to V5/MT**

Sheila Crewther[1] (s.crewther@latrobe.edu.au), Robin Laycock[1,2], Paul Fitzgerald[2], David Crewther[3]; [1]School of Psychological Science, La Trobe University, Melbourne, Australia, [2]Alfred Hospital, Monash University, Melbourne, Australia, [3]Brain Sciences Institute, Swinburne Univeristy of Technology, Melbourne, Australia

Purpose: Human visual motion processing is usually considered to occur

via feed-forward projections through V1 into dorsal extrastriate cortex (V5/MT), though evidence also exists for an early, direct midbrain or thalamic input to V5/MT which bypasses V1. Hence we used Transcranial Magnetic Stimulation (TMS) to investigate the sequence of temporal activation of V1 and V5/MT in motion processing.

Methods: Ten participants were exposed to TMS in the region of V1 and left V5/MT during performance on a 3AFCmotion direction detection task set at a 80% correct level. Stimulus was 80 dots moving coherently (2.2cm/sec) for duration 53-84ms. Double pulses were delivered with a stimulus-TMS onset asynchrony of between 0-220ms in 32ms intervals.

Results: Mean performance showed diminished accuracy during TMS to V1 and V5. Four participants showed a strong early inhibition of performance in V1 following TMS between 0-32ms while the other 6 showed a second smaller later inhibition effect at between 95-158ms post - stimulus onset. All participants showed diminished performance accuracy with TMS to V5 between 0ms and 32ms post stimulus onset only.

Discussion: This study demonstrates that accurate perception of direction of coherent motion requires activation of V5/MT within 30ms of stimulus onset suggesting that such early motion processing bypasses striate cortex.

F67 *679* Hemodynamic changes in visual motion detection measured by near infrared spectroscopy

Masamitsu Harasawa[1,2] (harasawa@be.to), Akiko Obata[3], Toshiya Morita[4], Takayuki Ito[1], Takahiro Saito[5], Takao Sato[2], Kiyoharu Aizawa[2]; [1]Japan Broadcasting Corporation, [2]The University of Tokyo, [3]Advanced Research Laboratory, Hitachi Ltd, [4]NHK Engineering Services, [5]Kanagawa University

Optical topography (OT) is an apparatus to measure cortical hemodynamic changes using near infrared spectroscopy and can be handled and maintained much more easily than fMRI, MEG and PET. However, there are few previous studies on relationship between OT signal and early visual processing. We investigated effects of motion signal intensity on OT signal, and suggested the usefulness of OT for vision sciences. **Method:** 100 white dots were randomly positioned within a 9.4° circular aperture in left visual hemifield. All dots moved in random direction with lifetime of 30 ms. Several seconds after the onset of random motion, a fraction (0, 20, 40 or 80%) of dots moved leftward or rightward coherently for 3 sec, and subsequently all dots disappeared. Participants pressed a button with their right hands as quickly as possible if they detected coherent motion. Hemoglobin concentrations were detected by an optical topography (Hitachi Medical Systems, ETG-100) every 0.1 sec at 24 measurement points. We positioned them on left and right side of participants' inions and repeated measurements at least 100 times for every condition. **Results and Discussion:** OT signals induced by coherent motion were obtained as differences of hemoglobin concentrations between "hit" and "correct rejection" trials. For every participant the higher motion signal intensity induced the shorter behavioral reaction time and the higher OT signals in right hemisphere. Our results indicated the relationship among stimulus intensity, behavioral response and hemodynamic response, and suggested the usefulness of this newly emerging apparatus.

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F68 *680* Motion streaks lower global-motion thresholds.

Mark Edwards[1] (mark.edwards@anu.edu.au), Monique Crane[1]; [1]School of Psychology, Australian National University, Canberra, ACT, 0200, Australia.

Recent studies have shown that motion streaks (speed lines) can influence the perceived direction and speed of moving stimuli. The present study investigates whether motion thresholds can also be affected and whether a purely motion-based model could account for any observed facilitation. A 3-frame global-motion stimulus was used. Signal dots were manipulated in order to control the strength of the motion streak. In the Strong-Streak condition, the same dots carried the global-motion signal over successive motion frames, while in the Weak-Streak condition, different dots carried the signal over successive frames. Noise dots always moved in different directions over successive frames. While lower thresholds in the Strong-Streak condition could be explain by motion-streak facilitation, it could also be explained in terms of interactions purely within the motion system. Specifically, by excitatory feed-forward connections between neighbouring local-motion units tuned to the same direction of motion. In order to test these two models, speed and contrast were varied. If lower thresholds are due to motion streaks (form input to motion) then maximum facilitation should occur at high speeds (no streak at low speeds) and high contrast (due to reduced streak magnitude and the low contrast sensitivity of the form cells that extract the motion streak). Lower thresholds were obtained for the Strong-Streak condition only at high speeds and this facilitation was lost, or at least greatly reduced, at low (5%) contrast. These results support the notion that detection thresholds were facilitated by a motion-streak system.

F69 *681* Reciprocal interaction between high and low frequencies in the perception of motion

Frank H. Durgin[1] (fdurgin1@swarthmore.edu), Jeremy Freeman[1], Alex Huk[2]; [1]Swarthmore College, Department of Psychology, [2]University of Texas at Austin, Section of Neurobiology and Center for Perceptual Systems

The phenomenon of "motion capture" posits that coherent object motions are estimated after discarding high spatial frequencies. Here we show that "captured" dot motion signals are not discarded, but are instead combined with the low-frequency carrier signal. Although low-frequency carrier gratings influence the perceived speed of superimposed high-frequency dot elements (consistent with capture), the speed of the dot elements also affects the perceived speed of the carrier grating. Stimuli were vertical gratings (0.5 cpd; 40% peak contrast) with superimposed random dots (20 dots/deg^2; 40% peak contrast) that moved coherently in a Gaussian window. Dot and grating speed were varied independently. Seven frames of motion were shown at 10 Hz. Naïve subjects compared test stimuli to a remembered standard (2.67 deg/s). Subjects were instructed to judge either dot or grating speed exclusively. For grating trials, superimposed dot motions of 2.00, 2.67 or 3.33 deg/s yielded average PSEs of 3.21, 2.91, and 2.71 deg/s of grating motion, respectively. This is consistent with dot speed having a weight of about 0.25 in the estimation of grating motion. For dot trials, carrier gratings with speeds of 2.00, 2.67, or 3.33 deg/s yielded average PSEs of 3.43, 2.89 and 2.53 deg/s of dot motion, consistent with a 0.40 weight for grating speed in the estimation of dot speed. We conclude that motion mechanisms estimate coherent motion by integrating across a wide spectral range (with limited task-dependent tuning). Motion capture phenomena probably do not depend on selective capture (or inhibition) of high-frequency signals by low-frequency carriers.

F70 *682* The Relationship between Motion Sensitivity and Fixation Variability in Eccentric Gaze.

Thao C. Lien[1] (thaocaplien@excite.com), Jianliang Tong[1], Harold E. Bedell[1,2], Patricia M. Cisarik[1], Saumil S. Patel[1,2,3]; [1]College of Optometry, University of Houston, [2]Center for Neuro-Engineering & Cognitive Science, University of Houston, [3]Department of Electrical and Computer Engineering, University of Houston

Purpose. Murakami (Vision Res. 2004) hypothesized that normal motion sensitivity is limited by the variability of fixational eye velocity. The present study tested this hypothesis by increasing fixation variability preferentially in one meridian. **Methods.** Motion thresholds were measured for 8 gaussian-modulated random dot patches, arranged symmetrically at an eccentricity of 10 deg around a central fixation spot. On each trial, the random dots in each patch translated for 500 ms to produce common motion in the horizontal, vertical, or rotary direction. The motion threshold in each meridian was the target velocity that yielded 50% correct judgments. Fixation variability was the SD of eye velocity during monocular fixation in the horizontal, vertical and torsional meridians, as measured

with a search coil. Subjects (N = 10) viewed the stimulus with gaze either straight ahead or deviated temporally by 45 deg. **Results.** A shift from straight ahead to temporal gaze increased the SD of eye velocity substantially more in the horizontal meridian (~3x) than in the vertical or torsional meridians (~1.5x). Horizontal motion thresholds increased by an average of 1.6x, much less than the SD of eye velocity. In temporal gaze, no relationship existed between the motion threshold and the SD of eye velocity in the horizontal, vertical or torsional meridians.**Conclusions.** The results are not consistent with the hypothesis that fixation variability universally limits motion sensitivity, and suggest a role for extra-retinal eye-movement signals to reduce the influence of retinal image noise on motion processing.

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F71 *683* Eye movement correlograms reveal first-order interocular motion processes.

AVESH RAGHUNANDAN[1] (araghunandan@uh.edu), SCOTT B STEVENSON[1]; [1]University of Houston - College of Optometry

It has been suggested that first-order motion mechanisms are low-level, reflexive and luminance-driven systems while third order/feature-tracking mechanisms are high-level, salience-driven systems. It is unclear which mechanism is responsible for sensing interocular motion, in which frames are presented to different eyes. In this study we used the Eye Movement Correlogram (EMC) technique to investigate reflexive and attention-driven contributions to pursuit eye movement responses made to motion stimuli that were first-order (binocular luminance sine gratings), third-order (disparity-defined randot square wave gratings), or interocular (spatio-temporal quadrature phase disparity "Shadlen-Carney" sine gratings). Methods: The stimuli were 0.4-cpd horizontal gratings presented with random vertical motion trajectories. Subjects either TRACKED or IGNORED the grating motion while eye movements were recorded with a SRI dual-Purkinje image eye tracker. The eye position was differentiated to derive velocity. The saccade-free eye velocity signal was cross-correlated with stimulus velocity to produce an eye movement correlogram (EMC) for each trial. Results: TRACKING the first-order and interocular gratings produced two-component EMC profiles that comprised an early component peaking between 130 and 150 ms and a late component peaking at 300ms. However, TRACKING of the third-order grating produced a unimodal EMC profile that peaked at 300ms. IGNORING the motion of the first order and interocular gratings produced single-component profiles that peaked early at 120ms. The third-order grating failed to show any significant correlation when IGNORED. Conclusions: Pursuit EMC profiles support the existence of first-order type processing of interocular motion, although about 4 octaves weaker compared to first-order processes.

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F72 *684* A Pareto-optimality theory of motion perception

Sergei Gepshtein[1] (sergei@brain.riken.jp), Ivan Tyukin[1], Michael Kubovy[2], Cees van Leeuwen[1]; [1]Laboratory for Perceptual Dynamics, Brain Science Institute, RIKEN, Japan, [2]Department of Psychology, University of Virginia, USA

In previous work we found that Korte's law and other characterizations of apparent motion are special cases of a simple new law (Gepshtein & Kubovy, 2003; Gepshtein, Kubovy, & Tyukin, under review), which is consistent with what is known about human sensitivity to continuous motion, summarized by Kelly's (1979) spatiotemporal threshold surface. Our goal is to explain Kelly's surface and our results.We propose that visual sensitivities are allocated in accordance with a *Pareto criterion of optimality*, first proposed in economics in 1906. According to the Pareto criterion, uncertainties due to different sources are balanced such that no improvement can be achieved by decreasing losses due one source of uncertainty without increasing losses due to another. To satisfy the criterion, the parameters of the *most sensitive* motion detectors must tradeoff: detectors tuned to high speeds must be tuned to low spatial frequencies and high temporal frequencies, whereas detectors tuned to low speeds must be tuned to high spatial frequencies and low temporal frequencies, just as they are in human vision (Burr & Ross, 1982; van Doorn & Koenderink, 1982; Nakayama, 1985). To achieve a constant error of speed estimation across speeds (Weber's law), the sensitivities of those detectors must be scaled logarithmically (Nover, Anderson, & DeAngelis, 2005). This induces an order across the space of prameters, such that the conditions of *isosensitivity* must be distributed as described by Kelly's surface and our results on apparent motion.

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F73 *685* V3A processes contour curvature as a trackable feature for the perception ofrotational motion

Peter U. Tse[1] (Peter.U.Tse@dartmouth.edu), Gideon P. Caplovitz[1]; [1]Dartmouth College

In a remarkable set of visual illusions, an object appears to change the angular velocity of its rotation as its shape changes. We (Caplovitz et al, VSS 2004, SFN 2005) have argued that contour curvature (CC) is a vital cue for the analysis of both form and motion that underlies this effect. Using fMRI, we localized the neural correlates of CC for the processing and perception of rotational motion. We found that the blood oxygen level dependent (BOLD) signal in retinotopic area V3A varied parametrically with the degree of CC. Control experiments ruled out the possibility that these modulations resulted from changes in the area of the stimuli, the velocity with which contour elements were translating, and perceived angular velocity. Based on the results of these experiments, we conclude that neuronal processing in area V3A serves to analyze CC as a trackable feature for the perception of rotational motion, and that this form-based feature is used to determine the speed and direction of motion. This raises the possibility that V3A functions in part as an area that processes form, not to solve the 'ventral problem' of determining object shape, but in order to solve the 'dorsal problem' of what is going where. We predict that this area will respond to the continuous motion of other contour discontinuities as well, such as junctions, corners, and terminators.

F74 *686* Dynamic evolution of motion perception

Bhavin Sheth[1,2] (brsheth@uh.edu), Ryota Kanai[3], Shinsuke Shimojo[3]; [1]Electrical and Computer Engineering, University of Houston, [2]Center for Neuroengineering and Cognitive Sciences, University of Houston, [3]Biology, California Institute of Technology

In visual perception, position and motion interact reciprocally. While motion is a construct consisting of a series of sequential changes in position, the perception of motion is considered to be more than just a series of changes in the perceived stimulus position. To investigate the evolving process of motion percept starting from the onset of motion, we had observers detect a small transient gap (13 ms long) within an otherwise smooth motion sequence. Observers were highly sensitive to a gap that occurred early in the motion (< 200 ms from motion onset). However, their sensitivity to detect the gap deteriorated as the motion continued (> 300 ms), indicating perceived motion became smoother and filled in over the course of motion. Moreover, the same temporal pattern of decline in detection performance was observed for transient change in shape or color. Experiments suggest that motion blur does not account for the effect, as blur has different temporal characteristics, and blur decreases, not increases with time. Our results together imply that the visual system processes a moving stimulus initially as a series of snapshots, but then gradually develops a holistic percept of motion as the motion continues. Once the motion system is sufficiently activated, stimuli presented at different times begin to be integrated into a single, coherent entity. Our results therefore suggest perception of object motion begins as a series of discrete, unintegrated snapshots in a way akin to that of an akinetopsic patient.

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F75 *687* Apparent speed increases at low luminance

Maryam Vaziri Pashkam[1] (mvaziri@fas.harvard.edu), Patrick Cavanagh[1]; [1]Vision Sciences Lab., Harvard University

Several visual attributes have been shown to change the perceived speed of moving objects regardless of their real speed. In this study we investigated whether changing the mean luminance of a rotating radial grating affects its perceived rotation speed. The stimulus was a circular disk with 5 radial black spokes on a white background, rotating around its center. A two-interval speed matching procedure was used. In the first interval, subjects viewed the disk at a low luminance level (1 cd/m2), rotating at one of three test speeds (4.2, 8.3, and 12.5 Hz). In the next interval, subjects viewed the same grating at high luminance (60 cd/m2) and adjusted its speed until it matched the apparent speed from the first interval. A control was also run with both intervals at high luminance. The results show that the apparent speed of a 8.3 Hz test viewed at low luminance was matched to a higher speed (10.8 Hz, a 30% speed up) at high luminance. The effect was smaller at 12.5 Hz (10% speed up at low luminance compared to high) and absent at 4.2 Hz. Results with gratings having fewer spokes suggested that the effect was specific to temporal frequency rather than rotational velocity.

F76 *688* Perceived speed of intermittently occluded motion

Scott N J Watamaniuk[1] (scott.watamaniuk@wright.edu), Emily L Blaser[1]; [1]Wright State University

Intermittent occlusion has little effect on the detection of a target moving in a fixed direction embedded in random motion noise (Watamaniuk & McKee, 1995) but the perceived speed of such a target may be consistently underestimated (Hecht et al., 2002). The present study sought to determine whether this perceptual speed reduction is due to the occlusion per se or to poor local motion signals.In each trial, an observer saw a moving target spot that was intermittently occluded and then a moving target spot that was constantly visible. Target direction in the first interval was randomly selected to be leftward or rightward while that in the second interval was the opposite. The constantly visible target moved at 6°/sec while the intermittently occluded target moved at one of five speeds centered on 6°/sec. The observer's task was to judge which stimulus moved faster. The duration of the visible and occluded segments were varied systematically and independently between 20-140 msec to create 26 different stimulus conditions. Total duration of all stimuli was set so that the observer saw, on average, 400 msec of motion. Perceived speed and speed discrimination thresholds were computed from the psychometric functions for each visible/occluded duration condition.The data show that both speed discrimination and perceived speed varied inversely with visible segment duration, but show little relationship with occlusion duration. These results suggest that it is the integrity of the visible local motion signals that determines the accuracy and precision of the speed percept.

F77 *689* SALIENCY FROM ORTHOGONAL VELOCITY COMPONENT IN TEXTURE SEGREGATION

Clara Casco[1] (clara.casco@unipd.it), Alba Grieco[2], Enrico Giora[3]; [1]Department of Psychology, University of Padova, [2]Department of Psychology, University of Padova, [3]Department of Psychology, University of Padova

We show that a moving target line, more–vertical than 45°-oriented background lines, pops-out (d'=1.2) although it moves at the same speed of background elements and although it is invisible in static presentation (d'=. 5). We suggest that the moving more-vertical target is more salient because the motion system responds to the orthogonal-velocity-component (V?= Äd/Ät sinè) that is larger for the more-vertical target than for distracters.However, motion does not produce high d' when the target is more horizontal than background (d'= .6). This result is not expected if saliency resulted from the sum of saliency of orientation and motion independently coded but is instead predicted. A line length effect on the moving target saliency also suggests that V? is extracted on the whole line and this operation is facilitated by line length in the same way for more-vertical and more-horizontal targets.Altogether, these results demonstrate that speed-based segmentation operating on V? not only affects speed and direction of motion discrimination, as previously demonstrated, but accounts for high saliency of image features that would otherwise prove undetectable of the basis of orientation-contrast.

F78 *690* The effect of contrast variations on the perception of Glass patterns

Charles C.-F. Or[1] (cfor@yorku.ca), Sieu K. Khuu[2], Anthony Hayes[2]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada., [2]Department of Psychology, The University of Hong Kong, Pokfulam Road, Hong Kong, China.

The perception of global structure of a static concentric Glass pattern is difficult, but not impossible, when its dot-pairs are of opposite polarity (see, e.g., Badcock, Clifford, & Khuu, 2005). We investigated whether the addition of motion signals enhance extraction of local orientation from opposite-polarity dot-pairs. The stimuli were random-dot patterns (radius: 14 deg visual arc) consisting of 200 dot-pairs (dot width: 5 min; length of pair: 20 min) orientated along circular trajectories, or at random orientations, on a background at 45.5 cd m^{-2} luminance. For each dot-pair, one dot was always light increment (90.9 cd m^{-2}), and the other was varied over conditions in the range between 0.0718 cd m^{-2} and 90.9 cd m^{-2} (i.e., Weber contrast from approx. -1 to 1). The dot pairs were either stationary (static condition), or randomly re-positioned at a rate of 17 Hz (dynamic condition) in a 1.06 s stimulus presentation. The observer's task was to identify the interval containing the circular structure in a temporal two-interval forced-choice procedure. The detection threshold for each contrast difference within the dot-pair was determined by an adaptive staircase. The results showed that perception of global structure is more salient with dynamic than with static Glass patterns regardless of variations in contrast, and for dynamic presentations salience improvement was greater for opposite-polarity than for same-polarity patterns. These findings suggest that motion processing mechanisms are more capable than form processing mechanisms in tolerating contrast differences for the perception of global structure.

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F79 *691* Anti-Glass Patterns and real motion: same or different mechanisms?

Maria Michela Del Viva[1,2] (michela@in.pi.cnr.it), Monica Gori[3,4]; [1]Università di Firenze, Dipartimento di Psicologia, Firenze Italy, [2]Istituto di Neuroscienze CNR , Pisa, Italy, [3]Università di Genova, DIST, Genova, Italy, [4]IIT, Italy

A succession of uncorrelated anti-Glass Patterns, composed by dot pairs with opposite luminance polarity, elicits a clear perception of motion in the direction of the white dot of the pair. This effect is due to a delayed perception of black dots with respect to whites (Del Viva et al., VSS 2004). Given the real motion information carried by anti-glass patterns, here we compared it to real motion perception. We measured coherence sensitivities to both stimuli by manipulating several parameters (luminance, dot distance, duration) and found the same behavior in real motion and anti-glass patterns. We also found that motion induced by anti-glass patterns annuls real motion, presented simultaneously in the same display but moving in opposite direction, when the coherence of the two stimuli is comparable. By lowering contrast of one of them, motion toward the stimulus with higher contrast prevails. This suggests that, like real motion (Morrone et al., Nature 1995), anti-glass pattern are processed at two different stages: the first contrast dependent and the second motion dependent. Our data indicate also that anti-glass patterns and real motion interact at low level, suggesting similar mechanisms of analysis.

F80 *692* **The effect of eccentricity on detection of a moving object by a moving observer.**

Constance S. Royden[1] (croyden@mathcs.holycross.edu), Erin M. Connors[1]; [1]College of the Holy Cross, Worcester, MA

To detect an object moving with respect to stationary items in a scene, an observer moving in a straight line must identify the object whose image motion differs from the radial motion pattern of the images of stationary items. We tested whether the ability to detect a moving object varies with its distance from the center of the radial pattern (the focus of expansion, or FOE). In each trial, observers viewed a scene consisting of 25 white circles moving in a radial pattern on a black background. In half the trials the target circle moved with some angular deviation from the radial pattern. Observers pressed a key to indicate whether or not this target circle was present in a trial. We measured the percentage of correct responses for angular deviations ranging from 8 to 40 deg and target positions of 2.5, 5.0 or 10.0 deg from the FOE. For 6 observers, the average angular deviation threshold for detection was 25.7, 14.9 and 12.3 deg for the 2.5, 5.0 and 10.0 deg eccentricities, respectively. The thresholds for the 2.5 and 5.0 deg eccentricities were consistent with an error in localizing the FOE of about 1.3 deg, similar to the accuracy with which humans judge the location of the FOE. This suggests that error in locating the FOE may be one factor limiting the ability to identify moving objects for small eccentricities. It is likely that speed also plays a role, because images move faster at larger distances from the FOE.

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F81 *693* **The effects of age an attention on the perception of motion**

Maureen J. Reed[1] (mreed@ryerson.ca), Lauren Weingarten[2], Todd Cunningham[3]; [1]Ryerson University, Toronto, Ontario, [2]Ryerson Univesity, Toronto, Ontario, [3]OISE, University of Toronto, Toronto, Ontario

Purpose: Deficits of motion perception have been reported for older adults. Here we examine the effects of attention and aging on the detection of motion and judgments of motion direction. Methods: Twenty-one older and twenty-one younger adults were asked to view a fixation cross and determine the direction and location of motion in a single dot moving in one of eight directions at one of eight equally distant peripheral locations. In addition, attention was reduced in some conditions by having subjects perform a subsidiary letter naming task. Results: In comparison to younger adults, we found that older adults had difficulties determining the direction of motion and these difficulties were exacerbated by reductions in attention. However, both older and younger adults were able to detect the location of motion targets and perform the letter naming task with accuracy. Conclusions: We suggest that deficits in naming motion direction found in older adults may result from reductions in general processing and attention deficits that lead to poor focus on object detail.

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F82 *694* **The spatial resolution of visual attention in a motion direction discrimination task.**

Ryo Sasaki[1] (r-sasaki@med.juntendo.ac.jp), Takanori Uka[1]; [1]Department of Physiology 1, Juntendo University School of Medicine

Crowding refers to a subject's difficulty in identifying a target in the presence of distracters. As a first attempt towards identifying the neural mechanism of crowding, we investigated perceptual crowding using a random-dot kinematogram. Subjects were required to report the direction of moving dots (up or down) within a center patch (3 deg) of a center/surround display presented 10 degrees to the left of fixation, and to ignore the dots in the surround. Motion coherence of the dots in the center patch, as well as surround size (3, 4.5, 6, 9, 12 deg) varied randomly across trials. Motion coherence of the surround was always set at 0 percent. For each of 11 subjects, we calculated direction discrimination thresholds (at 82% correct) at each surround size. Consistent with crowding, thresholds increased when surround size was 4.5 and 6 degrees, compared to those with no surround. Surprisingly, however, thresholds started to decrease when surround size was 9 and 12 degrees, relative to 6 degrees. Our results show that the spatial resolution of motion direction discrimination improves when the area we have to ignore exceeds a defined size. We propose that the improvement of spatial resolution with increased surround noise can be explained by the inhibitory receptive field of a motion area such as the middle temporal area (MT).

F83 *695* **Modulation of local and global motion responses by sustained visual attention**

Anthony M. Norcia[1] (amn@ski.org), Ying Han[1], Mark W. Pettet[1], Vladimir Y. Vildavski[1], Alexander R. Wade[1], L. Gregory Appelbaum[1]; [1]The Smith-Kettlewell Eye Research Institute

Previous fMRI studies have shown that global motion responses in human MT+ depend on attention. Global motion responses in areas such as MT+ are fed by local motion detectors in first-tier visual areas. Here we used high-density EEG recording and dynamic optic flow stimuli to determine if attentional modulation has comparable effects at these two levels of processing. EEG recording allowed us to monitor directly both dot-related, local motion responses as well as global motion responses in several visual areas that were defined separately by functional MRI mapping.Responses were recorded when attention was directed to optic flow (during discrimination of changes in the coherence of the global motion: Motion task) or when it was diverted to a foveal letter discrimination task (during detection of a randomly oriented letter T in a matrix of randomly oriented L's: Letter task). The global-flow-related EEG response is about a factor of two smaller in the Letter task than in the Motion task. The local motion response was largest when flow was present and task relevant and was smallest when flow was absent and motion was task irrelevant. Attentional modulation of dot-related activity took two forms: a gain enhancement in hMT+ and a timing change in a range of areas extending from roughly the IPS to V1. The observation that attentional modulation of local motion responses is strongest in the presence of flow, suggests the presence of top-down influences of both flow and attention. Supported by EY015790 and the Pacific Vision Foundation.

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Poster Session G

Sunday, May 7, 2006

Attention: Spatial, Object, and Feature Selection (696-711, 162) Object Recognition II (713-730), Motion and Depth (731-742), Motion Integration (743-750), Stereopsis (751-763), Face Perception: Neural Mechanisms (764-781)

Poster Session: 4:15 - 7:15 pm ***Municipal Auditorium***
Author presents: 5:30 - 6:30 pm

Attention: Spatial, Object, and Feature Selection

G1 *696* Individual Differences in Attention Capture

Michael S. Ambinder[1] (ambinder@casper.beckman.uiuc.edu), Daniel J. Simons[1]; [1]University of Illinois, [2]University of Illinois

The sudden appearance of a new object in a search display is thought to capture attention in a stimulus-driven fashion. That is, people tend to search the onset location first, even if it does not predict the search-target location. Our previous research (VSS-2005) showed that attention capture by an onset is less robust than previously thought, and that minor variations on seemingly irrelevant task parameters modulated capture. Here we examine whether individual differences in experiences or personality might explain variability in capture. We hypothesized that extensive experience with visual tasks requiring divided attention across regions of a display might attenuate capture. 112 participants completed surveys on their TV-watching and video game experience and their tendency to internalize or externalize stimuli. They then performed a visual search task with an abrupt onset in the display, and we examined whether capture was modulated by their experience, personality, and motivation (rated by the experimenter). Neither the amount of TV watched nor the tendency to internalize or externalize stimuli had an effect on capture. However, female subjects were more likely to exhibit capture than male subjects. Moreover, previous video game experience appeared to modulate capture, with puzzle-game players exhibiting more capture and real-time strategy game players showing less capture. Participants who appeared more highly motivated to participate in the experiment also showed less capture. These findings show that individual differences can mediate attention capture and that these differences might contribute to variations in the extent of capture across experiments.

G2 *697* Effects of Attention on the Spatial Extent of Crowding

Devin K Brady[1] (dkbrady@bu.edu), Jascha D Swisher[1], David C Somers[1]; [1]Boston University

The recognition of a peripherally presented target letter is impaired by the presence of nearby flanking distractors. The spatial extent (or "critical spacing") of this crowding effect scales with target eccentricity. The critical spacing has been suggested to reflect either the spatial resolution of attention, or alternatively low-level cortical scaling properties that are not subject to cognitive control. However, previous work on crowding and attention has yielded mixed results, with some studies showing (e.g. Van der Lubbe and Keuss 2001) and others failing to show (e.g. Nazir 1992) attentional effects, leaving this issue unresolved.To help address this question, we have adapted a simple endogenous precueing paradigm. Briefly presented low-contrast letters flanked by higher contrast distractors are displayed parafoveally in one of two possible locations. An arrow cue indicates the position of the upcoming target with 75% validity. Using a performance measure, we find that the effects of cue validity vary both with flanker position and training: in highly trained subjects, cue validity has little effect; conversely, in relatively naive subjects we find the strongest cueing effects with closely spaced flankers. This finding reconciles several apparently conflicting prior results, and suggests a strong perceptual learning component in the identification of crowded stimuli.

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G3 *698* Is there a "spotlight reflection" during covert attention?

Luiz Henrique M. Canto Pereira[1] (canto@usp.br), Ronald D. Ranvaud[1]; [1]Department of Physiology and Biophysics, Institute of Biomedical Sciences, University of São Paulo, Brazil

Covert attention is the ability to select a certain location of the visual field, without eye or head movements, and give it priority in perceptual processing (Carrasco et al. 2002). In a series of experiments we measured RTs in both overt and covert attention tasks and data were analyzed through geostatistical methods.In Experiment 1 participants oriented their attention to the center of the screen coincident with the fixation point (overt attention). We showed that participants indeed focused their attention toward the center of the screen, with spatial distribution similar to the topography of cone distribution of the human retina (Curcio et al. 1990).Experiments 2 and 3 were designed to assess the spatial patterns of covert attention to left and right, respectively. Results showed that participants were able to direct attentional focus away from their gaze and toward areas of the computer screen they should attend, thus characterizing covert attention. The focus of attention on the left hemi-field, i.e. right hemisphere (experiment 2) was more evident than the contra-lateral experiment, these data are consistent with hemispheric asymmetries reported in the literature.Surprisingly, in both experiments 2 and 3 there was an almost symmetrical contra-lateral facilitation (slightly displaced upward). This facilitation was not as evident as the focus of covert attention, but was clearly distinguishable from the surroundings. These results suggest a top-down inter-hemispheric modulation of attention, which is more evident in the right hemisphere. Here a "spotlight reflection" metaphor is proposed to describe this phenomenon.

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G4 *699* Exploring how Object-based Attention Interacts with Uniform Connectedness and Self-Splitting Figures

Hope I. Denney[1] (hopie@uga.edu), James M. Brown[1]; [1]University of Georgia

Purpose: Uniform connectedness (UC) is an organizing principle thought to underlie the segregation of the visual field into figure/ground and ultimately into separate objects. At what point does object-based attention

begin to have an influence as processing progresses from UC regions to objects? To address this question we explored a boundary condition of the object advantage utilizing a cuing paradigm with a self-splitting figure that was a single UC region. Would object-based attention treat the UC region as a single object, or separate objects, as the splitting figure was perceived? *Method:* The self-splitting figure was perceived as two pairs of "objects," rectangles diagonally overlapping elongated ovals. In separate sessions, participants started a trial when the rectangles were perceived in front, and when the ovals were perceived in front. Cues and targets appeared at four equidistant positions in the regions where the rectangles and ovals overlapped. On 10% of the trials no target appeared. Cues were valid on 70% of the trials and invalid on 20%, with half the invalid trials requiring a within-object shift and half requiring a between-object shift of attention. RT to target onset was measured. *Results:* RTs were always faster on valid than invalid trials. Invalid within- and between-object RTs were the same. *Conclusions:* Although our single UC region stimulus was parsed perceptually into separate objects, object-based attention treated it as a single UC region/object indicating the representation associated with the perceptual experience may be different from that which object-based attention operates on.

G5 *700* The distribution of visual attention: evidence based on temporal order judgment (TOJ) task.

Cesar Galera[1] (algalera@usp.br), Mikael Cavallet[1], Michael von Grünau[2], Guilherme Caserta[1], Afroditi Panagopoulos[2]; [1]FFCLRP-DPE, University of São Paulo at Ribeirão Preto, Brazil, [2]Department of Psychology & CSLP, Concordia University, Montreal, Que, Canada

Purpose: The focus of selective attention can be concentrated in areas with different size and specific shapes. In this study we employed a temporal-order-judgment task (TOJ) to explore the differences in the concentration of attentional resources inside and outside the attended area.

Methods: The method of constant stimuli was used in two experiments. Subjects' task was to judge which of two sequential letters ("F" or "J") was presented first (Experiment 1, 2A) or second (Experiment 2B). Randomly, one of the letters was presented inside an area delimited by a frame, an outlined rectangle (6.4^o x 1.1^o). On each trial the frame was presented horizontally or vertically around the fixation point for 100 ms. One of the letters was presented inside and the other outside the frame. Stimulus onset asynchrony (SOA) between the first and second letter varied by 20, 30, 60, 100 and 200 ms.

Results:. In Exp. 1 the point of subjective simultaneity (PSS) was -43ms when the first letter was presented inside the frame and 35 ms when presented outside. In Exp 2, mean PSS values were -28 ms and 33 ms respectively, and did not differ from zero when the frame was absent.

Conclusion: The stimulus presented inside the frame had a clear advantage in relation to the stimulus presented outside, independent of whether the subject judged the stimulus as appearing first or second. The results suggest that attentional resources are more concentrated inside a delimited area than outside it.

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G6 *701* Object-Based Attention Does Not Automatically Spread Throughout An Object

Adam S. Greenberg[1] (agreenb@jhu.edu), John T. Serences[2], Steven Yantis[1]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University, [2]Systems Neurobiology Lab-B, Salk Institute

The prevailing view of object-based attention holds that once any part of an object is attended, attention automatically "spreads" throughout the object. This view, which accounts for the same-object advantage in the two-rectangle spatial cueing paradigm (Egly et al., 1994), has been challenged recently (Shomstein & Yantis, 2002, 2004). We examined whether the effects of contingent attentional capture (Folk et al., 1992) are modulated by ignored distracters appearing on either a cued or uncued object. Displays contained a multicolored RSVP stream located at each of four rectangle ends. A central (Experiment-1) or peripheral (Experiment-2) 100% valid cue indicated the stream that would contain a red (green for half the subjects) target letter, which subjects identified. Two frames prior to target onset, a target-colored or nontarget-colored distracter could appear in one of two uncued locations (same or different rectangle). Robust contingent capture was observed in both experiments, but its magnitude did not differ for distracters on the same versus different objects. A control experiment ensured that our paradigm is capable of producing an object-based attention effect. Thus, when attention is directed with 100% certainty to a cued location, other locations on that object do not enjoy an attentional advantage. These data are consistent with priority-based theories of object-based attention (Shomstein & Yantis, 2002, 2004) in which the same-object advantage is a result of a predisposition to explore unattended parts of a currently-attended object when target location is uncertain. We conclude that object-based attention does not automatically spread throughout the object.

G7 *702* Selecting Multipart Objects: Is Uniformity Necessary?

Lauren N. Hecht[1] (lauren-hecht@uiowa.edu), Shaun P. Vecera[1]; [1]University of Iowa

What object properties warrant selection by object-based attention? Previous research has suggested that uniformity is required for object-based attentional selection (Watson & Kramer, 1999), yet non-uniform objects are encountered frequently. In the current experiments, we investigated the interplay between uniformity and part-boundaries, as well as their effect on object-based attentional selection. Specifically, we asked if attention can select non-uniform objects under appropriate circumstances. If so, then objects with regions that are dissimilar in color may be selected as easily as uniform objects when uniformity changes occur at the part-boundary. Using a modified object-based attention task (see Egly et al., 1994; Vecera, 1994), observers viewed two outline rectangle stimuli, each with a different contour color on either half (Experiment 1). No object-based attention effects were found, indicating that object-based attention did not select the non-uniform rectangles. To address the potential interplay between uniformity and part-boundaries, we used two-part objects (hourglass-shaped objects) and manipulated surface uniformity. In Experiment 2, strictly uniform surfaces were used to ensure object-based attention could select these hourglasses. For the remaining experiments, the hourglasses had a different color on either half with the change occurring at the part boundary (Experiment 3), with the color change shifted off the part-boundary (Experiment 4A), or with the part-boundary shifted and the color change occurring precisely halfway through the objects (Experiment 4B). Object-based effects were only found for Experiment 2, suggesting that attention can only select non-uniform objects when the change occurs at a part-boundary.

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G8 *703* On-line updating of object representation: Same-object effect obtained from last-minute amodal completed objects

San-Yuan Lin[1] (d94227106@ntu.edu.tw), Su-Ling Yeh[1]; [1]Department of Psychology, National Taiwan University

In the double-rectangle cueing paradigm of Egly, Driver, Rafal (1994), one of the two oblong rectangles is cued and subsequently a target appears. Reaction time benefit is observed when the target appears on the same object as the cue, compared to when it appears on a different object (i.e., the same object effect). In this study, we manipulate the cue display and the display(s) afterwards to demonstrate that the target display rather than the cue display is crucial for object-based selection. The display was modified from that of Egly et al. by using four small rectangles during the cue presentation and introducing an occluder at different times after the cue display or concurrently with it. The occluder was presented to induce

amodal completion among the four rectangles to form two oblong rectangles as in Egly et al. Our results show that the same-object effect was obtained when the occluder was presented 100 ms before the target presentation, and when the target appeared together with the occluder. The observation that there is a same-object effect when an object representation is changed, but not when an occluder is not presented, points to the importance of an on-line updating process during object-based selection. The results are discussed in the context of the three hypotheses of the mechanism of object-based attention: the spreading, prioritization, and shift hypothesis.

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G9 *704* The spatial distribution of subjective time dilation

Joshua J. New[1] (joshua.new@yale.edu), Brian J. Scholl[1]; [1]Yale University

Time can appear to slow down in certain brief real-life events -- e.g. during car accidents or critical moments of athletes' performances. Such time dilation can also be produced to a smaller degree experimentally, e.g. when viewing an oddball stimulus in a sequence of otherwise identical stimuli (Tse et al., 2004, *P&P*). In this project we explored the spatial distribution of time dilation: Does time expand only for the oddball events themselves, or for all events occurring at that time? Observers viewed a sequence of centrally displayed shapes which appeared one at a time, and had to compare the duration of an intermittently appearing green target to the standard duration of the other randomly-colored nontarget shapes. A peripheral gray distractor disc was presented along with each shape for a shorter, fixed interval. Each distractor disc was either static or underwent a salient ('oddball') transformation, such as expanding in size or orbiting the central shape. With static distractors, targets' durations were accurately perceived. However, targets which were accompanied by oddball distractors were perceived to last considerably longer than their true durations, and in fact could not be distinguished from the objectively longer nontarget duration. Time dilation is thus not tied to oddball stimuli per se, and may be an invariably global experience. Additional experiments addressed whether this result is mediated via a spatial gradient of attentional enhancement, and the degree to which it is augmented by incorporating the target and distractor into a single object.

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URL: http://www.yale.edu/perception/

G10 *705* Does the strength of the attentional focus depend on the size of the cued area?

Afroditi Panagopoulos[1] (panag@vax2.concordia.ca), Michael von Grünau[1], Cesar Galera[2], Laura Ivan[1], Mikael Cavallet[2]; [1]Department of Psychology & CSLP, Concordia University, Montreal, Que, Canada, [2]FFCLRP-DPE, University of São Paulo at Ribeirão Preto, Brazil

Purpose: Using an exogenous cue, selective attention can be applied to a particular area in the visual field. It has been reported that in certain situations the efficiency of processing inside the attended area is inversely related to the size of the area; a smaller cue size leads to a stronger cue effect. This study investigated the effect of the size of the cue and the SOA between cue and test stimuli using three measures (simple RT, search RT and Temporal Order- TO). **Methods:** Peripheral cues were a briefly flashed black outline circle, always with central fixation. As a control, the task was also done without a cue. For RT, the test stimuli (either 1 target alone, or 1 target and 3 distracters) were presented inside or outside of the cued region and participants had to report the orientation of the target. For TO, observers viewed two small black circles, one inside the cue and one outside and had to decide which one appeared first (2AFC). **Results:** Though cue presence always led to faster processing, the cue-size effect was not universally present. For simple RT and TO, we found cue-size effects that depended on SOA. **Conclusion:** At least from our measures, the cue size effect is not robust. It depends on the task and the SOA.

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G11 *706* Combined Effects of Spatial and Feature-Based Attention in Human Visual Cortex

Melissa Saenz[1] (saenz@caltech.edu), Geoffrey M Boynton[2], Christof Koch[1]; [1]Caltech, Pasadena CA, [2]The Salk Institute, San Diego CA

Spatial and feature-based attention are known to modulate cortical visual responses, but little is known about how these (or other) forms of attention interact when combined. Using fMRI in humans, we measured the individual and combined effects of spatial and feature-based attention. Subjects (n=5) viewed two circular apertures of moving random dots presented to the left and right of central fixation. The *test* side had one field of dots moving either upward or downward. The other side had two overlapping fields of dots moving upward and downward. Subjects performed a threshold-level speed discrimination task on one of the three dot fields at a time. We measured the modulation in the response to the *test* field under three attention conditions. In the spatial condition (S), attention alternated between the test field and the field with the same motion direction on the other side (block design). In the feature-based condition (F), attention alternated between the fields with the same and opposite motion directions both on the other side. In the S+F condition, attention alternated between the test field and the field with the opposite motion direction on the other side. In areas V1, V2, V3, V3A, V4, and MT+, the response modulation caused by changing both the attended location and the attended feature (S+F) equaled the sum of that caused by changing the attended location (S) or the attended feature (F) alone. Thus, spatial and feature-based attention mutually reinforce their effects in the earliest stages of cortical visual processing.

G12 *707* The joint influence of space- and feature-based attention on visual perception

John Serences[1] (serences@salk.edu), Geoffrey Boynton[1]; [1]Salk Institute for Biological Studies

Directing attention to a peripheral location increases the firing rate of neurons with receptive fields at that location, effectively boosting the gain of objects appearing within the attended region of space (space-based attention, SA). In addition, directing attention to a visual feature (direction of motion, color, etc.) increases the firing rate of all neurons tuned to the attended feature, independent of the neuron's spatial receptive field (feature-based attention, FBA). While both SA and FBA have been studied extensively in isolation, little work has focused on understanding how SA and FBA combine to support efficient visual processing. In the present study, subjects performed a two-interval forced choice task in which they were cued to attend to a peripheral location, to a direction of motion, or to both. Each interval contained four random-dot apertures (200ms exposure, 200ms gap); one of the apertures contained correlated motion during either the first or the second temporal interval (one of four possible directions). Accuracy was higher overall when the cue was valid compared to when the cue was invalid (when the cue indicated incorrect location and/or direction motion). Moreover, cueing effects were largest when both the target location and the target feature were cued, slightly smaller when only the target location was cued, and smallest when only the feature was cued. The results support models in which the effects of SA and FBA combine to jointly influence the representation of attended stimuli in the visual field.

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G13 *708* The role of selective visual attention in the formation of visual afterimages: Experimental data and model simulations

Joshua L Wede[1] (jwede@purdue.edu), Gregory Francis[1]; [1]Purdue University

Suzuki & Grabowecky (2003) reported that a negative afterimage appeared later and was weaker when attention was focused on the inducing stimulus. We explored the effect of attentional focus on afterimages formed by a sequence of two inducing stimuli. After viewing two successive orthogonal bar gratings, observers frequently report an afterimage of

the first grating. We explored the effect of directing attention on the first stimulus (S1 - vertical bars) and the second (S2 - horizontal bars) by measuring the proportion of reported vertical afterimages. Subjects either attended to a feature of the inducing gratings (bar changing colors) or attended to centrally presented, rapidly changing numbers. Results show that when subjects attended features of S2, they reported a higher percentage of vertical afterimages. Thus, attentional focus on the inducing stimuli increased afterimage strength. Both sets of experimental results were interpreted in terms of Grossberg's FACADE model (Grossberg, 1994). In this model, an afterimage results from interactions between color complement after-responses from a Feature Contour System (FCS) and orientation after-responses from a Boundary Contour System (BCS). Previous results, and the current experiment suggested attention enhances signals in the BCS. With negative afterimages, increasing attention on the BCS signals leads to a mismatch between orientation after-responses and color after-responses, delaying afterimage appearance. In the two-stimulus case, attentional focus on S2 increases the strength of orientation after-responses that match the arrangement of color after-responses generated by the S1. Model simulations demonstrate that the model explains both sets of data.

G14 *709* Contingent Attentional Capture Occurs Only For Irrelevant Stimuli That Can Be Consciously Perceived

Chien-te Wu[1,2] (cvw3@duke.edu), Daniel H. Weissman[1,3], Marty G. Woldorff[1,3]; [1]Center for Cognitive Neuroscience, Duke University, [2]Department of Psychological and Brain Sciences, Duke University, [3]Department of Psychiatry, Duke University

Contingent attentional capture refers to an involuntary shift of spatial attention toward an irrelevant stimulus for it resembles relevant stimuli that are important for achieving behavioral goals. Here, we investigated whether attentional capture can be elicited by stimuli that never reach conscious awareness. Subjects performed a delayed match-to-sample task, which involved maintaining a centrally presented color patch in working memory. After the delay period, subjects indicated whether a test stimulus had the same color as the sample stimulus. During the delay period, participants made a speeded response to a probe stimulus presented to either the left or right visual field. Just before the probe, however, a pair of colored distracters was presented in the same left and right visual field locations where the probe could appear. In some trials, one of these distracters had the same color as the sample stimulus being held in working memory while the other had a different color. We manipulated whether the distracters reached conscious awareness by changing their presentation duration and by applying meta-contrast masks. As in prior studies (e.g., Downing, 2000), in unmasked trials we observed contingent attentional capture. Specifically, response times were faster for probes that occurred in the same location as the same-colored distracter than for probes that occurred in a different location. Of importance, this effect was eliminated for masked stimuli. We conclude that irrelevant items resembling behaviorally-relevant stimuli involuntarily capture spatial attention, but only if the irrelevant items can be consciously perceived.

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G15 *710* Comparing the effectiveness of spatial and feature-based attention

Taosheng Liu[1,2] (tl23@nyu.edu), Sean T. Stevens[1], Marisa Carrasco[1,2]; [1]Dept. of Psychology, NYU, [2]Center for Neural Science, NYU

Purpose: Visual attention can select locations, features, and objects. However, the relative contributions and the interactions among these selection mechanisms are less clear. One issue concerns the relative effectiveness of these mechanisms, which has been difficult to compare, given the different nature of the studies in the literature. Here we tested the effectiveness of space– and feature– based orienting in a single experiment with identical stimuli and task.Method: Moving dot patterns were presented in two apertures, one to the left and one to the right of fixation. Within each aperture, two superimposed dot patterns moved in opposite directions (leftward and rightward). On different trials, all dot patterns either moved at constant speeds or one dot pattern increased its speed briefly. Observers detected the presence of the speed increment (target), which appeared on half of the trials. Arrow cues were presented briefly 500 ms prior to the dot patterns. Cues pointed either to the left, to the right, or both directions (neutral). In separate blocks, the unidirectional cues either indicated the location or the direction of the target with a 100% validity. Attentional effect was measured as the performance difference between the unidirectional cues and the neutral cue.Results: Compared to the neutral cues, both the location and direction cues increased detection rate (d'). Furthermore, the attentional benefit for the two types of cues was equivalent. These results suggest that attention is a flexible mechanism allowing us to efficiently select task-relevant information based on either spatial or feature dimensions.

G16 *711* On the interaction between covert attention and contrast adaptation

Franco Pestilli[1] (fp302@nyu.edu), Jerry Viera[1], Marisa Carrasco[1,2]; [1]Department of Psychology and, [2]Center for Neural Science - New York University

Background: Transient (exogenous) attention automatically enhances contrast sensitivity at *valid-cue* locations and impairs it at *invalid-cue* locations, compared to a neutral condition (Pestilli & Carrasco, 2005). Contrast adaptation reduces contrast sensitivity to stimuli similar to the adapter. Here we investigated whether attention and adaptation act on similar neural mechanisms when processing contrast signals.Methods: We assessed accuracy in a 2AFC orientation-discrimination task for Gabors at 8 contrast levels (1-100%). There were 2 adaptation conditions and 3 attentional conditions. Adaptation: Observers adapted for 70s to either two 100%- or 0%-contrast vertical Gabors (counterphase modulated at 7.5Hz) in opposite hemifields along the horizontal meridian. Attention: Before each of the 20 test trials an uninformative precue directed transient attention to one of the Gabors. A response cue appeared after stimuli offset indicating the target Gabor. On *valid-cue* trials the response-cue pointed to the precued Gabor. On *invalid-cue* trials it pointed to the other Gabor. In the remaining trials the precue was presented at fixation and the response cue indicated either stimulus with equal probability (*neutral-cue*). Results: Adaptation decreased contrast sensitivity for all cue conditions. Transient attention increased contrast sensitivity at *valid-cue* locations and decreased it at *invalid-cue* locations in both adaptation conditions. The effects of transient attention were similar in magnitude in both adaptation conditions. Attention counteracted contrast adaptation: sensitivity for the adapted stimulus following a *valid-cue* was similar to that for the non-adapted stimulus following a *neutral-cue*. These results suggest that attention and adaptation tap into similar mechanisms.

712 Abstract 712 moved to Attention: Benefits of Selection and Modulation talk session, May 9, 8:00 am.

G17 *162* Change detection in pigeons: Stimulus attributes and binding

Edward A. Wasserman[1] (ed-wasserman@uiowa.edu), Olga F. Lazareva[1], Steven J. Luck[1]; [1]Department of Psychology, University of Iowa

In a two-alternative forced-choice task, pigeons were trained to discriminate whether two successive displays containing four differently colored bars at four different orientations were identical or nonidentical. Different-trial displays were distinguished by three features: color, orientation, and location. That is, the second display involved bars of different colors, different orientations, and different locations on the screen. Pigeons learned this change-no change discrimination to high levels of accuracy. In the first series of tests, only one attribute (color, orientation, or location) was changed in the second display. In the second series of tests, two attributes were changed (color and location, color and orientation, or location and orientation). The results indicated that location was the most salient feature and that orientation was the least salient feature; moreover, changes

in two features produced more "different" responses than changes in single features. Finally, we conducted a series of tests where different-trial displays did not contain new values of the three attributes; instead, the values of the attributes were swapped among the objects. The results disclosed no evidence of feature binding.

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Object Recognition II

G18 *713* Shape-shifters: Visual judgment of similarity across shape transformations

Elan Barenholtz[1] (elan_barenholtz@brown.edu), Michael, J. Tarr[1]; [1]Brown University Dept. of Cog. and Linguistic Sciences

A single biological object, such as a hand, can assume multiple, very different shapes, due to the articulation of its parts. Yet we are able to recognize all of these shapes as examples of the same object. How is this invariance to pose achieved? Here, we present evidence that the visual system maintains a model of object transformation that is based on rigid, convex parts articulating at extrema of negative curvature, i.e., part boundaries. We generated pairs of jagged polygonal contours that were identical except for a single 'part' (an extruding segment of the contour) that pivoted across the two contours. The two contours – the 'base' and 'transform' – were both used to divide a polygonal shape into two halves resulting in four closed shapes. Similar to an 'Attneave egg' (Attneave, 1971), the figure and ground of the dividing contours was reversed across the two halves of the split shapes; under one figural assignment the difference between the 'base' and 'transform' contours corresponded to a convex region pivoting at concavities – i.e., a legitimate articulation – while under the other assignment it consisted of a concave 'hole' pivoting at convexities. In a 2AFC similarity task, subjects were much more likely to match the base shape to a transform when it corresponded to a legitimate articulation then when it didn't, even though the underlying contour transformations were identical in the two cases. These results suggest that the visual system maintains expectations about the way objects will transform, based on their static geometry.

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G19 *714* The Dynamics of Pattern Identification and Categorization

Martin Wiesmann[1] (martin@ini.phys.ethz.ch), Paul F.M.J. Verschure[1], Daniel C. Kiper[1]; [1]Institute of Neuroinformatics, ETH / University of Zurich

Whether identification and categorization of visual stimuli are supported by separate or identical neural circuits remains a matter of debate. Similarly, the dynamics of these processes are poorly understood: Does identification precede categorization, or vice-versa? To answer these questions, we measured how fast visual patterns are identified and categorized. In our identification task, subjects were initially trained to recognize a given pattern. In subsequent sessions, they had to indicate whether each of a series of patterns was identical to the learned pattern or not. In the categorization task, subjects trained with similar patterns defining an arbitrary category. They then had to indicate whether subsequently presented patterns belonged to the category or not. We measured accuracy and reaction times in both tasks. Performance improved during the first 3 to 4 sessions, then stabilized. While accuracy in both tasks showed similar dynamics with practice, the reaction times behaved differently: In the first session, the average reaction time for categorization was 716±193 ms, and 550±78 ms for identification. With training, categorization reaction times decreased more rapidly than in the identification task. Both types of reaction times then converged around 467 ms (500±81 ms categorization; 434±24 ms recognition). These results suggest that identification and categorization are two independent processes.

G20 *715* The time course of visual object detection and categorization

Michael L. Mack[1] (michael.mack@vanderbilt.edu), Alan C.-N. Wong[1], Isabel Gauthier[1], Thomas J. Palmeri[1]; [1]Vanderbilt University

Recent work by Grill-Spector and Kanwisher (2005) examined the time course of visual object recognition, contrasting accuracy at object detection, basic-level categorization, and subordinate-level identification across a range of image presentation durations. One intriguing result was that the time-course of object detection and basic-level categorization was identical, prompting them to subtitle their paper "As soon as you know it is there, you know what it is." This tight temporal coupling is consistent with a view that basic-level categorization may be an initial stage of object perception. An alternative view is that detection, categorization, and identification are perceptual decisions that can be made easier or harder, faster or slower, depending on a variety of task factors. Detection and categorization are both perceptual decisions dependent on a hierarchy of perceptual processing, but they are not associated with any particular stage of perceptual processing per se. In the present work, we decoupled the time course of detection and categorization through task manipulations. For example, inverted objects were categorized significantly less accurately than upright objects across a range of image presentation durations, but inversion had no significant effect on object detection performance. By contrast, upright objects were detected and categorized equally well across presentation durations, replicating Grill-Spector and Kanwisher. Object detection and categorization may be based on the same general mechanisms involved in perceptual decision making, but the difficulty of those perceptual decisions can be selectively manipulated. As soon as you know it is there, you may or may not know what it is.

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G21 *716* Behavioral sensitivity to novel object features can be modulated by high-level knowledge of function.

David A Remus[1] (remus@stanford.edu), Kalanit Grill-Spector[1]; [1]Department of Psychology, Stanford University

Recent models of visual object recognition (Hochstein & Ahissar, 2002; Bar, 2004) suggest that rapidly deployed, high-level processes may dictate or aid low-level, fine-scale visual analysis. To examine the effects of high-level knowledge on basic visual processes, we developed a training paradigm in which subjects were trained to categorize novel objects based on their constituent features while learning the functional properties of those features. Subjects studied two prototypical objects from separate categories (tools). During study, subjects were provided with a story regarding the practical use of each object and learned the specific function of each feature. For each category, half of the features were assigned functions that were essential to object usage (critical features), and half were assigned secondary functions (secondary features). Functional significance for a given feature was counterbalanced across subjects. Following study, subjects were tested for their recall of category names and the function of individual features. After this testing, subjects were briefly (100ms) presented with variants and rotated versions of the prototype objects. In some trials, a number of critical or secondary features (1, 2, or 3) had been removed. Subjects were asked to rapidly judge whether a test object belonged to one of the trained categories. Results (n=6, trials>3,000) indicate that subjects were significantly ($p<0.032$) less likely to categorize objects into one of the trained categories when critical features were missing, than when only secondary features had been removed. These findings suggest that high-level knowledge of object functionality may influence the representation of novel object classes.

G22 *717* The structure of three-dimensional object representations for regular and irregular shapes: Evidence from whole-part matching and repetition priming.

Irene Reppa[1] (i.reppa@swansea.ac.uk), Charles, E. Leek[2]; [1]Department of Psychology, University of Wales, Swansea, [2]Centre for Cognitive Neuroscience, School of Psychology, University of Wales, Bangor

How does the human visual system represent 3D shape? One hypothesis is that object shape is represented in terms of its volumetric components and their spatial configuration. Another hypothesis predicts that 3D shape is represented in terms of regions of edge contour corresponding to surfaces. Recently Leek et al (2005) showed that there is a performance advantage in whole-part matching for configurations of edge contour that corresponds to surfaces or volumetric components as opposed to nonvolumetric shape regions. In this study we examined the role of three types of shape primitives: volumetric components, surfaces and non-volumetric regions in the representation of geometrically regular and irregular 3D shape. In Exp.1 participants were required to match object parts to novel 3D objects and in Exp.2 to decide whether an object was familiar or not following an object related or unrelated prime. The results showed (i) better performance when edge contour corresponded to surfaces or volumetric components as opposed to nonvolumetric closed regions; and (ii) regular objects benefited from surface groupings corresponding to volumetric components, whilst irregular forms benefited from surface groupings regardless of whether they corresponded to a volumetric part or not. The results are discussed in terms of the surface-based model of 3D shape representation.

G23 *718* Infants' Indexing of Objects vs. Non-Cohesive Substances

Rebecca D. Rosenberg[1] (rosenber@wjh.harvard.edu), Susan Carey[1]; [1]Psychology Department, Harvard University

The mechanisms that subserve mid-level attentional processes in adults have been implicated in infant object representation. One theoretical issue in both literatures concerns what entities can be attended, indexed, and traced through space and time. The theory of object-based attention states that objects are privileged in this mid-level system. Previous work with adults (Scholl & vanMarle, 2003) and infants has provided evidence that entity tracking is disrupted by non-cohesion. Huntley-Fenner et al. (2002) and Chiang & Wynn (2000) have shown that 8- and 12-month old infants cannot trace the numerical identity of non-cohesive entities through occlusion. But theories of adult attention propose that attention can also be assigned to locations, or to perceptual features, suggesting that infants may be able to index distinct portions of non-cohesive entities if no tracking of individuals through time and/or occlusion is required. In the present study, 40 8-month-old infants were habituated to displays of either one or two portions of sand poured onto a stage, or to one or two perceptually similar solid piles lowered by a string onto a stage, and their looking time to the familiar vs. novel number of entities (once they were at rest on the stage floor) was measured. Infants did not distinguish one from two portions of sand; in contrast, they easily differentiated one from two solid objects. These results provide strong evidence for object-based attentional processes in infancy, with perhaps even stronger constraints on attentional selection than in adulthood. Objects (bounded, cohesive wholes) attracted indexes, whereas non-objects did not.

G24 *719* Independent processing of object form and surface properties

Jonathan S. Cant[1,2] (jcant@uwo.ca), Mary-Ellen Large[1,2], Lindsay McCall[1], Melvyn A. Goodale[1,2]; [1]Department of Psychology, University of Western Ontario, Canada, [2]CIHR Group on Action and Perception

Most investigations of object recognition have focused on the form rather than the material properties of objects. Nevertheless, knowledge of the material properties of an object (via its surface cues) can provide important information about that object's identity. In this study, we used Garner's speeded-classification task to explore whether or not the processing of form and the processing of surface properties are independent. In an initial form task, participants made length and width classifications. Participants were unable to ignore length while making width classifications, and were unable to ignore width while making length classifications. This suggests that length and width, which are two cues to object form, share common processing resources. In a subsequent surface-property task, participants made texture and colour classifications. Participants were unable to ignore colour while making texture classifications, and were unable to ignore texture while making colour classifications. This result in turn suggests that texture and colour, which are two characteristics of an object's surface, share common processing resources. Finally, in a combined task, we directly examined possible interactions between the processing of form and the processing of surface properties. In contrast to the findings with the other two tasks, participants were able to ignore form while making surface-property classifications, and to ignore surface properties while making form classifications. These behavioural results converge nicely with neuroimaging studies (Cant et al. VSS 04 & 05) showing that the form of objects and their surface properties are processed by relatively independent neural mechanisms.

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G25 *720* Stimulus Control in Categorization: An Application of the Bubbles Procedure

Daniel I. Brooks[1] (daniel-brooks@uiowa.edu), Olga F. Lazareva[1], Frédéric Gosselin[2], Philippe G. Schyns[3], Edward A. Wasserman[1]; [1]University of Iowa, [2]Université de Montréal, [3]University of Glasgow

Four pigeons were tested in concurrent basic-level (cars, chairs, flowers, or people; four-key forced-choice procedure) and superordinate-level (natural or artificial; two-key forced-choice procedure) categorization tasks. Prior research revealed dissociation between natural and artificial stimuli: the discrimination of cars and chairs was acquired faster at the basic level than at the superordinate level, but the opposite was true for people and flowers. This dissociation between natural and artificial stimuli appeared in later stimulus control tests (e.g., blurring and scrambling). The results presented here are derived from an application of "Bubbles" (Gosselin & Schyns, 2001), a statistical technique used to assess areas of the pictures that contained potent information to categorization. This analysis found specific areas of the stimuli that mediated task performance at both basic- and superordinate-levels of categorization with different types of stimuli.

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G26 *721* Hierarchical feature learning using nested self-organizing maps

Albert C. Lai[1] (AlbertLA@usc.edu), Bartlett W. Mel[1,2]; [1]Department of Biomedical Engineering, University of Southern California, [2]Neuroscience Graduate Program, University of Southern California

Neurally-inspired approaches to object recognition often involve a hierarchy of feature-detecting neurons that become increasingly shape specific and spatially invariant in alternating processing stages (Fukushima 1982); the approach is loosely patterned after the progression of receptive field properties seen in the primate ventral visual processing stream. A key question in the design of such systems is how the parameters of the feature-extraction hierarchy should be set, that is, (1) which lower-order features should be bound together into higher-order combinations to increase shape selectivity at each stage, and (2) what kind and degree of spatial pooling should be carried out at each stage to increase spatial invariance. Several previous workers have explored "trace"-based learning rules, in which the spatio-temporal contiguity of visual features acts as a cue to the learning of higher-order invariant features (e.g. Foldiak, 1991; Wallis &

Rolls, 1997; Wiskott & Sejnowski, 2002). However a system designed to cope with a difficult full viewpoint-invariant 3D object recognition task involving a large set of self-similar objects has yet to emerge. We are developing a hierarchical feature-learning architecture based on a set of nested self-organizing maps (SOMs) biased to learn either a binding or a pooling operation at each stage. Our training set contains multiple instances of chairs; features are extracted from interactive 3-D virtual reality movies. The network has so far been developed and tested through the level of V1-like simple & complex cells; development of the V2, V4, and IT layers is ongoing.

G27 *722* Feedforward theories of visual cortex predict human performance in rapid categorization

Thomas Serre[1,2,3,4] (serre@mit.edu), Aude Oliva[3,4], Tomaso Poggio[1,2,3,4]; [1]McGovern Institute for Brain Research, [2]Center for Biological and Computational Learning, [3]Brain and Cognitive Sciences Department, [4]Massachusetts Institute of Technology

Rapid categorization has been extensively studied over the past years. How the visual system achieves object recognition with such speed and accuracy remains however a matter of debate. Here we show that a specific implementation (Riesenhuber & Poggio, 1999; Serre & Poggio, VSS 2005) belonging to a class of feedforward theories of object recognition - that extend the Hubel & Wiesel simple to complex cell hierarchy from V1 to AIT - can predict the pattern of performance achieved by human observers on a rapid animal vs. non-animal categorization task. We generated a balanced set of stimuli by selecting animal images from four different subcategories based on body size and viewing distance from the camera (from heads to full bodies in clutter). Recognition performance by human observers (n = 21) was tested with a backward-masking paradigm, i.e., 20 ms stimulus presentation followed by a variable inter-stimulus interval (ISI) then a 80 ms mask duration. We found that the feedforward model could predict the pattern of performance of human observers (both HIT and d') on the different animal subcategories for an ISI of 30 ms with an overall correlation between the model and the human observers $\tilde{n} = 0.72$, $p < 0.01$. To further challenge the model we tested the effect of image rotation on recognition performance. Consistent with previous psychophysics results (Guyonneau et al., ECVP 2005), both human observers and the model were fairly robust to image orientation.

G28 *723* The contributions of category experience and learning to perceptual expertise: A behavioral and neurophysiological study

Lisa Scott[1] (scottls@colorado.edu), James Tanaka[2], David Sheinberg[3], Tim Curran[1]; [1]University of Colorado at Boulder, [2]Univeristy of Victoria, [3]Brown University

In a recent study involving visual expertise training with birds, we identified two distinct ERP components, the N170 and the N250, that are correlated with the acquisition of perceptual expertise (Scott, et al., in press). Whereas the N170 is sensitive to the encoding of basic level, shape information, the N250 is modulated by the more fine grain perceptual detail required for subordinate level identification. The goal of this study was to further our understanding of these components. Subjects were either exposed to or learned to classify three categories of cars (sedans, SUVs, antique) at either the basic or subordinate level. ERPs were recorded before, immediately after, and 1-week after training. Behavioral results showed that compared to the basic level and exposure-only learning conditions, subordinate level training led to better discrimination of trained cars and this ability was retained a week after training. However, unlike the previous bird study, discrimination did not transfer to novel exemplars or novel categories of subordinate level cars. The ERP results showed an equivalent increase in the N170 across all three training conditions whereas the N250 was only enhanced in response to the cars trained at the subordinate level. In contrast to the behavioral results, the N250 generalized to novel exemplars and novel cars in the subordinate level condition. The current results suggest that an increased N170 is related to the amount of exposure to objects within the expert category. On the other hand, the enhanced N250 reflects subordinate level access to these objects.

G29 *724* Effects of Long Term Image Familiarity in Monkey Temporal Cortex

David L Sheinberg[1] (David_Sheinberg@brown.edu), Ryan EB Mruczek[1], Britt Anderson[1], Keisuke Kawasaki[1]; [1]Department of Neuroscience, Brown University

Recognition of repeatedly encountered visual objects must be accompanied by the modification of neural circuits, but where in the brain this occurs is not well understood. In previous studies in monkeys, we found that visual evoked potentials recorded from skull electrodes revealed enhanced responses to highly familiar images starting between 120ms and 140ms after stimulus onset. In the present study, we investigated the extent to which these changes could be traced to events occurring in the inferior temporal cortex (IT). Three monkeys were each trained to recognize 100 visual images of real world objects using a 2AFC classification task. Following extensive training, we obtained simultaneously recorded local field potentials and single unit activity from between one and four electrodes lowered into visually responsive regions of IT. Sites were selected by monitoring responses to a neutral set of trial unique patterns. We then interleaved presentations of highly familiar objects with totally unfamiliar objects during a viewing only task. In all three animals, significant effects of image familiarity were observed in the stimulus aligned LFPs starting 150-170ms after stimulus onset. Single unit responses had typical onset latencies around 110ms, and preliminary analysis suggests that robust, selective responses were much more common for familiar objects compared to novel ones. We never encountered single neurons that encoded stimulus familiarity, *per se*. We hypothesize that large populations of single neurons in IT become tuned to repeatedly encountered objects, and that the integrated output of these cells will, in turn, present a signal of familiarity.

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G30 *725* Abstract withdrawn.

G31 *726* Temporal integration of visually and electrically evoked activity in monkey inferior temporal cortex during visual discrimination learning

Keisuke Kawasaki[1] (Keisuke_Kawasaki@brown.edu), David L Sheinberg[1]; [1]Depeartment of neuroscience, Brown University

We have previously found that perturbation of activity in IT can be used to solve a visual discrimination task when the visual information alone is ambiguous. However, the degree to which independent visually and electrically evoked activities in IT contribute to this discrimination is not clear. To address this question, we designed a new discrimination paradigm based on relative stimulus timing. A monkey was trained in a two alternative forced choice classification task. We prepared novel stimuli for every experimental session. Two of the four stimuli consisted of identical visual patterns combined with electrical biphasic pulses delivered to a visually selective IT site; the relative timing between the visual and electrical stimulation consistently differed for each. For one stimulus, the electrical stimulation was delivered just prior to the visual stimulation and for the other, during the visual stimulation. In 9 of 13 experiments we observed clear evidence of learning, but found lower performance and slower learning in the combined, compared to visually distinct, classifications. The absolute timing of visual and electrical stimulation could not explain performance. As a probe test, we occasionally introduced a condition containing only the visual pattern that had been paired with electrical stimulation. On these trials, the monkey reliably chose the button corresponding to the pre-stimulation stimulus. These results suggest that the visually and electrically evoked activities in IT cortex contribute to discrimination learning in an integrative manner, and that the learning we observed is not a result of simply learning to detect electrical stimulation alone.

G32 *727* **Categorization training leads to sharpening tuning of shape-specific tuning in the lateral occipital cortex and learning of category-selective representations in the prefrontal cortex**

Xiong Jiang[1] (xj9@georgetown.edu), Evan Bradley[1], Leo Rini[1], Thomas Zeffiro[2], John VanMeter[2], Maximilian Riesenhuber[1]; [1]Department of Neuroscience, Georgetown University Medical Center, Washington, DC 20007, USA, [2]Center for Functional and Melecular Imaging, Georgetown University Medical Center, Washington, DC 20007, USA

Categorization is a fundamental human cognitive function. However, little is known about the neural mechanism underlying category learning. A recent computational model (Riesenhuber and Poggio, Nat Neurosci, 2000) proposed a two-layer framework, in which categorization is performed by category-selective circuits putatively located in the prefrontal cortex that receives input from shape-selective neurons in visual cortex tuned to representatives of the relevant object classes. To investigate the neural bases of human category learning, we trained subjects (n=15) for a mean of 5 hrs on a delayed match to category task using morphed images ("cars"), and assessed the learning-related shape- and category-selective cortical representations using an fMRI rapid-adaptation (RA) paradigm, in which pairs of cars were presented. When subjects performed an apparent motion task on the cars - for which category membership was irrelevant - we found reduced activations across the visual cortex during post-training scans relative to pre-training scans, and more importantly, a sharpening of the tuning to car shapes in the lateral occipital cortex (LOC). No explicit category-selectivity was found in LOC. However, category-selectivity was found at the inferior and middle gyri of dorsolateral prefrontal cortex while subjects (n=12) performed a categorization task. Interestingly, activity in LOC appeared to be modulated by subjects' judgment of category membership during the categorization task, putatively due to top-down influences from prefrontal cortex, paralleling recent findings from a monkey study (Freedman, Riesenhuber, Poggio, Miller, J Neuro 2003). These preliminary results appear to confirm the simple two-stage model.

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G33 *728* **A lateral occipital complex (LOC) localizer with precisely matched local feature composition in intact and scrambled images**

Kenneth J Hayworth[1] (khaywort@usc.edu), Xiaomin Yue[1], Irving Biederman[1]; [1]University of Southern California

LOC localizers compare pictures of objects with gird-scrambled versions producing a comparison of object vs. texture. However, this results in a markedly different set of local features: an increased number of line endings (creating new T-junctions even when using a superimposed grid) and a reduction in longer contours. Here we present a new localizer based on local feature deleted (LFD) line drawings of objects in which every other vertex and line was deleted from each part. These LFD stimuli remain readily interpretable, and complementary LFD stimuli prime one another (Biederman & Cooper, 1991) and produce equivalent adaptation in LOC (Biederman & Hayworth, 2005). Because LFD stimuli have undergone contour deletion, they can be scrambled (sLFD) to produce an image that is incoherent without any change in the number or nature of the local features. In theory, the LFD and sLFD stimuli should be processed similarly by the visual hierarchy, until a level is reached where the parts of an object are encoded. The comparison of fMRI activity for LFD > sLFD showed similar regions of activation as a grid-scrambled control but with differences in the region of maximal activation: LO for the grid-scrambled control, pFs for the LFD localizer. These results suggest greater sensitivity to object parts vs. local features in pFs than in LO. The opposite ordering (sLFD > LFD) was observed in area V2.

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G34 *729* **The psychological reality and neural basis of intermediate complexity features in perceptual categorization**

Assaf Harel[1] (assafusa@mscc.huji.ac.il), Shimon Ullman[2], Boris Epshtein[2], Shlomo Bentin[1]; [1]Department of Psychology, Hebrew University of Jerusalem, Jerusalem, [2]Department of Computer Science and Applied Mathematics, Weizmann Institute of Science, Rehovot

A recent computational model (Ullman, Vidal-Naquet, & Sali, 2002) proposes that viewpoint-dependent features of intermediate complexity (IC) are more informative about an object's category than either highly complex or very simple features of the object. Consequently, such IC features should be optimal for object categorization. We tested the psychological reality of this model by assessing the influence of the information delivered by a feature (mutual information - MI) on categorization speed and on ERPs. Participants categorized IC features of three object categories (faces, cars and various-class images) of varying MI levels. Both RT and accuracy of performance increased as a function of MI for both car and face features but not for the various-class-defined features. Faces were classified better than cars and MI value influenced differently the two classes, possibly pointing to the effect of different visual experiences with faces and cars. The face-sensitive N170 component was larger to face features than to car features and various-class features and delayed relative to full faces and objects. Moreover, only for faces the N170 amplitude increased as a function of features' MI. We conclude that IC features play a dominant role in object categorization and that MI has a psychological and neural basis. IC features extraction by maximization of information may serve as a new model for the detection of primitives evident in N170 and will thus allow a better understanding of the processes underlying face detection.

G35 *730* **The influence of perceived size/distance on object and place ROIs.**

Anthony D Cate[1] (acate@uwo.ca), Melvyn A Goodale[1], Stefan Kohler[1]; [1]Department of Psychology, University of Western Ontario

Distinct regions of posterior neocortex show reliable fMRI activation to images of objects and places (including buildings), respectively. What is not known is whether these regions are sensitive only to the geometry and surface cues defining the object and place stimuli, or whether the implied size and/or distance of those stimuli also matters. Regions of interest that responded primarily to images of places, faces, and small objects were determined with localizer fMRI scans. Participants then performed an oddball-detection task while viewing images of small objects (cameras) and buildings (garages) in different contexts: against a blank background (no size/distance cues other than those implied by the object's form); in the foreground of a simple size/depth illusion (implied small/close); and in the background of the illusion (implied large/far). Even though retinal size and eccentricity of the stimuli were equal in all conditions, activity in a 'place' ROI corresponding to the parahippocampal place area (PPA) was increased in the large/far conditions, relative to both the near/close and the blank background conditions. Conversely, activity in an 'object' ROI (lateral occipital area, LO) was increased in the near/close conditions. Both PPA and LO also showed category specificity. A more posterior place ROI (in the collateral sulcus) did not show the same effects of the size/distance manipulation as the PPA but was driven primarily by image category. This study clarifies the nature of the processing within higher-level visual areas by revealing the relative strengths of category and size/distance effects in different functional areas.

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Motion and Depth

G36 *731* Perception of stereomotion coherence in the presence of planar or volumetric dynamic noise

Finnegan J. Calabro[1] (fcalabro@bu.edu), Lucia M. Vaina[1,2]; [1]Brain and Vision Research Lab, Department of Biomedical Engineering, Boston University, Boston, MA, USA, [2]Harvard Medical School, Department of Neurology, Boston, MA, USA

The visual motion system can use disparity to segment a signal from noise (Snowden, Rossiter 1999). Here we use a stereomotion coherence task to examine how properties of segmentation vary as a function of disparity. **Experiments**: Subjects performed a left/right motion discrimination task. In Exp 1, a plane of signal dots was at fixation while the depth of a noise plane varied (0'-12'); In Exp 2 the signal plane was placed at +/-10'; in Exp 3 the noise plane was replaced by a 3D cloud of variable depth. **Results**: Exp 1: As expected, subjects' thresholds improved dramatically as disparity separation increased. Exp 2: For crossed disparities, motion discrimination thresholds were higher for noise in front of the signal, indicating that segmentation was more difficult. Exp 3**:** For signal planes at a fixed distance from the cloud thresholds remained constant, suggesting that the distance to the cloud, but not the depth of the cloud, had a strong effect on performance. The results of Experiments 2 and 3 show that the perception of motion when noise was a 3D cloud produced lower thresholds than when the noise was 2D (both were 2' from the signal plane). **Conclusions:** Taken together these results suggest a channel model which weights each noise dot by its distance from the signal. The model allows for estimates of disparity channel tuning widths as a function of depth. However, the near/far asymmetry we report requires a low-pass channel for crossed disparities without a corresponding channel for uncrossed disparities.

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G37 *732* Frontal Cortical Activation by Stereoscopic Motion-in-Depth

Lora T. Likova[1] (lora@ski.org), Christopher W. Tyler[1], Paul D. Gamlin[2]; [1]Smith-Kettlewell Eye Research Institute, San Francisco, [2]Vision Science Research Center, University of Alabama, Birmingham

Purpose. Motion-in-depth creates a profound perceptual experience involving many aspects of neural processing. We have previously identified areas specific to stereoscopic motion-in-depth in human posterior cortex (Likova & Tyler, 2003; 2004). Now we use whole brain fMRI to explore the entire stereomotion network. Methods. fMRI responses were obtained on a 3T scanner in 40 axial slices, 3 mm thick, at 3s TR. Both the test and the null stimuli were dynamic random-dot stereograms. Cyclopean stereomotion was generated by disparity modulation-over-time with no correlated retinal motion. Exp1: Stereomotion (test) was contrasted with a zero-disparity plane (null). Exp2: The null periods incorporated the stereomotion-disparities but as fixed planes. The observers maintained steady fixation, suppressing vergence tracking, and performed an attention control task. Retinotopic areas, hMT+ and vergence regions were mapped in separate sessions.Results. In addition to the previously-identified areas, stereomotion activated four distinct frontal-lobe sites: (i) a site in the precentral gyrus that may be homologous to a neurophysiologically-identified stereomotion region posterior to the arcuate sulcus in monkey cortex (Dearworth, Li & Gamlin, 2004), (ii) in the dorsolateral prefrontal region, known to be involved in attentional control and sequencing behaviors, (iii) in the paracentral sulcus, and (iv) in the ventrolateral prefrontal cortex, ventral to Broca's area, implicated in inhibitory decision making. Discussion. Stereomotion perception is a complex process incorporating, among others, dynamic sensory and attentional tracking components. The prominent sites of human frontal cortical activation may well reflect the involvement of such higher level processing. Their roles in the stereomotion network will be discussed.

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G38 *733* Aftereffect of motion-in-depth based on binocular cues: no effect of relative disparity between adaptation and test surfaces

Yuichi Sakano[1] (yuichi@cse.yorku.ca), Robert S. Allison[1], Ian P. Howard[1], Sabnam Sadr[1]; [1]Centre for Vision Research, York University, Canada

Previously, we found that a motion aftereffect (MAE) in depth can occur after adaptation to motion-in-depth in random-element stereograms (VSS 2005). In the present study, we investigated the depth selectivity of the MAE in depth. The adaptation stimulus consisted of two frontoparallel surfaces, one above and one below the fixation point. These surfaces were depicted by random-dot stereograms that were temporally correlated (RDS) or uncorrelated (DRDS). During the 2-min adaptation phase, the disparity of one surface increased and that of the other surface decreased linearly and repeatedly to simulate smooth motion-in-depth. The range of these disparity ramps was -26.2 to -8.72, -8.72 to +8.72, or +8.72 to +26.2 arcmin, where positive and negative values indicate crossed and uncrossed disparity. The test stimulus consisted of two stationary frontoparallel surfaces depicted by a RDS with a fixed pedestal disparity of either -17.4, 0, or +17.4 arcmin. Under RDS adaptation conditions, robust MAE in depth occurred. The duration of this MAE in depth did not depend on the relation between the disparity range of the adaptation stimulus and the pedestal disparity of the test stimulus. Under DRDS adaptation conditions, MAE in depth did not occur. These results suggest that the adaptable processes used to detect motion-in-depth from binocular cues are insensitive to pedestal disparity.

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G39 *734* The effect of edge polarity on the Pulfrich stereophenomenon

Frank E. Visco[1] (visco@uh.edu), Scott B. Stevenson[1]; [1]University of Houston College of Optometry

IntroductionThe Pulfrich stereo-phenomenon is a consequence of a difference in signal timing between the two eyes as a result of differing levels of retinal adaptation.ÿ Here we used moving edge stimuli to investigate the interaction between local light adaptation and luminance edges in generating these delays.MethodsThe "edge only" stimuli were moving sawtooth profiles with very shallow ramps, so that the luminance at a given point changed slowly (ramp) and then changed suddenly (edge) as the pattern moved across the CRT display. Depending on polarity and motion direction, the edge caused local luminance to increase from zero (leading edge) or to decrease from the top of the ramp (trailing edge). Each eye saw two ramps moving at 5 deg/sec in counterphase. Left and right eye images were fused with a mirror haploscope. Luminance differed between eyes by one log-unit to produce the Pulfrich phenomenon.Subjects judged the relative depth of the edges as they passed one another at the center of the display and adjusted the stimulus timing to null any apparent depth. The delay required to null the depth quantified the Pulfrich phenomenon.ResultsWith 1 log unit of interocular luminance difference, leading edges produced a relative interocular delay of 17msec. Trailing edges produced a relative delay of 7msec.DiscussionThe differences in timing between leading and trailing edges can be attributed in part to early multiplicative adaptation (Hayhoe etal. 1987), such that a trailing edge is subject to local adaptation whereas a leading edge is not.

G40 *735* Modeling Perceptual Bias in 3-D Motion

Martin Lages[1] (m.lages@psy.gla.ac.uk); [1]Department of Psychology, University of Glasgow, Scotland-UK

Recently, a motion-first and a disparity-first Bayesian model have been proposed to predict bias in binocular 3-D motion perception (Lages, 2005).

Here it is tested whether a motion-stereo model that combines uncertainty in velocity and disparity processing with suitable priors can explain perceptual bias better. Model fits were compared in an experiment where binocular disparity change and interocular velocity difference served as cues for the perception of 3-D motion. Stimuli were presented to the left and right eye on a calibrated flat CRT monitor in a split-screen Wheatstone configuration with a refresh rate of 120 Hz. On each trial observers verged on a fixation cross flanked by a fusion lock at 114 cm before target dots above and below fixation traveled on parallel trajectories for 0.833 sec. 3-D Trajectory angle (0 to 360 deg in steps of 10 deg) and velocity (0.02, 0.03, and 0.04 m/sec) of the targets varied in randomly intermixed trials. In separate blocks of trials four observers indicated trajectory angle and distance traveled by adjusting on screen a line probe in top view. The results indicate that the stereo-first model best explains systematic bias in perceived trajectory angle and velocity. Uncertainty estimates of the stereo-first model systematically increased with stimulus velocity. When observers adjusted line probes to static targets at corresponding 3-D motion endpoints then uncertainty estimates and bias were generally reduced. These observations support the notion of a stereo-first system in which disparity change introduces uncertainty and bias.

G41 *736* An Aubert-Fleischl-like illusion in depth

Harold T Nefs[1] (harold.nefs@st-andrews.ac.uk), Julie M Harris[1]; [1]University of St Andrews. The School of Psychology

The Aubert-Fleischl illusion is the false impression that objects move slower when they are pursued with the eyes as compared to when the eyes are kept stationary. Previous research on this illusion has focused on lateral motion and smooth pursuit eye movements. Here, we investigated the relationship between vergence eye movements and the perception of targets moving in depth. Observers saw two intervals sequentially. In each interval there were two targets that were separated vertically by 3 degrees. The top target was a stationary fixation target and the lower target oscillated in depth at eye height. In one of the intervals observers fixated the stationary target and in the other interval they pursued the oscillating target with their eyes. They were asked in which of the two intervals the lower target moved faster. We measured psychometric functions with the method of constant stimuli for speed discrimination. In Experiment 1 we varied the amplitude of the oscillating target; in Experiment 2 we varied the frequency and we kept the amplitude the same. Eye movements were recorded throughout for both eyes. All three observers in Experiment 1 and two out of three observers in Experiment 2 showed systematic biases in the predicted direction. As for the classic Aubert-Fleischl illusion, we demonstrated that a moving target is also likely to be perceived as slower when the eyes follow the target with vergence movements compared to when the eyes remain stationary.

G42 *737* Masking effect in visual perception of simultaneously presented dilating and contracting size-changing objects

Sergey L. Artemenkov[1] (slart@ostrov.net); [1]MSUPE/MGPPU

The Transcendental Psychology approach claims that internal mechanisms of perceptual processes may be manifested at the limit of human visual system functional range in critical spatial-temporal conditions. It therefore focuses on the way how the visual representations are created over time and seeks for phenomena which can provide important cues to the spatial and temporal properties of the representation process, e.g. showing theoretically supposed differences in perception of shortly presented dilating (A) and contracting (B) objects (Artemenkov, VSS, 2005). To get deeper understanding of these differences we have investigated the visual perception of simultaneous A and B objects by presenting contoured polygons changing size (7-12 deg) at the rate of 10-55 deg/s within a range of short durations (30-120 ms), and asking observers to identify object's form, size and movement. The results confirm that for A and B objects changing place of each other (7 and 12 deg) simultaneously or with small delay (10-40 ms) the processes are masking each other's movement sensation and this effect is better manifested at the lower movement's speed (18 deg/s) and is even more salient when A and B speeds are different (35 and 18 deg/s). While bifurcated objects show the noticeable absence of their initial state, merged objects were perceived differently at high and low speeds, so that at low speed they are seen as visually distinct, as if they are terminated at different depth planes. Discovered phenomena support a theoretical model predicting internal anisotropic properties of the representation process.

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G43 *738* Human perception of image speed derived from the simultaneous extraction and analysis of visual information in two- and three-dimensional space.

Sieu K Khuu[1] (skhuu@hkucc.hku.hk), Terence CP Lee[1], Anthony Hayes[1]; [1]The University of Hong Kong, Pokfulam Road, Hong Kong, China

An important task of the visual system is to extract speed estimates from the two-dimensional image plane (2D) and from motion in depth (3D), or, as in the majority of scenes, from a combination of both. However, it remains unclear from available research how 2D and 3D speeds are combined. We addressed this issue using a square (5x5deg) Global Dot Motion (GDM) stimulus consisting of 100 circular dots (radius: 8minarc, 90 cd/m^2) undergoing random motion on a grey computer screen (45cd/m^2). Concurrently, the entire GDM stimulus was displaced in depth (by systematically changing binocular disparity) towards the observer. Using this stimulus, we determined how the 3D speed of the dot-defined square is affected by systematic manipulation of 2D dot speed. A two-interval forced-choice procedure was used. One interval presented the reference stimulus: a dot defined square moving in depth at speeds of 4, 6 and 9cm/sec with no 2D motion, while the other presented the test stimulus: an identical dot defined square, but containing dots moving randomly at speeds of: 0 0.4, 0.8, 1.6 and 3.2cm/sec on the image plane. The task of the observer was to adjust the test stimulus 3D speed to match the reference stimulus. Results show that increasing 2D speed increased the apparent 3D speed of the dot-defined square in a manner consistent with the vector sum of 2D and 3D velocities. We discuss our findings in light of the functional properties of global motion detectors tuned for speed information.

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G44 *739* Comparison of 2D and 3D Ideal Observers to Characterize Heading Perception with Directional Range Noise

Elif M. Sikoglu[1] (melifs@bu.edu), Scott A. Beardsley[1], Finnegan J. Calabro[1], Lucia M. Vaina[1,2]; [1]Brain and Vision Laboratory, Department of Biomedical Engineering, Boston University, Boston, MA, USA, [2]Harvard Medical School, Department of Neurology, Boston, MA, USA

Purpose: In a heading perception task, we demonstrated that although error in the perceived heading direction is modulated by the range of directionally constrained noise, humans are proficient in integrating the noisy flow information to form a global percept. (VSS2005) To investigate how much of the information available in the velocity field is useful to observers, we now propose two ideal observer models (IOM).

Experiment: In a display of expanding random-dot-kinematograms (RDK) perturbed with directionally constrained noise, observers are required to determine the direction of straight-line-heading (left or right of a vertical reference line appearing after termination of motion). Accuracy of heading perception is measured by an adaptive-staircase.

Model: Given the vertical line's position and distance to the heading direction, the IOM decides whether the heading is to the right or to the left of the vertical line.

We constructed a 3D-IOM which has 3D information about every dot loca-

tion and a 2D-IOM which uses the projections of dot locations onto the computer-screen. The IOMs are applied to two experimental conditions we previously used in psychophysics: 1)Random-walk: Dot directions are independently perturbed frame-to-frame; 2)Fixed-trajectory: Dots keep same perturbed direction throughout their lifetimes.

Results: a) Fixed-trajectory condition is harder for both the human observers and IOMs. b) Heading perception accuracy in 3D-IOM is robust to increases in direction range, while in 2D-IOM it rapidly drops. Observers' efficiencies from 2D-IOM are higher than from 3D-IOM.

Conclusion: 2D-IOM results better resemble human data, thus reconstruction of 3D-environment is not necessary for heading perception

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G45 *740* Unconfounding the Time to Passage, Direction of Motion and Rotation Rate of an Approaching Object: Different Early Visual Processing in Expert Baseball Players and Nonplayers.

Rob Gray[1] (robgray@asu.edu), David M Regan[2]; [1]Department of Applied Psychology, Arizona State University, USA, [2]Department of Psychology, York University, Toronto, Canada

Observers were presented with a set of 216 simulated approaching textured baseballs in random order. Each had a different combination of time to passage (TTP), direction of motion in depth (dMID), and rate of ball rotation (RR). When required to discriminate TTP, dMID and RR in separate blocks (Expt 1), observers could not discriminate dMID independently of variations in TTP but instead showed a bias towards perceiving objects approaching on a trajectory close to the nose as having a shorter TTP than objects approaching on a trajectory that would miss the face. Judgments of dMID were affected by variations in RR and rotation direction: for simulated overspin the (i.e. the top of the ball spins towards the observer) perceived ball trajectory was biased towards the ground whereas for simulated underspin the perceived ball trajectory was biased towards the sky. RR could be discriminated independently of both TTP and dMID. When required to make all three of these judgments simultaneously on each trial (Expt. 2) discrimination thresholds were not significantly different from those found in Expt. 1. Judgments by expert (college) baseball players (Expt. 3) showed an interaction between TTP and RR (balls with overspin were judged to have a longer TTP) that was not found for nonplayers. We conclude that information about TTP, dMID and RR are processed in parallel but not completely independently within the human visual system and that the degree of independence can be influenced by sports experience.

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G46 *741* The Rubber Pencil Illusion

Lore Thaler[1] (thaler.11@osu.edu), James T. Todd[1]; [1]Department of Psychology, The Ohio State University

A rigid pencil can appear to bend when wiggled. Pomerantz (1983) suggested that this phenomenon only occurs when there is a curved envelope of the motion blur pattern, but this hypothesis has not been rigorously tested. Thus, the present experiments were designed to provide further insights about the mechanisms that underlie this illusion.Observers were shown computer displays of moving line-segments undergoing translation and rotation, and they were asked to indicate the apparent 'rubberiness' of the motion on a 10-point scale. The manipulation of speed, amplitude and relative phase of the rotational and translational motion components and introduction of additional motion enabled us to produce a wide variety of motion envelopes. We also manipulated the dynamic luminance contrast, the pattern of eye movements, and the structure and motion of the surrounding context. The results indicate that the illusion is unaffected by manipulations of the blur envelope or the dynamic contrast. Perceived 'rubberiness' is greatest when the rotational and translatory oscillations have a relative phase of approximately 110° and a frequency of 2.5-3 cycles/second. The strength of the illusion can be increased or decreased by changing the pattern of eye movements so as to alter the movement trajectories on the retina. It can also be greatly attenuated for certain types of backgrounds, when the movement of the background is identical to that of the moving line. These results suggest that the illusion is based on spatiotemporal stimulus dynamics and perceptual grouping mechanisms rather than the envelope of the motion blur pattern.

G47 *742* The discrimination of elasticity in bending motion

Elizabeth Y. Wiesemann[1] (elizabeth.wiesemann@wku.edu), J. Farley Norman[1], Hideko F. Norman[1], Warren D. Craft[2]; [1]Western Kentucky University, [2]Sewanee: The University of the South

Nonrigid motions frequently occur in nature. According to Koenderink and van Doorn (1986), bendings are "the most general class of deforming motions that permits a solution of the problem of shape from motion". Despite this fact, bending remains essentially uninvestigated. In our experiment, on any given trial observers viewed two bending rods (defined by the motions of 50 luminous points), and were required to judge which rod was more elastic (i.e., less "stiff"). The stimulus displays were created according to the methods described by Craft, Payne, and Lappin (1986). The method of constant stimuli was used to obtain elasticity difference thresholds. Thresholds were obtained for six experimental conditions formed by the combination of two standard elasticities and three bending planes. The rods bent in either the fronto-parallel plane or bent in a plane that was oriented 42.5 or 85 degrees from fronto-parallel (thus the rods in those two latter conditions bent in depth towards and away from the observers). All observers reliably perceived the bending motions, even those that bent in depth -- thus, the perceptual mechanisms that extract 3-D structure do not require rigidity. The observers' average elasticity difference threshold (i.e., Weber Fraction) was 7.6 percent of the standard. The observers' thresholds for bending in depth were quantitatively similar to those obtained for bending in a 2-D image (i.e., the fronto-parallel plane). The overall results reveal that human observers exhibit a moderately high sensitivity for detecting deviations in the elasticity of bending objects.

Motion Integration

G48 *743* The effect of age on the detection of coherent motion and radial flow

Jutta Billino[1] (jutta.billino@psychol.uni-giessen.de), Frank Bremmer[2], Karl R. Gegenfurtner[1]; [1]General and Experimental Psychology, Justus Liebig University Giessen, [2]Department of Neurophysics, Philipps University Marburg

Several studies have shown that motion sensitivity declines with increasing age. This decline cannot be attributed to optical changes but is due to changes in the central visual pathways. However, there is little knowledge which subsystems are prone to degeneration. The purpose of our study was to evaluate the effect of aging on motion processing at different stages in the visual system. We investigated age-related differences in the detection of coherent motion and radial flow. Whereas the former task is related to early processing stages, the latter task is supposed to rely on processing at advanced stages in the visual system. Data was collected from younger (19-57 years; n=16) and older subjects (63-82 years; n=27). The first task required subjects to detect which one of two random dot kinematograms displayed at 7.6° eccentricity and a size of 9.6° contained coherent motion. In the second task, subjects had to decide about the direction of heading of a radial flow large-field stimulation whose focus of expansion was shifted to 5.8° eccentricity. In both tasks, noise levels of the kinematograms were varied and thresholds were estimated. Thresholds for coherent motion detection differed significantly between age groups (14.4% vs. 26.9%). There was an overall effect of age on performance (r=.562). In contrast,

ability to detect radial direction was not affected by age. The results suggest that older observers' ability to analyze optic flow is preserved despite elevated detection thresholds for coherent motion. This finding puts into question a hierarchical view of visual motion processing.

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G49 *744* Age-related decrements in the discrimination of global coherent motion

Jeffrey D Bower[1] (jeffrey.bower@email.ucr.edu), Rui Ni[1], George J Andersen[1]; [1]University of California, Riverside

The present study examined age related differences in the perception of global coherent motion. The stimuli consisted of 256 random dots each moving in slightly different paths that average to a single coherent direction. 13 younger (mean age of 21.8) and 12 older (mean age of 77.3) subjects were asked to discriminate the coherent direction of motion for two sequentially presented stimuli. Two hypotheses were examined in the present study: 1) that older observers have a decreased tolerance for noise, and 2) that older observers have increased difficulty in sampling motion information. To examine the noise tolerance hypothesis we systematically varied the perturbation of each local motion from the coherent direction by sampling from a Gaussian distribution. The distributions had a standard deviation (SD) of, 0, 4.5, 18, or 36. To examine the sampling hypothesis we compared three different types of local motion paths--- continuous, limited lifetime, or random walk. The display duration of the stimuli was 150, 280, or 560 msec. Both younger and older subjects showed lowest discrimination thresholds for the random walk motion displays as compared to continuous motion and limited lifetime motion displays, suggesting that general sampling of visual information does not change as a function of age. However, older subjects had elevated thresholds for the highest noise condition, particularly with continuous motion displays. This finding suggests that older subjects have difficulty in sampling visual information under high noise conditions.

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G50 *745* Complex visual information processing in children after Mild Traumatic Brain Injury.

Odile Brosseau-Lachaine[1] (odile.brosseau-lachaine@umontreal.ca), Isabelle Gagnon[2], Robert Forget[2], Jocelyn Faubert[1]; [1]École d'optométrie, Université de Montréal, Montréal (Québec), Canada, [2]École de réadaptation, Faculté de Médecine, Université de Montréal, Montréal (Québec), Canada

Visual disturbances are often reported after Traumatic Brain Injury (TBI). However, no studies have documented the presence of complex visuo-spatial information processing deficits in children after a mild TBI. It is important to assess children's visual perception after mild TBI to ensure a safer return to their activities and sports. The purpose of the present study was to compare the sensitivity to complex visual information processing of children who have sustained a mild TBI to that of non-injured children matched for age. Sensitivity to static and dynamic forms of simple (first-order) and complex (second-order) stimuli were assessed at 1 week post-injury for 12 injured children and controls (8 to 16 years of age). Orientation (vertical vs horizontal) and motion-direction identification (left vs right) thresholds were measured for all participants. In addition, sensitivity to local (simple) and global (complex) optic flow stimuli was assessed (coherence thresholds). Results indicate that at 1 week post-injury, the sensitivity to all complex stimuli (static and dynamic second-order and global motion) were significantly reduced for the mild TBI children whereas sensitivity to simple information remained within the normal range. Results from this study indicate that children with mild TBI present selective processing deficits for complex information 1 week post-injury. Such measures can be potentially used to complement existing diagnostic measures to assess the cognitive status of children who have sustained TBI. The persistence in time of this effect on performance is being studied until 12 weeks post-injury.

G51 *746* Adults, but not Infants, Use Color as a Segmentation Cue for Motion Processing

Karen R. Dobkins[1] (kdobkins@ucsd.edu), Vanitha Sampath[1], Tina Chen[1]; [1]Psychology Department, UC San Diego

Purpose: Previous studies indicate that infants use color as a motion correspondence cue surprisingly well (Dobkins & Anderson, 2002). Here, we investigated whether color influences motion integration, thought to occur at a later stage in processing. We compared coherent motion thresholds for a "homochromatic" (signal and noise dots both red or both green) versus a "heterochromatic" (signal and noise dots different colors) stimulus. If color acts as a segmentation cue for motion, thresholds should be lower for the "hetero" condition.Methods: For 3-month-olds (n=16), data were obtained using a Directional (left/right) Eye Movement (DEM) technique. (Stimulus parameters: 43x34 deg display; 603 0.42 deg dots; 25 deg/sec; cone contrast between "red" and "green" = 27.7%; unlimited duration). Adults (n=12) were tested with the same stimuli (yet limited duration), using both psychophysical and DEM techniques. For each subject, a "color benefit ratio" was calculated: THR-homo/THR-hetero. Ratios > 1.0 indicate that color acts as a segmentation cue for motion. Results: In line with previous studies, the mean adult ratio obtained psychophysically was 2.1. However, the adult ratio decreased to 1.3 with DEM, suggesting that adults use a higher-level strategy when tested psychophysically. The mean infant ratio was 1.0, that is, infants did not use color as a segmentation cue for motion. This null result is unlikely to be accounted for by poor red/green contrast sensitivity. Conclusions: Possibly, infants use color as a correspondence, but not a segmentation, cue for motion. Alternatively, the use of color as a segmentation cue may require higher-level strategies, which infants lack.

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G52 *747* Perceptual development of directional transparent motion in infancy

So Kanazawa[1] (kanazawa@soc.shukutoku.ac.jp), Nobu Shirai[2,3,4], Yumiko Otsuka[2,4], Masami K. Yamaguchi[2]; [1]Shukutoku University, [2]Chuo University, [3]University College London, [4]Japan Society for the Promotion of Science

When the random-dot motion was superimposed on the other random-dots in different direction, we can see two global moving planes. In this study, we used this directional transparent motion as a stimulus and investigated the perceptual development of motion transparency in infants. Our previous study showed that the preference to the transparent motion developed from 3- to 5-month-olds (Kanazawa et al., 2006). Based on this result, we conducted experiments for total 62 3- to 5- month-old infants. In first experiment we controlled the directional difference between two random-dot motions. Stimuli were consisted of 230 dots placed within the 17.1 deg square field. Half of dots moved right and upward direction and remaining half 115 dots moved left and upward. We presented this transparent motion field as a target and the uniform motion as a non-target side by side. We measured the looking time to the target transparent motions and calculated the ratio of the preference to the targets. We prepared four kinds of directional differences; 6 deg, 10 deg, 20 deg and 40 deg. Results showed that the significant preferences to the target transparent motions were observed in 5-month-olds when the directional difference was above 10 deg and in 4-month-olds when that was 40 deg. However there was no significant preference to the target in 3-month-olds. These results suggest that the sensitivity to the directional transparent motion was developed from 4- to 5-month-olds. This result could be explained by the maturation of ventral stream in infants' brain.

G53 *748* Simultaneous Flash-Lag Effects in Two Directions Reveal a Slow Stage of Multi-directional Motion Integration

Haci H. Kafaligonul[1] (hhkafali@mail.uh.edu), Saumil S. Patel[1,2,3], Haluk

Ogmen[1,3], Harold E. Bedell[2,3], Gopathy Purushothaman[4]; [1]Department of Electrical and Computer Engineering, University of Houston, [2]College of Optometry, University of Houston, [3]Center for Neuro-Engineering and Cognitive Science, University of Houston, [4]Department of Psychology, The University of Chicago

Purpose. We used an illusion first discovered by Cai et al. (Cai's Line-length Effect: CLE) to investigate flash-lag effects simultaneously in two directions of motion. In the CLE, both position and length at the time of a flash are misperceived for a line that moves horizontally and simultaneously expands vertically. Methods. In 1-D motion conditions, subjects (N=2) indicated (a) the perceived position of a horizontally moving line when its vertical length remained constant and (b) the vertical length of a line when its horizontal position remained constant. In 2-D motion conditions, perceived horizontal position and vertical length were measured in the CLE paradigm. A flashed bar (1.2 LU above detection threshold) signaled the subjects when to judge perceived position or length. The moving lines were either 1.8 or 3.2 LU above their detection threshold and changed position and/or length at 1.9 deg/sec. Results. The average perceived lead of both position (equivalent to the classical flash-lag) and length increases virtually identically as the detectability of the moving/changing line increases in the 1-D and 2-D conditions (range = 42 to 47 ms/LU). However, the perceived lead of position and length is approximately 50 ms less at both levels of line detectability in the 2-D compared to the 1-D conditions.Conclusion. Within the framework of the dual-channel differential latency hypothesis, the additional processing delay for the 2-D motion condition is attributed to an increase in the complexity in motion integration when horizontal motion is combined with vertical expansion or contraction.

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G54 *749* Dual Pathways for Object Motion and Motion Energy

Howard S. Hock[1] (hockhs@fau.edu), David F. Nichols[1]; [1]Department of Psychology, Florida Atlantic University

A dominant idea in the motion perception literature is that 1st-order motion is specified by spatiotemporal changes in raw luminance; i.e., motion energy (ME). The underlying principle is that motion can be perceived without extracting the boundary and surface information that determines a moving object's form. This follows from the dispersal of boundary/surface features across the spatial frequency spectrum, and the detection of motion by spatiotemporal filters responsive to a limited range of spatial frequencies. We propose that these edge and surface features are responsible for perceiving an object's motion and its form (see also the formotion model; Francis & Grossberg, 1996), and further, that there are dual pathways, one for object motion and the other for ME. Support for this proposal comes from a stimulus composed of 6 adjacent rectangles. The rectangles vary in luminance such that ME and changes in edge contrast specify motion in opposite directions. Consistent with Wertheimer's distinction, "objectless" phi motion is perceived in the ME-specified direction, predominantly for brief frame durations (high speeds). Beta motion entailing the perception of a moving edge (as in the line motion illusion) is perceived in the direction specified by changes in edge contrast, predominantly for longer frame durations (slower speeds). Decreasing the width of the rectangles reduces edge-based motion and introducing thin gaps between them completely eliminates it. ME is minimally affected by these changes. Conversely, ME perception is substantially weakened by reducing the number of frame-changes, whereas a single frame change suffices for perceiving edge-based motion.

G55 *750* The effect of occlusion on motion integration in infants

Yumiko Otsuka[1,3] (o2341004@crow.grad.tamacc.chuo-u.ac.jp), So Kanazawa[2], Masami K Yamaguchi[1]; [1]Department of Psychology, Chuo University, [2]Department of Psychology, Shukutoku University, [3]Japan Society for the promotion of Science

Previous studies found that even 2-month-olds can integrate local motion signals into a coherent motion (Manny & Fern, 1990; Dobkins et al., 2004). However, not all the motion signals should be integrated. Previous psychophysical studies showed that human visual system makes use of form information such as occlusion to determine whether local motion signals should be integrated or segregated (McDermott et al., 2001). Using the diamond display developed by McDermott et al. (2001), we examined the effect of occlusion on motion integration in infants.Infants were familiarized with the diamond stimulus either in the occlusion condition or in the bar condition. After familiarization, they were shown two types of test displays; global motion (GM) test display and local motion (LM) test display. Both of the test displays were composed of four moving dots. In the GM test display, the movement of four dots simulated the coherent motion of the diamond behind the occluders. In the LM test display, the movement of four dots simulated the local motion of the line segments (local motion). We found that only 5- to 8-month-olds showed significantly greater preference for the LM test display in the occlusion condition than in the bar condition. These results suggest that 5- to 8-month-olds perceived motion to be more coherent in the occlusion condition than in the bar condition. The results from control experiment suggest that the effect of occlusion depend on the global completion of occluded diamond in infants as well as in adults.

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Stereopsis

G56 *751* Perceived stereo depth depends on relative disparity of similarly oriented components in test and reference stimuli

Yu-Chin Chai[1] (sunnia.chai@gmail.com), Bart Farell[1]; [1]Institute for Sensory Research, Syracuse University, NY, US

Human sensitivity to the disparity difference between two stimuli depends on the relative orientation of the stimuli (see Farell, VSS 2004). Does perceived depth also depend on relative orientation? To find out, we used a stereo plaid made of two superimposed sinusoids with different disparities. The envelope of the plaid was ring-shaped and surrounded a central comparison-grating patch. One of the plaid's components had zero disparity, the other had non-zero disparity and the central grating matched one of these components in orientation. The observer's task was to judge the depth of the center grating relative to the surrounding plaid. The perceived depth of the plaid might be expected to depend only on the disparity of the plaid. However, our results showed the importance of the relative orientation of the comparison grating and the components of plaid. When the comparison grating and the plaid's non-zero-disparity component were parallel, the perceived-depth PSE occurred when the comparison grating had a disparity proportional to the component's disparity, with a gain that depended on the horizontal disparity of the plaid as a whole. When the comparison grating and the zero-disparity component were parallel, the gain was lower and independent of disparity of the plaid. We conclude, first, that relative depth from stereopsis varies with the relative orientations of the one-dimensional components of the stimuli, lessening as the orientation difference increases, and, second, that this is the case because relative depth from stereopsis is computed within orientation channels.

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G57 *752* 3D surface orientation based on orientation disparity alone

Carlo Fantoni[1] (fantoni@psico.units.it), Walter Gerbino[1]; [1]Department of Psychology and B.R.A.I.N. Centre for Neuroscience, University of Trieste, via Sant' Anastasio 12, 34134 Trieste, Italy

The 3D orientation of planar surfaces can be perceived in the absence of edge information. Here, we provide a theoretical and empirical demonstration that 3D orientation is specified by the orientation disparity of surface contours (i.e., intrinsic lines belonging to the same plane).The Local Orientation Disparity of correspondent lines [LOD] was described as a function of the Local Average Orientation [LAO], taking egocentric distance and surface inclination relative to the vertical and to the horizontal as unknowns. We found that unknowns are recoverable by fitting such a function to the orientation disparity map (i.e., to the set of points in LOD-LAO space used as a compact representation of the impoverished stimulus).We tested the model by instructing observers to set the V/H-inclination of a planar surface specified by randomly-oriented lines intersecting in a common point. The surface was visible through a circular aperture in a fronto-parallel screen. Observers produced 64 surface orientations resulting from the factorial combination of 4 repetitions by 16 V/H-inclinations in the 0-45 deg range. Despite the absence of matchable points and the high portion of un-matchable regions, estimated surface orientation was highly correlated with V/H-inclination. Systematic orientation biases were also observed.Empirical results, including bias effects, highly correlated with model predictions, suggesting that the orientation-from-disparity problem can be solved by matching input data to the implicit knowledge on the LOD-LAD correlation. An ideal observer capable of encoding orientation disparities can achieve a veridical 3D representation by performing the mathematical analysis described in our model.

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URL: http://www.psico.units.it/users/fantoni/3DOrientationByOrientationDisparity

G58 *753* Aging preserves sensitivity to smooth stereoscopic surfaces

J. Farley Norman[1] (Farley.Norman@wku.edu), Hideko F. Norman[1], Crystal L. Walton[1], Elizabeth Y. Wiesemann[1]; [1]Western Kentucky University

Past research on aging and the perception of stereoscopic shape and depth (Norman, Dawson, & Butler, 2000; Norman, Crabtree, Herrmann, Thompson, Shular, & Clayton, in press) has found that while there is a quantitative effect of age, that the qualitative patterns of performances are essentially identical for younger and older adults. Many extant models of stereopsis are cooperative. The "pulling phenomenon" found by Julesz and Chang (1976) demonstrates the cooperative nature of stereopsis. The purpose of the current experiment was to use the methods of Julesz and Chang to determine whether and to what extent aging affects how well binocular disparity detectors interact within a cooperative network. Twenty observers (ten younger & ten older) viewed ambiguous random-dot stereograms that incorporated varying numbers of bias points with unambiguous disparity (0, 50, 250, 500, 1000, & 2000 bias points). Consistent with the earlier findings of Julesz and Chang, we found that a relatively small percentage of bias points (5.6 percent) was sufficient to "pull" the observers' stereoscopic percepts into an organization that was completely different from that perceived in the unbiased state. For example, if an observer's natural bias was to perceive the ambiguous stereoscopic surfaces (defined by the disparities of 10,000 points) as uncrossed/behind, a sufficient number of unambiguous bias points with crossed disparity (560 on average) could pull the entire surface to the front. There was no significant difference between the younger and older observers in the numbers of bias points that were required to obtain stereoscopic "pulling".

G59 *754* Stereoscopic surface slant adaptation occurs before slant awareness: multiple slant signals adapt independently

Raymond van Ee[1] (r.vanee@phys.uu.nl), Tomas Knapen[1]; [1]Dept Physics, Helmholtz Inst, Utrecht University

Background Although it is known that high-level spatial attention affects adaptation for a variety of stimulus features (including binocular disparity), the influence of attentional control ---and the associated awareness--- on adaptation has remained unexplored. We developed a surface slant adaptation stimulus with conflicting monocular and binocular slant signals that instigated two mutually exclusive surface percepts with opposite slants, enabling us to dissociate slant adaptation due to awareness from stimulus-induced slant (*Brouwer, van Ee & Schwarzbach, J. NeuroSci, 2005, 25, 10403-13; for demonstrations of the stimulus: http://www.phys.uu.nl/~vanee/*).**Results** We found that slant aftereffects (SAE) for monocular and binocular test patterns had an opposite sign when measured simultaneously. In addition, the magnitude of SAE did not correlate with the magnitude of perceived slant. For example: although a disparity gradient induces a larger perceived slant in the presence of a reference, its SAE is smaller. Using adaptation to one slant cue, and testing with the other cue, we demonstrated that multiple slant signals adapt independently.**Conclusion** We conclude that slant adaptation occurs before the level of slant awareness. Our findings place the site of stereoscopic slant adaptation after disparity and eye posture are interpreted for slant [*as demonstrated by Berends, Liu & Schor (JOV, 2005, 5, 71-80), using that disparity scales with distance*], but before other slant signals are integrated for the resulting awareness of the presented slant stimulus.

URL: http://www.phys.uu.nl/~vanee/

G60 *755* Stereoscopic depth in anticorrelated stereograms and the sensitivity to interocular delay

Satoko Yasuoka[1] (syasuoka@bpe.es.osaka-u.ac.jp), Seiji Tanabe[1], Ichiro Fujita[1]; [1]Grad. Sch. Frontier Biosciences, Osaka Univ, Toyonaka, Japan

In stereovision, images are slightly disparate, but usually correlated and synchronized between the two eyes. When an image in one eye is given a reversed luminance contrast (binocularly anticorrelated), or when the image sequence in one eye is given a time lag, there is no global-match solution to the stereo correspondence problem. Despite the absence of a global-match, disparity energy mechanisms can convey a nonzero depth signal. We examined whether human subjects can discriminate stereoscopic depth in anticorrelated random-dot stereograms (RDS) and in RDS with interocular delay. The subjects were asked to report whether the center portion of a dynamic RDS appeared nearer or farther than the annular portion. The direction of perceived depth was reversed in anticorrelated RDS with small interocular delay (12 ms). As the interocular delay increased, subjects' performance approached chance for both correlated and anticorrelated RDS. At intermediate interocular delay (108 ms), there was another depth reversal in which subjects chose the correct depth in anticorrelated RDS. These stereo judgments did not accompany perception of clear surface contours. In order to account for the psychophysical performance of perceived depth, we incorporated the temporal dimension into the standard disparity energy model. The amplitude of the model's disparity tuning curve gradually decreased as interocular delay increased, and even inverted at intermediate interocular delay. Thus, reversed depth perception for both anticorrelated RDS and interocular delay is accounted for by the disparity energy signals computed in early stereo processing stages.

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G61 *756* The Accuracy of Observers' Estimates of Their Own Stereoacuity

Richard A. Tyrrell[1] (tyrrell@clemson.edu), Christine E. Beck[1], Johnell O. Brooks[1], D. Alfred Owens[2]; [1]Clemson University, [2]Franklin & Marshall College

Are observers aware of their own visual limitations? We reported previously that observers do not estimate accurately the extent to which their visual acuity would decline as luminance decreases (Brooks, et al., VSS'05). We now explore the accuracy of observers' estimates of their depth perception. After dark adapting, 30 naive young observers estimated their depth thresholds using a modified Howard-Dolman apparatus. Observers sat to the side of the apparatus and adjusted the lateral separation of two vertical

sticks to estimate the average alignment error that would exist if they were to perform the task in the conventional manner (sitting at the end of the apparatus and adjusting the stick in depth). Depth thresholds were estimated for both monocular and binocular vision at increasing luminances from 0.0325 to 325 cd/m^2. After dark adapting again, observers performed the task in the conventional manner (adjusting the stick in depth) under the same viewing conditions. As expected, depth thresholds were significantly lower with binocular viewing and at high luminance. Comparing estimated and actual thresholds revealed that although observers recognized that two eyes would be better than one, they failed to appreciate the *extent* to which binocular viewing enhances depth perception. In general, observers' estimated their monocular performance fairly accurately but overestimated binocular depth thresholds at all but the lowest scotopic luminance. That is, observers underestimated their stereoacuity. These findings add to the evidence that observers cannot accurately estimate their visual abilities in familiar conditions.

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G62 *757* What is retinal disparity?

Kai M Schreiber[1] (kai@berkeley.edu), Clifton M Schor[1]; [1]School of Optometry, UC Berkeley

Retinal disparity is usually thought of as a 2D vector representing the deviation from retinal correspondence. It's assumed to decompose naturally into two orthogonal components, called horizontal and vertical disparity. Extensive literature has shown these components to be processed in fundamentally different ways. But when eye movements and non-identical correspondence patterns are taken into account, the simple definition of retinal disparity breaks down. In general, neither horizontal, nor vertical disparity, nor, indeed, the disparity vector itself, are well defined entities. Retinally, a binocular target is represented by one 2D position vector for each eye, or four dimensions. If disparity is assumed to be the difference between these projection vectors and a retinal correspondence pattern, the resulting entity has eight degrees of freedom - four more than a retinally located 2D disparity vector would have. Only when empirical retinal correspondence obeys certain constraints can disparity be reduced to such a vector. But even then it can not be simply split into retinal horizontal and vertical components, because moving eyes change the relationship between retinal locations and epipolar projection geometry. A practical consequence of these theoretical issues is demonstrated using the induced effect as an example. We also present a review of the experimental disparity literature and compare the coordinate systems and effective retinal disparity stimuli used across studies.

G63 *758* Disparities in non-vertical spatial frequency components extend the range of accurate depth perception in humans.

Saumil S. Patel[1,2,3] (saumil@swbell.net), Harold E. Bedell[2,3]; [1]College of Engineering, University of Houston, Houston, TX., [2]College of Optometry, University of Houston, Houston, TX., [3]Center of Neuro-Engineering and Cognitive Science, University of Houston, Houston, TX.

Purpose>> We tested how disparity information from non-vertical spatial-frequency components (SFCs) contribute to the range of the human stereovision system by comparing the perceived depth of stimuli that contained differing orientation bands . **Methods>>** Observers (N=3) adjusted the perceived depth of a small (4x4 arc-min) bright probe to match SF band-pass (2-4 cpd) and orientation low-pass filtered random-dot stimuli (mean luminance = 3 cd/sq. m, 24% RMS contrast) with crossed and uncrossed relative disparities up to 30 arc-min. The highest orientation present in the orientation band of the stimulus (cut-off orientation) ranged from 15 to 89 o[rientation]deg, where 0 odeg represents a vertically oriented SFC. From the data, we computed the range of stimulus disparities for which perceived depth (1) changed monotonically in the veridical direction (VDmax) and (2) was in the veridical direction with respect to the reference plane (Dmax). In addition, we assessed the discrepancy between the changes in perceived and veridical depth within the VDmax range (Quality). **Results>>** For all observers, VDmax increased by a factor of 2 as cut-off orientation increased from 15 to 89 odeg. Across observers, Dmax also increased by approximately a factor of 2 as the cut-off orientation increased and exceeded VDmax by at least a factor of 2. The Quality of perceived depth was within approximately 10% of veridical for all cut-off orientations. **Conclusions>>** Perception of accurate suprathreshold depth results from the pooling of disparity signals from vertically and non-vertically tuned neural mechanisms.

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G64 *759* "Stereoscopic Depth and the Occlusion Illusion"

Karen B. Schloss[1] (kschloss@berkeley.edu), Stephen E. Palmer[1]; [1]Department of Psychology, University of California, Berkeley

In the occlusion illusion, the visible portion of a partly occluded object appears larger than a non-occluded, physically identical region (Kanizsa, 1979). Does the visual system ?fill in? a strip along the occluded border (the partial modal completion hypothesis), or does it perceive the occluded object as farther away and therefore larger (the apparent distance hypothesis), as in the moon illusion? Previous experiments using flat displays revealed larger illusions with stronger occlusion cues and stronger evidence for partial modal completion than apparent distance (Brooks, Lai, & Palmer, VSS-04). The present experiments used stereoscopic displays to better understand this illusion. A ?standard? partial-circle was presented in the monitor?s depth plane simultaneously with a ?comparison? partial-circle and its rectangular occluder. The depth plane of the rectangle and comparison partial-circle varied independently, each appearing in front of, co-planar with, or behind the standard. Additional control conditions contained no rectangle. Participants judged the size (Experiment 1) or depth (Experiment 2) of the comparison figure relative to the standard. Experiment 1 showed that when the comparison figure was stereoscopically in front of the adjacent rectangle, the occlusion illusion was significantly reduced, but not eliminated, probably because monocular T-junctions continue to support the perception of occlusion. Experiment 2 showed that depth judgments of the comparison figure were not measurably influenced by the rectangle, suggesting that differences in apparent distance in Experiment 1 are unlikely to have produced the occlusion illusions. The results are interpreted as consistent with the partial modal completion hypothesis. (See http://ist-socrates.berkeley.edu/~plab/ projects.htm)

URL: http://ist-socrates.berkeley.edu/~plab/projects.htm

G65 *760* Effects of Spatial Frequency, Contrast, and Stimulus Size on the Magnitude of Perceived Depth and Speed

Jin Qian[1] (lucy_tsan@hotmail.com), Saumil S. Patel[1, 2, 3], Harold E. Bedell[1, 3]; [1]College of Optometry, University of Houston, [2]Department of Electrical and Computer Engineering, University of Houston, [3]Center for Neuro-Engineering and Cognitive Science, University of Houston

Purpose. To investigate if similar neural processing underlies the perception of stereoscopic depth and motion, the effects of spatial frequency, contrast, and stimulus size on the perceived magnitude of suprathreshold depth and speed were studied using identical stimuli. Method. To assess perceived depth, Gabor pairs with different phase disparities were presented simultaneously for 167 ms at a distance of 1 m. In different blocks of trials, the test stimuli had a spatial frequency of 1 to 4 c/deg, a contrast of 3 to 50%, and a size of 1 to 4 deg. The subjects (N=2) free fused and reported if the test stimulus was further from or closer to the reference plane than a comparison stimulus – a black-white edge that varied in disparity from trial to trial according to a staircase. The stimuli used to assess perceived speed were identical, except they were presented successively to produce two-frame apparent motion. The subjects reported if the speed of the test stimulus was faster or slower than the comparison moving edge. Results. Across subjects, the perceived depth and speed of the test stimulus varied idiosyncratically with spatial frequency. However, for both subjects per-

ceived depth was independent of stimulus contrast and size, whereas perceived speed increased systematically with the contrast and size of the test stimulus. Conclusion. The dissimilar effects of changing stimulus contrast and size on the perception of suprathreshold depth and speed indicate that distinct neural processing underlie the perception of stereoscopic depth and motion.

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G66 *761* Stereograms that consist of veridical image for one eye and lightness afterimage for the other eye

Masahiro Ishii[1] (ishii@iis.toyama-u.ac.jp), Zheng Tang[1], Hiroki Tamura[1]; [1]University of Toyama

Stereograms are pairs of images that differ in the relative lateral displacement of elements such that, when viewed stereoscopically, they produce compelling illusions of depth from a completely flat surface. In the meantime, prolonged steady viewing of an achromatic stimulus with high contrast produces afterimage that has opposite lightness of its original stimulus. This study examined if a stereogram that consists of a veridical image for one eye and a lightness afterimage for the other eye produces depth perception. In experiment, human subjects observed computer-generated stimuli with a mirror stereoscope in a darkroom. Each trial of the experiment consisted of an adaptation phase and a test phase. Random-dot stereograms, in which a central square area had crossed or uncrossed disparity against the surround area, were used. In an adaptation phase, a random-dot image that consisted of white colored dots on black background was displayed to one eye, while the other eye's image was fully black. Subject stared at a fixation point provided at the center of the stimulus for 45 seconds. In a test phase, the random-dot image was erased and fully white display was alternatively given to the one eye, while the half of the random-dot stereogram was given as a veridical image, black dots on white background, to the other eye. Ten subjects, every subject could perceive depth from conventional random-dot stereograms and lightness afterimage took part in the experiment. As the experimental result, all the subjects perceived depth from the stereograms with lightness afterimages and veridical images.

G67 *762* Computations underlying fine and coarse stereopsis

Takahiro Doi[1] (taka_d@bpe.es.osaka-u.ac.jp), Seiji Tanabe[1], Ichiro Fujita[1]; [1]Laboratory for Cognitive Neuroscience, Graduate School of Frontier Biosciences, Osaka University, Japan

In the early stage of stereo processing, neurons encode the disparity energy of stereo images. These neurons appear to encode the depth of images without a global-match solution to the stereo correspondence problem. In higher processing stages, responses to false matches are attenuated in the ventral pathway, while the disparity-energy signal is passed on to the dorsal pathway. To understand how these two types of depth information contribute to stereopsis, we examined human psychophysical performance in depth discrimination at various binocular disparity levels. Subjects were required to discriminate the depth of a random-dot stereogram that comprises two groups of dots: one with the same contrast between the two eyes, and the other with the opposite contrast. Altering the percentage of dots belonging to each group allowed us to test the computation underlying stereo performance at each disparity level. In trial blocks in which the disparity was large, subjects perceived no depth when the percentage of the two groups was equal, and reversed depth when the opposite-contrast group dominated. In blocks in which the disparity was small, subjects perceived correct depth when the percentage of the two groups was equal, and no depth when the opposite-contrast group dominated. We conclude that the two depth representations contribute to stereopsis in a manner that depends upon the disparity scale demanded by the task. The disparity energy-like representation is used for coarse scale discrimination, while the false-match-attenuated representation is employed for fine depth discrimination.

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G68 *763* Combination of horizontal and vertical disparity gradient with concentric pattern

Céline Devisme[1,2] (devismec@essilor.fr), Björn Drobe[2], Annie Monot[3], Jacques Droulez[1]; [1]LPPA - Collège de France CNRS, 11 place Marcellin Berthelot, 75005 Paris, France, [2]Essilor International, R & D Vision, 57 avenue de Condé, 94106 Saint-Maur, France, [3]MNHM, CRCDG - Equipe Vision, 36 rue Geoffroy-Saint-Hilaire, 75005 Paris, France

The effect of vertical and horizontal disparities can locally enhance or cancel each other as a function of their depth sign (Matthews et al., 2003 Vision Research 43 85-99). Can vertical disparities, suitably computed, minimize the depth effect of horizontal disparity gradient? We have already shown that thresholds of plane deformation detection, either concave or convex, induced by concentric gradient of horizontal disparity depended on disparity gradient and on its location (Devisme et al., 2004 Perception 33 Supplement 93). In this last experiment, we were interested in whether the presence of subthreshold vertical disparities would affect thresholds of deformation detection induced by disparity gradient. The stimulus consisted of a sparse random-dot display (Devisme et al., 2005 Perception 34 Supplement 114). A concentric pattern of vertical disparity gradient was applied on the stimulus between two eccentricities. Vertical disparities were computed to have opposite signs between adjacent quadrants of the visual field. However these vertical disparities had to involve no depth deformation perception. Horizontal disparity gradient, which progressively increased, was added at the same location. The observer's task consisted in detecting the deformation of the frontoparallel plane. Results suggested that the addition of vertical disparity gradient can decrease the sensitivity to horizontal disparity gradient in peripheral visual field. The processing of combined horizontal and vertical disparity gradients of opposite depth sign depend on the location in the visual field: vertical disparities, in concentric variation, seem to be differently processed according to eccentricity.

Face Perception: Neural Mechanisms

G69 *764* Characterization of subjects with congenital prosopagnosia by combined electrophysiological and behavioural data

Joachim E. Weber[1] (j.e.weber@t-online.de), Tilmann Sander[2], Claus C. Carbon[3], Thomas Grueter[4], Martina Grueter[4], Gabriel Curio[1], Lutz Trahms[2], Andreas Lueschow[1]; [1]Dpt. of Neurology, Charité-Universitätsmedizin Berlin, Germany, [2]Physikalisch-Technische Bundesanstalt, Berlin, Germany, [3]Faculty of Psychology, University of Vienna, Vienna, Austria, [4]Münster, Germany

Recently a form of prosopagnosia has attracted attention that is not accompanied by any discernible brain lesion. Because subjects complain a lifelong impairment and because a familial clustering has been reported this condition has been termed congenital prosopagnosia (cPA) although sensu stricto "congenital" requires the molecular establishment of a genetic basis. In the absence of such determination of this neuropsychological condition as an entity on its own it is necessary to aim at a delineation by neuroimaging and behavioural data. In 14 subjects with cPA and 19 controls (screened by a specially developed questionnaire) evoked responses were measured by simultaneous EEG and MEG in a viewing task with a sequence of faces and houses. A double dissociation between methodology and category was revealed: only MEG, but not EEG, showed an M170 (a component that has been linked to structural encoding of faces and to intercategorical discrimination) that was significantly delayed over the left hemisphere and reduced over the right hemisphere in the cPA group. The M170 for houses was not altered, suggesting that the deficit is restricted to a face processing system. Additional analysis with accuracy data from three basic tests (face-familiarity, face recognition, face imagery) revealed a

significantly negative correlation between hit rate and latency of M170 over the left hemisphere for subjects with cPA only. Peak amplitude over the right hemisphere was not correlated with accuracy, one possible reason being simply that amplitude measures (especially in MEG) are much more susceptible to error than measures of latency.

G70 *765* Voice Recognition in a Prosopagnosic Patient: an fMRI Study

Stephen R. Arnott[1] (sarnott3@uwo.ca), Robert W. Kentridge[2], Charles A. Heywood[2], Jennifer K. E. Steeves[3], Melvyn A. Goodale[1]; [1]Department of Psychology, The University of Western Ontario, [2]Department of Psychology, University of Durham, [3]Department of Psychology, Atkinson College, York University

Voices, in addition to faces, enable person identification. In particular, voice recognition has been shown to evoke a distributed network of brain regions that includes, amongst others, the fusiform face area (FFA) and the anterior temporal lobe. In the present fMRI study, we examined fMRI brain activation in a prosopagnosic patient M.S. who, despite extensive late-onset damage to these two areas, nevertheless retains the ability to recognize people based only on their voice. Relative to speech-modulated noise, familiar and unfamiliar voices elicited enhanced hemodynamic activity in the posterior portion of the left superior temporal gyrus, as well as the left planum temporale (pT) and posterior cingulate gyrus (pCG). Region-of-interest analyses on those areas revealed that pT and pCG activity was greater for voices rated as familiar as opposed to unfamiliar. Results are consistent with the notion that an intact FFA is not essential for voice recognition. Instead, the activation seen in this face-sensitive region during voice recognition tasks in healthy subjects may reflect some form of implicit face imagery.

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G71 *766* Motion-Defined Face and Object Recognition: Evidence from Psychophysics, Neuropsychology, and Functional Imaging

Reza Farivar[1] (reza.farivar@mail.mcgill.ca), Jürgen Germann[1], Michael Petrides[1], Olaf Blanke[2], Avi Chaudhuri[1]; [1]Department of Psychology, McGill University, Montreal, Canada, [2]Brain-Mind Institute, École Polytechnique Fédéral de Lausanne, Switzerland

The studies we report concern recognition of complex objects, such as faces, defined solely by motion cues. Dynamic object shape cues, such as structure-from-motion, are thought to be largely mediated by dorsal-stream areas, such as MT and MST. However, object recognition in general, and unfamiliar face recognition in particular, are strongly believed to be mediated by ventral stream areas. Thus, recognition tasks involving motion defined faces offer a unique opportunity to probe dorsal-ventral integration and its role in complex object recognition. Here, we report data from several psychophysical, neuropsychological, and functional imaging studies that we have conducted in exploring these questions. Our results show that (a) purely motion-defined unfamiliar faces can be recognized, (b) classic effects such as the Inversion Effect may also apply to the recognition of unfamiliar faces defined by motion, (c) intact cortical motion processing mechanisms are necessary for the perception of structure-from-motion objects, (d) intact cortical face processing mechanisms are necessary for the recognition and learning of motion defined faces, and finally, (e) motion-defined faces may not engage the Fusiform Face Area, but the Occipital Face Area. Taken together, our results make several important theoretical contributions. First, that dorsal-ventral integration is necessary for motion-defined object recognition. Second, putative face areas identified thus far with face photographs may not be responsive to dynamic 3D percepts. Finally, the presence of this integration suggests our simplistic hierarchical view of the ventral stream is incomplete.

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G72 *767* A Normal N170 Response in Acquired Prosopagnosia with Damage to Right Anterior Temporal Lobe

Cindy M. Bukach[1] (cindy.bukach@vanderbilt.edu), Jessie Peissig[2], Michael J. Tarr[2]; [1]Vanderbilt University, Tennessee, [2]Brown University, Rhode Island

The N170 is a component measured with event-related potentials (ERP) that typically shows a higher amplitude to faces than to non-face objects and is delayed when faces are inverted. Of the acquired prosopagnosics that have been studied, only one has shown evidence for normal face-selectivity in the N170 (Rossion et al., 2004), and none have demonstrated a normal N170 delay in response to inverted faces. Thus, the functional significance of the N170 is still very much an open question. LR is a prosopagnosic who, after suffering damage to his right anterior temporal lobe, can no longer recognize faces, familiar or otherwise. Behavioral testing reveals that LR has a remarkably preserved ability to make local fine-level discriminations and shows some holistic processing of coarse-grain information. LR's impairment appears to disrupt his ability to integrate multiple fine-grained features into a more complex representation (Bukach et al., 2006). Interestingly, LR does seem to retain the ability to process fine-grained details in a limited region around the mouth. Here, we present evidence that LR shows a normal N170 to faces, and a delayed N170 to inverted faces. These findings are consistent with the idea that the N170 is a marker for the preprocessing of faces rather than their recognition and that LR's impairments have left early visual processing relatively preserved.

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G73 *768* Face detection in normal subjects and prosopagnosics

Bradley Duchaine[1] (b.duchaine@ucl.ac.uk), Lucia Garrido[1], Ken Nakayama[2]; [1]Institute of Cognitive Neuroscience, University College London, London WC1N 3AR UK, [2]Harvard University

In theories of normal face recognition and in machine vision, face detection is a crucial stage. Despite its importance we know little about face detection in normal subjects or prosopagnosics. To investigate this, we compared normals and prosopagnosics on two face detection tests.In the first test, two tone images were created by adjusting the threshold controls in Adobe Photoshop, so that darker areas became black and lighter areas became dark. Each face was surrounded by a large field of individual features drawn from other faces that served to make the facial configuration much more difficult to perceive. Blocks consisted of 48 stimuli, 36 contained a face while 12 did not. Subjects did upright and inverted blocks, and they were counterbalanced. They were asked to make a key press when they detected a face. Controls were nearly three times slower with inverted faces than with upright faces and accuracy was far worse with inverted faces. In the second test, subject were presented with 5x5 arrays of photographs and made a key press when they detected a photograph containing a face. Thirty-seven stimuli were presented, 25 contained a face while 12 did not. It took approximately twice as long for controls to detect inverted faces compared to upright faces. Prosopagnosics were tested with upright versions of each test. Most prosopagnosics performed normally on both face detection tests, but some showed clear impairments with both tasks. The results indicate that face detection is separate from later face processing.

769 Abstract withdrawn.

G74 *770* Cortical responses to invisible facial information

Sheng He[1] (sheng@umn.edu), Yi Jiang[1]; [1]Department of Psychology, University of Minnesota

Recent studies have revealed that stimuli of high valence can activate the emotional system in the human brain without observers' awareness. In the current study, we used event-related fMRI to measure the hemodynamic

response of face-selective brain regions when observers viewed neutral, fearful and scrambled faces. These stimuli were either presented consciously or rendered invisible through interocular suppression. Using scrambled faces as the baseline, results show that both the fusiform face area (FFA) and superior temporal sulcus (STS) had strong activations to visible neutral and fearful faces. In the suppressed condition, when observers were not aware of the face pictures, the FFA still showed substantial activation for both invisible neutral and fearful faces, whereas the STS only responded to invisible fearful faces. This pattern of results suggests that FFA and STS play different roles in the processing of facial information. Our observation provides further support for the dissociable neural systems that are specialized for facial structural encoding vs. facial expression analysis (Bruce & Young, 1986, BJP) or invariant aspects of faces vs. changeable aspects of faces (Haxby et al., 2000, TICS). More surprisingly, the separate functions for facial information processing were only revealed in the invisible condition. We hypothesize that when images were suppressed interocularly, the observed BOLD responses reflect more of a feed-forward visual information processing without the influence of the feedback modulation from conscious representation of faces, and such isolation of the feed-forward process made it possible for us to reveal the distinct functions of FFA and STS.

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Sunday Posters

G75 *771* An exploration of face selectivity in human inferior frontal cortex

Annie W-Y Chan[1] (pspc1f@bangor.ac.uk), Marius V Peelen[1], Paul E Downing[1]; [1]School of Psychology, University of Wales, Bangor, UK

We used fMRI to ask whether stimulus driven face selectivity exists in human prefrontal cortex, as found in the macaque (OScalaidhe et al., 1999). In Experiment 1, faces, bodies, tools, and scenes were presented in a blocked design, with either a free viewing task (N=8) or a 1-back task (N=8). Unbiased ROI analyses showed right posterior inferior frontal gyrus (pIFG) selectivity for faces in the 1-back task, and for faces and bodies with passive viewing. The right fusiform face area (rFFA) showed a comparable (although more selective) pattern. Experiment 2 (N=14) tested faces, bodies, and objects, and their component parts, in an event-related passive viewing paradigm. The global rFFA response was stronger than in pIFG, but both areas showed similarly strong body and face selectivity (relative to objects) for wholes, with little (rFFA) or no (pIFG) selectivity for parts. Experiment 3 (N=6) focused on the contribution of the eyes. Whole faces, faces with the eyes masked, pairs of eyes alone, and flowers were passively viewed in a blocked design. The two areas responded differently: while the rFFA responded maximally to whole faces, the pIFG responded most to the eyes alone, and did not distinguish between faces with eyes masked and flowers. We conclude that there is significant face-selectivity in human pIFG. Experiment 3 indicates that this selectivity is driven by different aspects of the face compared to rFFA, likely including the social, emotional, or attentional characteristics of human eyes.

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G76 *772* House Training: Neural correlates of object learning

Jesse S Husk[1] (huskjs@mcmaster.ca), Lisa R Betts[1], Kathleen M O'Craven[3], Patrick J Bennett[1,2], Allison B Sekuler[1,2]; [1]Department of Psychology, Neuroscience, & Behaviour, McMaster University, [2]Centre for Vision Research, York University, [3]The Rotman Research Institute

The Fusiform Face Area (FFA) is associated with stronger BOLD responses to faces than to other objects (Kanwisher et al., 1997). Expertly processed objects also are associated with stronger activity within this region (Gauthier & Tarr, 1997; Gauthier et al., 2000), suggesting the FFA may not be devoted to faces per se, but to within-category discrimination of expertly-learned objects. However, these studies have not addressed the effect of learning on regions beyond the FFA.Using whole brain imaging, we examined the activity associated with faces, and trained and untrained houses before and after 5 days of training on a 4AFC house-discrimination task. The parahippocampal place area (PPA) responds preferentially to houses and scenes (Epstein & Kanwisher, 1998), so we sought to determine whether training induces a shift in the cortical locations responsive to houses (for example, a shift from PPA to FFA activation), or a change specifically within the PPA. A partial least squares analysis showed that the data were well described by a contrast of the activity for houses versus faces. The strength of this contrast grew with training, suggesting greater differentiation of faces from houses after training. Despite this global change, a region of interest analysis indicated no significant activity changes within either FFA or PPA.Together, these results suggest that house training enhances the global patterns of activity differentiating faces from houses, without substantially altering activity within more localized object processing regions.

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G77 *773* The effect of picture-plane rotation on early face categorization processes

Corentin Jacques[1] (corentin.jacques@psp.ucl.ac.be), Bruno Rossion[1]; [1]Unite Cognition & Developpement, University of Louvain, Belgium

Picture plane inversion of a face image dramatically impairs face recognition. This effect occurs at perceptual encoding, as suggested by the observation of a peak latency delay and amplitude increase of the early face event-related potential (ERP) N170 to inverted compared to upright faces (e.g. Rossion et al., 1999). However, the factors driving this latency and amplitude increase, as well as the relationship between these modulations and behavioral face inversion effects remain unclarified. To address this question, we presented subjects (n=25) with faces at 12 different orientations in 30° steps while recording ERPs. At the N170, parametric changes in face orientation yielded distinct patterns of amplitude and latency modulations. Whereas the entire amplitude modulation of the N170 was observed in the 0° to 90° range with no further increase from 90° to 180°; the latency increase with orientation was mostly observed in the 60° to 180° range. Behavioural performances over the 12 orientations were measured in a same/different matching task. Accuracy and reaction times data followed a sigmoid-like function with modulations mostly observed between 30° and 120°. This pattern of behavioral result closely matches the observed amplitude modulation pattern of the N170, not the latency. These results show for the first time a dissociation between amplitude and latency modulations of the N170 as a result of picture-plane rotation of face images. Moreover they suggest a strong relationship between N170 amplitude increase and the behavioral face inversion effect.

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G78 *774* On the nature of privileged visual stimuli: Partial immunity from within-class inhibition

Bethany L. Schneider[1] (bschneid@indiana.edu), Jordan E. DeLong[1], Thomas A. Busey[1]; [1]Department of Psychological and Brain Sciences, Indiana University, Bloomington

In four experiments we examine whether upright and inverted faces are processed by a single class of neurons with identical response properties, or by two separate and non-interacting populations. In Experiment 1, we examined upright and inverted faces across two contrast levels and one signal to noise ratio, yielding a crossover interaction of the N170 amplitude: when presented in noise, the amplitude of the inverted face was smaller than the upright face, while the reverse is true without noise. In Experiment 2, we showed that the amplitude reversal was robust for full but not partial faces across all noise levels. In Experiment 3, we varied contrast to see if reversal was a result of degrading a face. We observed no

reversal effects. Thus, across conditions, adding noise to full faces was a necessary and sufficient condition for the N170 reversal. This is consistent with a model in which inhibition occurs between neurons processing noise and inverted faces, but not upright faces. In Experiment 4, we delayed onset of the upright/inverted face presented in noise. We replicated the smaller N170 for inverted faces at no delay, but observed recovery of the N170 for inverted faces at longer delays. These data support a model in which neurons responding to noise inhibit those responding to inverted faces, with inhibition waning to produce selective recovery at longer SOAs. Thus, two visual stimuli processed by the same population may result in a competition via inhibition for neural representation, which spares stimuli processed by separate populations.

G79 *775* Distributed representation of facial identity studied with fMRI

Amy L. Thomas[1] (thomasam@mail.med.upenn.edu), Geoffrey K. Aguirre[1]; [1]University of Pennsylvania

Visual stimuli may be represented by ensembles of neuronal activity. We tested if the perceptual similarity of faces is reflected in the similarity of neural patterns evoked by those faces.During pilot studies, the pair-wise, perceptual similarity of 27 photo-realistic, synthetic faces was determined. During fMRI scanning, subjects viewed repeated, counterbalanced presentations of the faces while they performed a perceptual judgment orthogonal to face similarity (a separate manipulation of apparent age). The pattern of fMRI activity across voxels was obtained for each face, and used to create a matrix of pair-wise similarity measures of neural responses between the face stimuli. This matrix of neural similarity was then correlated with a separately obtained matrix of perceptual similarity, as well as a physical (pixel-based) measure of stimulus similarity. These analyses were conducted for voxels within ventral extra-striate cortex (VES) and within earlier visual areas (V1/V2).Within VES, the average correlation across subjects between perceptual and neural measures of face similarity was 0.22 (diff from zero, p=1.7e-5). The physical similarity matrix produced significantly (p=0.004) lower correlations (r=0.17). Within V1/V2, the correlation of the neural similarity matrix with the perceptual (r=0.08) and physical (r=0.10) measures were significantly weaker (p=0.005). Physical similarity fit the neural responses within V1/V2 better than perceptual similarity, although not significantly so (p=0.15).A measure of facial representation can therefore be derived from large scale patterns within VES. We are currently determining the degree to which categorically defined cortical regions within VES (i.e., FFA, PPA, LOC) contribute to this representation.

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G80 *776* Symmetry is in the eye of the Fusiform Face Area

Roberto Caldara[1] (r.caldara@psy.gla.ac.uk), Mohamed Seghier[2]; [1]Centre for Cognitive Neuroimaging, Department of Psychology, University of Glasgow, United Kingdom, [2]Functional Imaging Laboratory, University College of London, United Kingdom

Symmetry in objects pervades our visual world, so perhaps it is not surprising that human beings show a strong sensitivity to this geometrical constraint. Among symmetrical objects, the most relevant class of stimuli is undeniably constituted by human faces. Symmetry in faces has often been considered an important property for beauty and genetic fitness, both representing crucial factors for social and biological interactions. At the neural level, we recently demonstrated that particular low-level structural properties shape the responses of the right middle fusiform gyrus (the Fusiform Face Area - FFA), an area showing a preference for faces over objects. The FFA is tuned to curvilinear patterns with more high-contrasted elements in the upper part, a mechanism that might drive the automatic detection of faces in the visual world (Caldara et al., 2006). However, it is still unknown whether and how the neural structures devoted to process faces are sensitive to symmetry. Here, we used functional Magnetic Resonance Imaging to investigate this question. Participants were presented with symmetrical and asymmetrical curvilinear head-shaped patterns with either more elements in the upper or the lower vertical part. These patterns were not perceived as faces. The FFA showed larger activations for curvilinear patterns with more elements in the upper part, replicating our previous observations. Crucially, a violation of symmetry significantly decreased the responses of this neural structure. These findings provide direct evidence that the FFA is tuned for geometrical properties best fitting with the structure of faces and that symmetry finely calibrates such neural tuning.

G81 *777* View-specific coding of face shape

Linda Jeffery[1] (linda@psy.uwa.edu.au), Gillian Rhodes[1], Tom Busey[2]; [1]The University of Western Australia, [2]Indiana University, Bloomington

View-specific face neurons occur in monkey and human cortex, but it remains unclear whether these code face shape. We tested the view-specificity of face shape coding by inducing figural face aftereffects at one viewpoint (3/4 left) and testing generalization to different viewpoints (front-view and 3/4 right). The aftereffects are induced by adaptation to consistent figural distortions (contracted or expanded), which shift the distortion perceived as most normal toward the adapting distortion. A strong aftereffect was observed at the adapting view, which was significantly and substantially reduced for front-view test faces, indicating view-specificity. For mirror image (3/4 right) test faces, the opposite aftereffect was observed, which cannot be accommodated by a view-independent account of face shape coding. The aftereffects survived a size change between adapt and test faces (Experiment 2), ruling out low-level adaptation. We further demonstrated view-specificity by inducing figural aftereffects that were contingent on viewpoint (Experiment 3). Simultaneous adaptation to contracted faces at 30 degree right views and expanded faces at one of the following views, 30 degrees left, front view, 30 degrees right, 60 degrees right, 90 degrees right or no contingency, produced view-contingent aftereffects in 30 degree right test faces that reduced as the expanded adapting viewpoint approached test viewpoint. These results provide strong evidence that face shape coding is view-specific, with broad tuning for view.

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G82 *778* Recognizing a person by face: dissociating brain regions involved in perceptual and conceptual components of person identification

Nikolaus Kriegeskorte[1] (niko@nih.gov), Marieke Mur[1], Douglas Ruff[1], Jerzy Bodurka[1], Peter Bandettini[1]; [1]Section on Functional Imaging Methods, Laboratory of Brain and Cognition, National Institute of Mental Health

Recognition of a familiar face affords access to a wealth of perceptual and conceptual information about the identified person, including biographical information. The fusiform face region and anterior temporal cortex have been implicated in person identification by face. However, it remains unclear what precise roles they serve in the process. Here we attempt to dissociate the diverse perceptual and conceptual representations automatically activated when a face is recognized. We measured brain activity with functional magnetic resonance imaging (fMRI) while subjects viewed face images of three levels of familiarity: (1) faces they had never seen before (unfamiliar faces), (2) faces repeatedly viewed previously (perceptually familiar faces) and (3) faces repeatedly viewed previously in conjunction with associated names and short biographies (known individuals). Blood-oxygen-level-dependent fMRI measurements were performed at high resolution (1.95 x 1.95 x 2 mm3 voxel volume) using a 3T scanner (GE) and a custom-made 16-channel head coil. In the three subjects studied so far, we found similar patterns of activity during perception of faces of all three levels of familiarity, including early visual regions and the fusiform face region. We found a slightly greater response to less familiar faces (greatest for unfamiliar ones) in the fusiform face region in one of three subjects analyzed so far. Anterior temporal regions showed a slightly

greater response to faces of known individuals than to merely perceptually familiar faces in two of three subjects.

G83 *779* I can't recognize your face but I can recognize its movement

Leslie L. Steede[1] (lls21@sussex.ac.uk), Jeremy J. Tree[2], Graham J. Hole[1]; [1]University of Sussex, [2]University of Exeter

Recent research indicates that idiosyncratic facial movements can provide a route to facial identity (review in Roark et al., 2003), but it is unclear whether recognizing a face by its idiosyncratic facial movements involves the same neural mechanisms that are involved in recognizing a static face image. Here we report the results from a developmental prosopagnosic (CS), who, whilst being severely impaired at recognizing static faces, can discriminate between dynamic identities (experiments 1a & 1b) and learn to name individuals on the basis of their idiosyncratic facial movements (experiment 2). Across 3 experiments, CS's ability to use idiosyncratic facial motion as a cue to identity was either comparable to (experiments 1a and 2) or significantly better than (experiment 1b) that of matched and undergraduate control groups. CS's superior performance in experiment 1b may reflect a dependence on motion information as a compensatory strategy to recognize people around him. This dissociation between an impairment in using static facial information to compute identity, and preserved ability in using idiosyncratic facial motion information to compute identity, indicates that the neural mechanisms involved in recognizing a static face image may be dissociable from those involved in recognizing an individual on the basis of their idiosyncratic facial movements.

G84 *780* Visual competition during early face processing is driven towards stimuli at the fovea

Guillaume A Rousselet[1] (rousseg@mcmaster.ca), Olivier D'Arripe[2], Bruno Rossion[2], Corentin Jacques[2]; [1]McMaster University, Department of Psychology, Hamilton, ON, Canada, [2]University of Louvain, Unite Cognition et Developpement and Laboratoire de Neurophysiologie, Belgium

The N170 component to a face stimulus presented in the periphery is strongly reduced when another face is present at the fovea (Jacques & Rossion, NeuroReport, 2004). A similar but smaller reduction is observed for fixated faces in the context of peripheral faces (Jacques & Rossion, JOV, in press). Together with the fact that the N170 decreases with eccentricity (Rousselet et al., JOV 2005), these results suggest the existence of a visual competition modulated by a foveal bias, the N170 amplitude being mostly driven by the stimulus at the fovea. Here we clarify this question in an experiment in which a face or a scrambled-face was presented at the fovea together with 2 peripheral faces or scrambled-faces centered at 5 degrees to the left and right of the fixation point. As hypothesized, the N170 amplitude was mostly driven by the stimulus at the fovea.This was particularly true for a foveal face stimulus, in which case there was no increase associated with peripheral faces at left and temporal sites, and a small increase at occipital right hemisphere sites. The presence of a scrambled-face at the fovea, presented simultaneously with peripheral faces, tended to drive the signal toward the lower N170 response to a scrambled-face alone. Yet, there was still an increase due to faces presented in the periphery. This effect had a bilateral occipital-temporal topography. These results suggest that foveal stimuli have a strong competitive advantage over stimuli in the periphery, an effect that is even stronger for faces.

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G85 *781* A Contralateral Preference in Face and Object Selective Cortex

Christopher C. Hemond[1] (chemond@mit.edu), Hans P. Op de Beeck[1], Nancy G. Kanwisher[1,2]; [1]McGovern Institute for Brain Research and Department of Brain & Cognitive Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139, USA, [2]Martinos Center for Biomedical Imaging, Charlestown, Massachusetts, USA

Early visual areas respond preferentially to the contralateral visual field, whereas this contralateral preference becomes weaker at higher levels of visual cortex. Here we used fMRI to test whether a contralateral preference exists in object-selective and face-selective regions generally considered to be 'high-level' visual regions. Subjects (N=9) fixated on a central spot while blocks of faces, objects, scenes, and scrambled images were presented in the right or left visual field (with the closest edge of stimuli being 1.3 degrees from the vertical meridian). These images were slightly colored, and subjects performed a color change detection task. We compared responses to ipsilaterally and contralaterally presented images in primary visual cortex (V1), in two face-selective areas – the occipital face area (OFA) and fusiform face area (FFA) – and two object-selective areas – the lateral occipital gyrus (LO) and posterior fusiform gyrus (PF). V1 showed the expected absence of ipsilateral responses. Regions in the two lateral occipital regions showed more graded contralateral preference, with a response to ipsilateral stimuli that was 45% and 36% the magnitude of the response to contralateral stimuli in OFA and LO, respectively. The contralateral preference was smallest in fusiform gyrus, with a response to ipsilateral stimuli that was 75% and 67% the response to contralateral stimuli in FFA and PF, respectively. Nevertheless, the contralateral preference was significant in each region ($p<0.01$). Overall, our results show that a preference for contralateral over ipsilateral stimuli is still present in high-level object-selective and face-selective cortex, albeit weaker than found in 'earlier' cortical areas.

Monday Talk Sessions

Monday, May 8, 2006

Perceptual Learning (782-787), Face Perception: Behavioral and Clinical (788-793), Neurons and Perception (794-800), Adaptation (801-806)

Perceptual Learning

8:00 - 9:30 am

Hyatt Ballroom North

Moderator: Michael J. Wenger

8:00 *782* **Learning to parse images through dynamic experience**

Yuri Ostrovsky[1] (yostr@mit.edu), Pawan Sinha[1]; [1]Massachusetts Institute of Technology

Motion has been identified as a primary cue for object segmentation in infant development (Kellman & Spelke, 1983; Johnson & Aslin, 1995). Our work with patients with late visual onset (Ostrovsky & Sinha, 2005) indicates that motion-based segmentation processes are evident soon after sight onset, despite many years of visual deprivation. Because motion analysis is both robust and early, it is possible that motion might serve as a bootstrapping mechanism for the subsequent learning of static segmentation cues such as junctions, line continuity and other figural Gestalt cues (Wertheimer, 1912; Kanizsa, 1979).To explore this hypothesis, we have developed a class of ambiguous figures using osculating (aka "kissing") junctions. This junction has two possible interpretations: two curves touching at a point (kissing) or a curved X junction. The kissing interpretation is generally the preferred one. Our experiments suggest that motion is highly effective at disambiguating the figures toward the less-preferred X-junction interpretation, whereas color is relatively ineffective. To investigate a possible role of motion in the learning of object parsing cues, we trained normal adult subjects with these motion stimuli in order to shift the interpretation of the ambiguous junction toward the X interpretation. This shift generalized to other types of figures and even to static presentations, effectively reprogramming the object parsing cues of the visual system. This provides evidence that motion-based segmentation may serve as the base upon which image processing heuristics that are relevant to both dynamic and static displays are learned.

8:15 *783* **Parts to wholes: Configural learning fundamentally changes the visual information processing system**

Leslie M Blaha[1] (lblaha@indiana.edu), James T Townsend[1]; [1]Department of Psychological and Brain Sciences, Indiana University

Models of configural processing often neglect an explanation of how configural mechanisms and representations develop in visual perception. Employing standard information processing models (see Townsend & Ashby, 1983), we investigate how configural learning via perceptual unitization affects and is affected by the underlying information processing system. Over the course of training in a conjunctive categorization task, participants unitized a novel object by perceptually joining individual features into fewer, larger features, leading to a single, holistic representation. Using the capacity coefficient (Wenger & Townsend, 2000), which provides an index of work-load efficiency, we demonstrate that the configural learning process leads to a qualitative shift from extremely limited- to extremely super-capacity processing due to the effective reduction in work load via unitization. Thus, configural learning qualitatively changes the way configural information is processed; additionally, after training, the processing system is consistent with Townsend and Wenger's (2001) working model of configural processing: an exhaustive parallel or coactive system with facilitatory channel interactions which exhibits super-capacity processing. We have modeled these capacity changes with a neurologically-motivated Hebbian learning rule embedded in a parallel system; limited capacity is produced by negative interactions and super capacity by positive interactions (Townsend & Blaha, In Preparation). Alternatively, the shift in capacity could reflect a structural change in architecture from slow, serial processing to fast, parallel processing. Current experiments investigate processing architecture in order to determine which system best captures the essence of configural learning.

8:30 *784* **The space-time continuum: Spatial visual statistical learning produces temporal processing advantages**

Nicholas B. Turk-Browne[1] (nicholas.turk-browne@yale.edu), Brian J. Scholl[1]; [1]Yale University

A central task of vision is to parse undifferentiated input into discrete objects and groups. Visual statistical learning (VSL) may provide an implicit mechanism for such segmentation via the extraction of covariance between features, parts, and groups. However, because the stimuli in previous VSL studies were identical during training and test, it is unclear what is really being learned: the resulting representations could incorporate all visual details of the learning context, or could be more abstract. We have been exploring such issues using 'transfer' designs in which the stimuli differ between training and test. Persistent VSL across changes along a given dimension indicates that such information is not intrinsic to the resulting representation. Here, we report one of the most extreme possible cases of transfer: from space to time. Observers viewed a seven minute sequence of spatial grids, each containing several adjacent shapes. Unbeknownst to observers, shapes were arranged in fixed spatial configurations that could only be segmented into discrete pairs on the basis of covariance. In a subsequent test, observers performed a target detection task on rapid sequences of shapes presented centrally, one at a time. Targets preceded by their spatial mates were detected more quickly than targets preceded by shapes with which they were not paired during training. Because there was no temporal information during training, and no spatial information during test, these results provide striking evidence for a purely associative component of VSL, and also highlight the incredible flexibility of such learning.

Acknowledgment: (BJS was supported by NSF #0132444. NTB was supported by an NSERC PGS-D award.)

URL: http://www.yale.edu/perception/

8:45 *785* **Psychophysical and fMRI Studies of the Role of Prior Knowledge in Visual Perception.**

Jay Hegdé[1] (hegde@umn.edu), Serena K. Thompson[1], Daniel Kersten[1]; [1]Department of Psychology, University of Minnesota, Minneapolis, MN 55455.

Since natural visual images rarely contain locally unambiguous information about visual objects and their boundaries, the visual system must use prior knowledge of relevant objects to constrain possible interpretations of a given image. We explored the neural mechanisms of this process using camouflaged objects, which are difficult to detect without prior knowledge, even when in 'plain view'. We created visual scenes each of which contained a single novel foreground object ('digital embryo', Brady and Kersten, 2003) camouflaged against a cluttered background of additional novel digital embryos. Subjects were trained to detect five different individual foreground embryos ('learned targets') using a bootstrapped learning paradigm. All subjects performed at chance levels during initial phases of the training, indicating that the camouflaged embryos were not detectable without prior knowledge. However, 5 of the 7 subjects learned within 300 trials to reliably detect the designated targets (d' analysis, $p < 0.05$). Following successful training, rapid event-related fMRI scans were carried out while the subject reported whether or not the scene presented during a given trial contained a learned target. We found several cortical foci in either hemisphere that were significantly more responsive during trials that contained a learned target than during trials that contained an unfamiliar target. Furthermore, some foci, including the lateral occipital complex (LOC), were selectively responsive when the subject correctly identified a learned target ($p < 0.05$). Together, these foci may represent parts of a neural mechanism by which prior knowledge of visual objects is brought to bear on visual perception.

Acknowledgment: This work was supported by NEI grant R01 EY015261 and ONR grant N00014-05-1-0124 to DK. The 3T scanner at the University of Minnesota Center for Magnetic Resonance Research is supported by BTRR P41 008079 and by the MIND Institute.

URL: http://jh.psych.umn.edu/digital_embryos

9:00 *786* **Cue Acquisition Based on Visual-Auditory but not Visual-Visual Correlations**

Melchi M. Michel[1] (mmichel@cvs.rochester.edu), Robert A. Jacobs[1]; [1]University of Rochester, Department of Brain and Cognitive Sciences, Rochester, NY

Wallach (1985) hypothesized that people will acquire a new cue to a perceptual judgment when a novel stimulus is correlated with a known cue. We tested this hypothesis in four experiments in which we introduced novel and systematic correlations between different pairs of sensory signals. The first three experiments each paired the visual motion direction of a random-dot-kinematogram with one of three signals. Experiment 1 used an auditory signal (broadband auditory stimulus) whereas Experiments 2 & 3 used visual signals (binocular disparity or brightness). Using a near-threshold conflict between the actual visual motion direction and the direction indicated by the new signal, subjects were evaluated for whether they used the new signal when making direction judgments. Though the procedure was identical in all three experiments, and the signals were each adjusted to be equally salient, subjects learned to use the auditory signal as a cue to motion direction but failed to learn to use either of the novel visual signals. Experiment 4 checked whether subjects' inability to learn the new visual cues was particular to the motion direction discrimination task by asking subjects to make a different perceptual judgment (determining light source direction). As in Experiments 2 & 3, however, subjects were unable to learn a new visual cue. Overall, the results suggest that the learning processes underlying cue acquisition are not equipotent but rather are biased--novel contingencies involving cross-modal signal pairings are easier to learn than novel contingencies involving only visual signals.

Acknowledgment: This work was supported by NIH research grant RO1-EY13149.

9:15 *787* **Distinguishing sensory from perceptual bias in perceptual learning for contrast detection: What is and is not learned**

Michael J. Wenger[1] (mjw19@psu.edu), Jennifer L Bittner[1], Rebecca J. Von Der Heide[1]; [1]The Pennsylvania State University

In a series of studies (reported at VSS '03-'05), we have shown thatperceptual learning for contrast detection may be more complex and/orless dramatic than is assumed. Specifically, we have shown thatreductions in detection threshold are regularly accompanied by liberalshifts in response bias. These shifts are due to false alarm ratesthat either do not change or that increase as a function ofpractice. To date, all of this evidence has been obtained in tasksthat require explicit presence/absence responses, responses that aretypically not required in most studies of visual perceptuallearning. This leaves open the possibility that the effects in biasand false alarm rates might be due to the act of repeatedly givingpresence/absence responses. We tested this hypothesis in experimentsin which observers' performance was assessed in two ways across 12days of practice. On days 1 and 12, thresholds and false alarm rateswere obtained using the method of constant stimuli. On days 2-11,thresholds were estimated using a variety of two-intervaltwo-alternative forced-choice staircase procedures. Thus, on days2-11, no presence/absence decisions were made. Results showed reliabledecreases in threshold, reliable increases in false alarm rates, andan absence of bias for choice of interval. This suggests that even inthe absence of making presence/absence decisions, observers experiencea shift in decisional criteria that is specific to sensorydetection. Implications for what is being learned are considered, withemphasis on the need for a distinction between sensory detection andperceptual labeling.

Face Perception: Behavioral and Clinical

8:00 - 9:30 am

Hyatt Ballroom South

Moderator: Isabel Gauthier

8:00 *788* **Holistic crowding: selective interference between configural representations of faces in crowded scenes.**

David Bressler[1] (xwd40x@hotmail.com), David Whitney[1]; [1]UC Davis, Center for Mind and Brain

When you stare at a face in a crowd, you can easily recognize that person's face. However, it is very difficult to recognize a face that falls in the peripheral visual field when there are other faces surrounding it. There is a great debate about why this crowding effect occurs. It could simply be a function of the eccentricity and complexity of faces and their many parts (interference between the low-level parts or features). Alternatively, many psychophysical, single unit, and functional imaging studies have demonstrated that upright faces, unlike most other objects, are coded holistically in face selective regions of the brain such as the fusiform face area. We might therefore expect crowding of faces to arise because of interference between higher-level holistic representations of these faces. Here we tested this by presenting upright or inverted target faces in a crowd of additional upright or inverted faces. We found that face recognition was selectively impaired only when target faces were presented upright in a crowd of other upright faces. This selective deficit shows that there is a representation of upright faces that is independent from the representation of inverted faces. More importantly, the results demonstrate that crowding can occur between high level representations of objects (the configural aspects), and not just between the low-level features as is often thought. Crowding - interference between similar stimuli - therefore occurs at multiple stages in the visual system.

8:15 *789* **A new type of prosopagnosia? A brain-damaged patient who can recognize faces but cannot discriminate races.**

Shinichi Koyama[1,2] (skoyama@med.showa-u.ac.jp), Akira Midorikawa[1,3], Atsunobu Suzuki[4], Haruo Hibino[2], Mitsuru Kawamura[1,5]; [1]Showa University School of Medicine, [2]Chiba University, [3]National Institute of Neuroscience, NCNP, [4]University of Tokyo, [5]CREST

[Case report] We report a case of a 61 year-old woman with brain damage in the left fusiform and parahippocampal gyri, as well as in the right fusiform gyrus. The patient claimed that she could not perceive "looks" of faces, although she could easily recognize pictures of famous people. She could also discriminate sex and facial expressions in the pictures normally. However, she frequently failed to discriminate races and occasionally failed to see the hollow-face illusion (Gregory 1970), although she could see shading-defined convexity and concavity (Ramachandran 1888). [Method] The patient and 3 normal controls judged if a person pictured was Asian or Middle-Eastern to examine whether perception of faces defined by edge, surface, or edge-surface integration was impaired. Using morphing, we mixed an Asian face and a Middle-Eastern face in 7 different proportions (20% Asian plus 80% Middle eastern => 80% Asian plus 20% Middle-Eastern). After morphing, 3 sets of pictures were made: (1) original pictures, (2) inverted pictures, and (3) edge-defined pictures. Each picture was presented 5 times. [Results] The classification of the inverted and edge-defined pictures by the patient was very similar to that of normal controls whereas the classification of the original pictures by the patient was significantly impaired. [Conclusion] We concluded that the integration of edge and surface was selectively impaired in this patient. These results suggest that integration of the edge and surface plays an important role in the perception of faces, especially in the discrimination of races.

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8:30 *790* **Holistic processing of faces in adolescents with autism spectrum disorder**

Isabel Gauthier[1] (isabel.gauthier@vanderbilt.edu), Cheryl Klaiman[2], Robert T. Schultz[2]; [1]Vanderbilt University, Center for Integrative and Cognitive Neuroscience, [2]Yale Child Study Center

Although it has been suggested that individuals with Autism process faces less holistically than typically developing controls, there have been few direct investigations of this hypothesis. In a recent study (Teunisse & DeGelder 2003), this question was investigated using the composite paradigm. The results revealed that adolescents with Autism were less sensitive than controls to the misalignment of face parts and it was concluded their face processing was less holistic. However, in that study it was not possible to distinguish whether individuals with Autism processed both aligned and misaligned composites in a part-based fashion, or both in a holistic fashion. We compared 21 adolescents with Autism spectrum disorder to 15 controls matched on sex, age and IQ on a modified version of the composite paradigm that included not only trials on which irrelevant parts were different, but also trials in which irrelevant parts were the same. The results revealed that when facial features are in a normal configuration, individuals with Autism, just like controls, experience interference from facial features that they are told to ignore. However, while such interference is released for controls when facial features are misaligned, individuals with Autism show comparable interference from irrelevant parts regardless of alignment. The results are consistent with the idea that individuals with Autism lack expertise with faces. This is because a similar pattern of performance has been observed when control subjects process non-face objects for which they have no expertise, under unusual testing conditions that force them to encode a broken configuration.

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8:45 *791* **Discrimination of facial feature displacement in individuals with autism**

Allison B. Sekuler[1,2] (sekuler@mcmaster.ca), M. D. Rutherford[1], Kathleen A. Clements[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Centre for Vision Research, York University

Individuals with autism spectrum disorders (ASD) have impairments in face recognition tasks. It has been suggested that this impairment occurs in part because, in contrast to typically developed individuals, individuals with ASD do not spontaneously make use of the eyes region of the face. Indeed, some researchers have suggested that individuals with ASD attend preferentially to the mouth. To test this hypothesis, we adapted Barton et al.?s (2001) feature displacement discrimination task for 16 high-functioning adult males with ASD and 19 sex- and IQ-matched controls. Like Barton and colleagues, for typically developed individuals, we found relatively low displacement thresholds for both eye and mouth discriminations when stimuli were upright. When stimuli were inverted, thresholds remained low for eye discriminations, but were significantly elevated for mouth discriminations, consistent with the interpretation that typically developed observers give priority to processing eyes (e.g., Sekuler et al., 2004). If individuals with ASD prioritize the mouth over the eyes, one would expect the reverse pattern of results (low thresholds in both orientations for mouth discriminations, and low thresholds only when upright for eye discriminations). In contrast to this prediction, we found no inversion effect for individuals with ASD when viewing eyes, but overall performance was significantly impaired relative to controls. Performance on discriminations of mouth displacements did not differ significantly across groups. As such, our results are consistent with the view that a deficit exists in processing eyes in ASD, but the mouth does not appear to receive processing priority.

Acknowledgment: Natural Sciences and Engineering Research Council of Canada, and the Canada Research Chairs program

9:00 *792* **What is adapted in face adaptation? A study of the representation of expression in the human visual system.**

Christopher J. Fox[1,2] (cjfox@interchange.ubc.ca), Jason J.S. Barton[2]; [1]Graduate Program in Neuroscience, [2]Division of Neurology and Department of Ophthalmology and Visual Sciences, The University of British Columbia

The neural representations of facial expression are not well defined. We used an adaptation paradigm to determine how a variety of images affected perception of expression in a subsequently viewed series of ambiguous target faces that were derived by morphing between two facial expressions. When subjects viewed one of the emotional faces that had been used to generate the morphed series, there was a substantial shift towards perceiving the emotion opposite to the adapting stimulus in the ambiguous face. However, this aftereffect was not due to low-level image adaptation, as an equally strong aftereffect was generated when using a different image of the same expression from the same individual for the adapting stimulus. A weaker but significant aftereffect was still generated when the adapting stimulus was the same expression on the face of a different person, regardless of gender. Non-face visual, auditory, or verbal representations of emotion did not generate a similar after-effect. The results suggest that adaptation affects at least two neural representations of emotion: one that is specific to the individual involved (but not specific to image), and one that represents emotion across different facial identities. The identity-independent aftereffect suggests the existence of a generalizable visual semantic representation of facial expression in the human visual system.

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9:15 *793* **On Holistic Processing of Facial Expressions**

Martha D Kaiser[1] (marthakaiser@gmail.com), Richard Le Grand[2], Jim W Tanaka[3]; [1]Rutgers University, [2]Kwantlen University College, [3]University of Victoria

It has been claimed that identification of a face relies more on the perception of the whole face than the perception of its constituent parts (e.g., eyes, nose, mouth). The face inversion, face composite, and parts/wholes tasks are well-established paradigms demonstrating the holistic perception of facial identity. However, less is known about the cognitive mechanisms mediating recognition of facial expressions. In these experiments, we applied established paradigms to test the holistic processing of emotional expressions. The stimuli were face halves displaying the same (e.g., happy top/ happy bottom) or different expressions (e.g., angry top/happy bottom). In all tasks, participants were instructed to attend to and label the expression (i.e., 'angry' or 'happy') in the top (or the bottom) half of the face and ignore information in the irrelevant half. When labeling inconsistent expressions, evidence of holistic interference effects were found such that recognition of the expression in the attended half was affected by conflicting information in the irrelevant face half. Interference effects were reduced or abolished when the faces were presented upside-down, as spatial or temporal composites or as isolated parts. However, there was less evidence of facilitative effects in the consistent condition where the inversion, composite and parts manipulations had little effect on performance. Collectively, these results suggest that in situations where information about the facial expression is clear and unambiguous, processing is more analytic and less dependent on information from the whole face. However, in cases, where the information is conflicting or ambiguous, holistic face processes are engaged.

Neurons and Perception

11:00 - 12:45 pm

Hyatt Ballroom North

Moderator: David Sheinberg

11:00 *794* **A fresh look at receptive-field size and illusory contour detection**

Margaret Livingstone[1] (mlivingstone@hms.harvard.edu), Arash Yazdanbakhsh[1]; [1]Neurobiology Dept., Harvard Medical School, 220 Longwood Ave., Boston, MA 02115

V2 but not V1 cells respond to illusory contours defined by inducers outside the cell's classical receptive field (von der Heydt 1984). Thus the "classical" rf (the region giving an audible response to a stimulus) must not comprise all the parts of the visual field that can contribute to the activation of a cell. We studied 43 cells in V2 and 41 cells in V1. For each cell we first mapped the receptive field using an optimal moving bar stimulus and listening to the response; we will call this the "audible rf". Second we re-mapped the receptive field using sparse noise, and defined the "noise-based rf" as those regions where the visually-driven spike rate was significantly above the spontaneous firing rate ($p < 0.05$). In V1 the two ways of measuring the rf gave comparable rf sizes, but in V2 the noise-based rf was invariably larger than the audible rf. We then tested whether cells responded to illusory contours when:1-The inducers were outside the audible rf but inside the noise-based rf 2-The inducers were outside the noise-based rfOnly in #1 did the cells respond to illusory contours; there was no significant response in # 2.Thus regions outside the classical rf that can drive illusory-contour responseiveness are not qualitatively different from the classical rf, but are merely less effective in driving the cell, and therefore undetectable by ear. Non-linear response summation to collinear stimuli could then explain the responsiveness of V2 cells to illusory contours.

Acknowledgment: Supported by NIH (EY13135)

11:15 *795* **Contrast-sign selectivity of End-stopping and Length-summation**

Arash Yazdanbakhsh[1] (arash_yazdanbakhsh@hms.harvard.edu), Margaret Livingstone[1]; [1]Neurobiology Dept., Harvard Medical School, 220 Longwood Ave., Boston, MA 02115

In this study we determined the contrast-sign selectivity of the mechanisms involved in contour integration and terminator detection in V1 of alert macaques. The inhibitory effect of the end zones in end-stopped cells was highly selective for the relative sign of contrast between the central activating stimulus and stimuli presented to the end zone. On the other hand, the facilitatory effect of end zones in length summating cells was not selective for the relative sign of contrast between the central activating stimulus and stimuli presented to the end zone. Thus end stopping may belong more in the category of contrast-sign selective cortical computations such as direction selectivity and disparity selectivity, rather than those that arise from a non-selective cortical network, such as contrast gain control. We also confirmed that the end-stopping crosses the eyes, ruling out the possibility that it arises as early as the LGN and confirming a cortical origin for end-stopping.

Acknowledgment: Supported by NIH (EY13135)

11:30 *796* **Contextual Influences on the Chromatic Properties of Macaque V4 Neurons**

Sherry X Xian[1] (xian@stanford.edu), Tirin Moore[1]; [1]Dept. of Neurobiology, Stanford Univ. School of Medicine, Stanford, CA, USA

We recently found that a large proportion of V4 neurons are highly selective to cone isolating stimuli. Most color selective V4 neurons respond best to a narrow range of chromaticities in color space, and thus these neurons indeed seem to play a role in color perception. V4 neurons also have large, suppressive non-classical receptive field surrounds (Schein & Desimone, 1990). Here we examine how contextual influences from complex backgrounds modulate responses of V4 neurons and how these modulations correspond to perceptual measurements of color appearance changes caused by local induction and induction from grouping (Xian & Shevell, 2005). The experiments were carried out in two alert, fixating monkeys. Stimuli were chromatic, oriented bars (1°×0.25°, 25cd/m2) presented on a complex and variable background (16° diameter, 15cd/m2) and centered on the receptive field (RF) of individual V4 neurons. Each bar had different L- or S-cone contrasts relative to equal energy spectrum and the luminance of all bar colors was held constant. A minimum motion technique was used to determine equiluminance for each monkey using the method of Logothetis and Charles (1990). During each experimental trial, monkeys fixated a central point to receive a juice reward. Once the monkey began fixating, a pseudo-random sequence of 5-11 colors was presented. Each bar stimulus lasted 100-250 msec and was followed by 50 msec of background. We found that the chromatic tuning of V4 neurons could be significantly altered by changes in chromatic context, and in ways consistent with perceptual observations from human psychophysical experiments.

Acknowledgment: NIH EY014924, Pew and the Sloan Foundation

11:45 *797* **Suppressive lateral interactions in the lateral intraparietal area (LIP) of the monkey may have a role in the "line-motion" illusion**

Annegret L. Falkner[1,3] (alf2111@columbia.edu), B. Suresh Krishna[1,3], Michael E. Goldberg[1,2,3]; [1]Center for Neurobiology and Behavior, [2]Neurology, Columbia Univ., New York, NY, USA, [3]New York State Psychiatry Inst., New York, NY, USA

When a static line appears immediately after a brief cue at one end, observers sense motion propagating from the cued end towards the uncued end (the "line-motion" illusion, Hikosaka et al. 1993). Since endogenous attention and cross-modal stimuli can also induce the line-motion illusion (Shimojo et al. 1997), both attentional factors and low-level stimulus summation are believed to play a role. We recorded responses from single

cells in area LIP of the fixating macaque to stimuli which induce the line-motion effect in humans. We found that a spot flashed well outside the classical excitatory receptive-field (RF) strongly suppresses the onset-response to a line terminating at the center of the cell's RF. Maximal suppression was observed at spot-line onset asynchronies between 100 and 200 ms. Furthermore, a line with one end terminating at the RF center evoked a much larger response when preceded by a spot cue at the RF center than it did when preceded by a spot cue at the end away from the RF center; this was true even if the line-end away from the RF center lay entirely outside the excitatory RF. These results indicate that the activity evoked in the LIP neuronal population encoding the cued end of the line is larger than that in the LIP neuronal population encoding the uncued end of the line, thereby potentially leading to greater attentional allocation to the cued end of the line. This difference in attentional allocation may contribute to the attentional component of the line-motion illusion.

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12:00 *798* **Representation of numerical magnitude in posterior parietal cortex**

Jamie D Roitman[1] (roitman@neuro.duke.edu), Elizabeth M Brannon[2,3], Michael L Platt[1,3,4]; [1]Dept. of Neurobiology, [2]Dept. of Psychology, [3]Center for Cognitive Neuroscience, [4]Dept. of Biological Anthropology and Anatomy, Duke University

Posterior parietal cortex has been implicated in the representation of number in humans and monkeys. Recently, Nieder and Miller (2004) reported that single parietal neurons selectively responded to visual arrays containing 1-5 elements, and that tuning bandwidth was proportional to preferred magnitude. However, spatial selectivity of the neurons was not considered, and the proportion of neurons sensitive to number was small (~20%). To address these issues, we used an implicit numerical discrimination task to measure responses in the lateral intraparietal area (LIP) to visual arrays comprised of 2-32 elements. On each trial, a numerical cue predicting reward size was presented briefly while monkeys planned a saccade to a remote target. Stimulus controls balanced density, total pixels, and cumulative circumference. In each block, a standard numerosity (2,4,8,16 or 32) was presented on 50-60% of trials predicting a small reward, while deviant numbers were presented on the remaining trials predicting a large reward. For each neuron studied, the response field (RF) was first mapped, then the monkey performed 2-4 blocks of the implicit discrimination task with the numerical cue located in the RF and the saccade target in the opposite hemifield. In contrast with Nieder and Miller's (2004) report, we found more than half of LIP neurons were sensitive to the number of elements in the visual array and, moreover, neuronal activity varied monotonically with numerosity. Activity did not depend on stimulus frequency or reward expectation, suggesting that some parietal neurons encode the numerical magnitude of visual elements within their response fields.

Acknowledgment: Supported by EY014742, the Klingenstein Foundation and the John Merck Fund

12:15 *799* **Recognition choice behavior is predicted by activity in inferior temporal cortex**

Ryan E.B. Mruczek[1] (Ryan_Mruczek@Brown.edu), David L. Sheinberg[1]; [1]Department of Neuroscience, Brown University, Providence, RI

The remarkable selectivity of some cells in inferior temporal cortex (IT) suggests that these cells contribute to the perceptual awareness of complex visual images. However, few studies have tested the relationship between neural activity in IT and behavioral performance. Those that have explored this relationship have concentrated on extended displays of ambiguous stimuli. Here, we sought to create a relatively natural task with few behavioral constraints to test whether neurons in IT fire more robustly when a monkey recognizes and responds to a complex visual object.A monkey was trained to freely view an array of images and locate one of many possible target images previously associated with one of two button presses. On normal trials, the monkey naturally made a saccade to the target image and pressed the appropriate button. On *swap trials*, the identity of the target was changed during the monkey's targeting saccade. Furthermore, the response association of the pre-swap target and the post-swap target differed (i.e. *left target* swapped to *right target*). We can infer that the monkey noticed the pre-swap target if his manual response matched the association of the pre-swap target. Neural activity in cells selective for the pre-swap target was significantly higher when the monkey recognized that target. Furthermore, the monkey's response time was predicted by the magnitude of the presaccadic firing rate on normal trials. Our results provide direct support for the role of IT in visual awareness during natural behavior.

12:30 *800* **Supplementary eye field (SEF) neurons encode rules, but don't make the decision**

Stephen Heinen[1] (heinen@ski.org), Jeremy Badler[1], Shun-nan Yang[1]; [1]Smith-Kettlewell Eye Research Institute

We previously showed that SEF neurons encode the trajectory of a moving target within the context of a rule in our ocular baseball task (Kim et al., 2005). Ocular baseball is a go/nogo task in which the player predicts whether or not a moving spot target will intersect a visible "strike zone." The player's task is to use eye movements to pursue the target if it crosses the strike zone ("strike"), or remain fixated if it does not ("ball"). Here, we studied neuronal activity during behavioral error trials to ask if SEF neurons simply encode the trajectory of the target, or whether their activity is linked to the behavioral decision. Neurons were recorded from the SEF of monkeys while they played ocular baseball. To force errors, task difficulty was altered by varying the approach angle of the target. Surprisingly, 78% of the neurons correctly signaled the target trajectory (strike or ball) even on behavioral error trials, indicating that veridical information was available to the monkey, but it was ignored. Given the apparent sensory nature of the neurons, a second experiment was done to determine if SEF neurons truly encode the rule. Here, plate size was varied (16 or 8 deg) so that the same trajectory could either be a strike or a ball. Neurons in this experiment adjusted their firing rate accordingly, evidence that the SEF can truly encode the rule-based state of an object's trajectory.

Acknowledgment: This study is supported by NIH EY117720

Adaptation

11:00 - 12:30 pm

Hyatt Ballroom South

Moderator: Benjamin Backus

11:00 *801* **Positive and negative contingent aftereffects**

Benjamin T Backus[1,2] (backus@psych.upenn.edu), Patrick Garrigan[3], Qi Haijiang[4], Vijay Balasubramanian[3]; [1]Department of Psychology, University of Pennsylvania, [2]Institute for Neurological Sciences, University of Pennsylvania, [3]Department of Physics, University of Pennsylvania, [4]Bioengineering Graduate Group, University of Pennsylvania

The visual system faces two challenges in trying to construct stable and useful percepts (appearances) from measured signals. First, it must keep itself calibrated. To do this, the response of a sensor can be corrected by making it dependent on additional signals that correlate with what the sensor measures, exploiting an assumption that the signals' joint distribution is stationary. Adaptations of this sort can explain negative aftereffects in which apparent color, velocity, texture density, stereoscopic depth, etc. become contingent on some other signal in a display (McCollough 1965, Allan & Siegel 1993; Mayhew & Anstis 1972; Durgin 1996; Blaser & Domini 2002). Second, the system must monitor the ecological validities of poten-

tial cues to exploit new cues in a changing world (Brunswik, 1956). In this type of learning, a new signal comes to have the same effect as cues that were contingent during training, so aftereffects are positive (Haijiang et al., 2005). Since both types of perceptual adaptation might be engaged by stimuli with strong contingencies between signals, a theory is needed to predict which effect will dominate in a given experiment. Here we discuss the role of some factors that are, from a computational view, involved: the rates at which sensors drift; how signals' actual distributions vary over time in natural environments; the system's ability to monitor changes in the distributions of signal values (which depends in part on sampling density); and the manner in which the ecological validities of signals change over time in the organism's environment.

Acknowledgment: NIH grants EY-013988 and P30 EY-001583

URL: http://psych.upenn.edu/backuslab

11:15 *802* Complex channels become more complex: Modeling a contrast adaptation process

Norma V. Graham[1] (nvg1@columbia.edu), S. Sabina Wolfson[1]; [1]Department of Psychology, Columbia University

We have found a new (at least to us) kind of contrast adaptation in which differences between contrasts near the adapted level are harder to perceive than differences between contrasts further away. In one experiment, the observer is briefly adapted to a grid of Gabor-patch elements at some contrast level (C_0). We then probe the adapted state using a striped element-arrangement pattern where the Gabors in alternating rows (or alternating columns) change contrast level to C_1 while the Gabors in the remaining rows (or columns) change to C_2. If C_1 is an increment in contrast relative to C_0 (that is, if C_1=C_0+ÄC) and C_2 is a decrement in contrast relative to C_0 (that is, if C_2=C_0-ÄC), the orientation of the striped pattern is very hard to identify. However, the orientation is easy to identify if the same size difference (2*ÄC) does NOT cross C_0 (for example, if C_1=C_0+ÄC_1 and C_2= C_0+3*ÄC).We can model this contrast-controlled adaptation process by inserting an additional linear filter (F_2) and rectification-type nonlinearity (N_2) into a complex channel ($F_1N_1F_3$), resulting in a $F_1N_1F_2N_2F_3$ structure (which we call a Buffy channel). F_2 is a small blur circle, so the output of it is a measure of local contrast. N_2 is adaptable: the zero-point of N_2 adapts to be equal to the recent time-averaged contrast (at that position), so the output is (approximately) zero if the current contrast equals the recent contrast (at that position). Predictions from Buffy channels agree with experimental results.

Acknowledgment: Supported by NIH grant EY08459

11:30 *803* Orientation-selective adaptation to illusory contours in human visual cortex

Leila Montaser Kouhsari[1] (lmk306@nyu.edu), Jonas Larsson[1,2], Michael S Landy[1,2], David J Heeger[1,2]; [1]Department of Psychology, New York University, New York, NY, USA, [2]Center for Neural Science, New York University, New York, NY, USA

Purpose: Humans can perceive illusory contours in the absence of any real physical boundaries (e.g., between abutting gratings). Single-unit recordings in cats and monkeys have found neurons selective for illusory contour orientation. We used an adaptation protocol to identify orientation-selective neural responses to illusory contours in human visual cortex.Methods: Event-related fMRI was used to measure post-adaptation responses to illusory grating stimuli. Each trial consisted of a 4s adapter (vertical or horizontal illusory contours defined by abutting line gratings), a 1s ISI, a 1s probe (illusory contours parallel or orthogonal to the adapter, or a blank) and 1.2s behavioral response period. Every 500 ms, inducer line orientation ($\pm 45^{\circ}$), inducer phase, and illusory contour phase were varied to minimize adaptation to the inducers. Stimuli were presented in an annulus (1.5-5 deg) around the fixation point. A highly demanding task at fixation was used to equate attentional load across stimulus conditions. Data were analyzed independently in nine visual areas (V1, V2, V3, V3A/B, V4, V7, VO1, LO1 and LO2), each defined by standard retinotopic mapping procedures.Results: We found orientation-selective adaptation to illusory contours in most visual areas, evidenced by reduced fMRI responses for probe stimuli parallel to the adapter compared to those orthogonal to the adapter. This difference disappeared if inducer line positions were jittered so as to eliminate the illusory contour percept. This suggests that both early and higher visual areas are involved in the processing of illusory contours in humans.

Acknowledgment: Support: NEI (R01-EY11794, R01-EY16165) and the Seaver Foundation

11:45 *804* Dissociating microgenesis of retinal and non-retinal adaptation

Naotsugu Tsuchiya[1] (naotsu@klab.caltech.edu), Lee A Gilroy[2], Randolph Blake[2], Christof Koch[3]; [1]Division of Humanities and Social Sciences, California Institute of Technology, [2]Department of Psychology, Vanderbilt University, [3]Devision of Biology, California Institute of Technology

Negative afterimages have traditionally been ascribed to retinal adaptation, but recent studies suggest that adaptation mediating afterimage formation occurs at multiple levels of visual processing. Here, we use an interocular suppression technique, called continuous flash suppression (Tsuchiya 05 NatNeuro), to dissociate microgenesis of retinal adaptation (which should be immune to suppression) from non-retinal adaptation (which is susceptible to suppression). We achieve this dissociation by holding retinal adaptation constant at 5 sec while manipulating the duration of suppression. Remarkably, presentation of five, brief flashes during the last 500 msec of adaptation was sufficient to reduce the magnitude of non-retinal adaptation by half. To quantify the strength of suppression, we used a forced-choice probe detection task and found that as few as five successive, brief flashes interfered with probe detection as much as continuous flash suppression. However, a single flash only exerted suppression within a narrow window of time between onset of the probe and onset of the suppression figure; moreover, the suppression from this single flash did not sum its effect when we paired flash suppression with conventional binocular rivalry suppression. This modified flash suppression technique provides a useful method for dissecting adaptation arising within mechanisms at multiple visual processing levels.

Acknowledgment: EY13358, NIMH, NSF, the Keck Foundation, the Moore Foundation

URL: http://www.klab.caltech.edu/~naotsu/CFS_color_demo.html

12:00 *805* Perceptual regularization after adaptation

Ryota Kanai[1,2] (kanair@caltech.edu), Chris L E Paffen[1], Frans A J Verstraten[1]; [1]Universiteit Utrecht, Helmholtz Institute, Dept. of Experimental Psychology, Heidelberglaan 2, NL-3584 CS Utrecht, The Netherlands, [2]California Institute of Technology, Division of Biology, M/C 114-96, Pasadena, CA 91125, U.S.A.

The visual system has the ability to generalize a variety of shapes as a common category. At the same time, it is able to distinguish small differences among otherwise similar images. We studied how these two mechanisms interact in the visual system. For this, we introduced some degree of irregularity to highly regular patterns. Our first stimulus was a grid pattern in which the pattern was regular at the center of the stimulus. This regularity was disturbed gradually towards the outer edges of the stimulus. As one looks at the center of such stimulus, the irregular part of the grid slowly becomes regular in percept and eventually the entire stimulus is perceived as a regular grid. The effect seems to reflect the brain's preference for regularity, because reversing the center-peripheral organization (i.e., irregular center and regular periphery) did not result in any perceptual effect. A similar perceptual change was observed for distorted circles. In both cases, the irregular 'glitches' disappeared and eventually a coherent regular structure was perceived. Interestingly, the afterimage of an irregular pat-

tern was also regular. The fact that this phenomenon of perceptual regularization requires prolonged viewing suggests some involvement of adaptive neural substrates. That is, information of small-scale deviations from a global picture is represented separately, perhaps in early visual areas, and adaptation diminishes this component selectively. When the signals for the deviations are small, signals for a global picture, or a prototype, may overrule, possibly adjust the low-level representations.

12:15 *806* Strength of early visual adaptation depends on visual awareness

Duje Tadin[1] (duje.tadin@vanderbilt.edu), Randolph Blake[1], Sang Chul Chong[2]; [1]Vanderbilt Vision Research Center & Department of Psychology, Vanderbilt University, 111 21st Ave S, Nashville, TN 37203, [2]Department of Psychology, Graduate Program in Cognitive Science, Yonsei University, Seoul, Korea

We measured visual adaptation strength under variations in awareness by manipulating phenomenal visibility of adapting stimuli using visual crowding. Results showed that the threshold elevation aftereffect (TEAE) was substantially reduced during crowding, but only if the adapting contrast was low enough to prevent TEAE saturation. This suggests that the previous results reporting the failure of crowding to affect the TEAE (He et al., 1996, Nature) may be explained by TEAE saturation at high adapting contrasts. Importantly, crowding's weakening influence on the build-up of the TEAE was correlated with the crowding strength indexed by performance on the orientation discrimination task. We also examined the effect of crowding on the motion aftereffect (MAE) and found even stronger reduction in the aftereffect strength. These findings indicate that neural events underlying crowding are inaugurated at an early stage of visual processing, since both TEAE and MAE arise, at least in part, from adaptation at the earliest stages of cortical processing. We hypothesize that the absence of visual awareness occasioned by crowding results from a cascade of neural events inaugurated in V1 and culminating in the complete abolishment of neural activity ordinarily associated with visual awareness. This conclusion is supported by the stronger effect of crowding on MAE than TEAE. These findings are analogous to our experiments where we used binocular rivalry to suppress adapting stimuli, including results previously reported at VSS. Taken together, our findings force reinterpretation of previous reports, whose results formed key psychophysical evidence against the direct role of V1 in visual awareness.

Acknowledgment: Supported by EY13358

Poster Session H

Monday, May 8, 2006

Lightness, Brightness, Luminance and Transparency (807-827)
Action and Space Perception (828-836), 3 D Space (837-848), Attention and Reward: Cortical Physiology (849-856), Perceptual Organization: Grouping & Segmentation (857-871, 435), Object Tracking, Enumeration, and Individuation (872-891)

Poster Session: 8:00 - 11:00 am ***Municipal Auditorium***
Author presents: 9:30 - 10:30 am

Lightness, Brightness, Luminance and Transparency

H1 *807* The dependence of laser-induced lens fluorescence on laser irradiance

Peter A Smith[1] (peter.smith@ngc.com), Gary L Martinsen[2], David E Kee[1], Paul V Garcia[1]; [1]Northrop Grumman Corporation, San Antonio, Texas, [2]Air Force Research Laboratory, Brooks City-Base, Texas

When the human eye is exposed to a short-wavelength light in the near-ultra violet region, the light causes the lens to fluoresce, which produces a widespread glare effect on the retina. This glare may interfere with normal vision, especially at lower ambient illumination conditions. This study characterized the relationship between fluorescence-induced glare from an ultraviolet laser and the laser irradiance. An equivalent veiling luminance technique was used to estimate the luminance of fluorescence-induced glare from an ultraviolet laser operating at 364 nm. First, threshold vs. intensity (TVI) relationships were determined for a Landolt ring target with a critical detail of 0.5^o against a background luminance from 1 $cd.m^{-2}$ to 100 $cd.m^{-2}$. Threshold measurements were then made for the same target against a lens fluorescence-induced glare field. The laser exposures were from 0.6 $mW.cm^{-2}$ to 60 $mW.cm^{-2}$ at the cornea, and were 5 s in duration. The angle between the laser beam axis and the visual task was 10^o. Initial results indicate that the glare luminance, estimated from the TVI curves, varies non-linearly with respect to laser irradiance, with more veiling glare than expected at higher irradiances. These non-linearities are thought to be related to the equivalent luminance estimation technique rather than any physical mechanisms. Notwithstanding this, exposure to a near-ultra violet laser at safe exposure levels can induce a veiling glare intense enough to impair contrast acuity significantly.

H2 *808* Measurement of luminance contrast sensitivity of chimpanzees (Pan troglodytes)

Toyomi Matsuno[1,2] (matsuno@pri.kyoto-u.ac.jp), Masaki Tomonaga[1]; [1]Primate Research Institute, Kyoto University, [2]The Japan Society for the Promotion of Science

The detectability of luminance-modulated grating patches was determined for 4 adult chimpanzees. For efficient measurements of contrast thresholds, an adaptive psychophysical measurement, PEST (Parameter Estimation by Sequential Testing), was used in chimpanzees? behavioral experiment. In the detection task for a 0.5 c/deg horizontal Gabor-type patch, consistency and reliability of the estimated thresholds in the procedure were evaluated in comparison with the data collected in the method of constant stimuli. Chimpanzees showed very small between-session variances of threshold values, which were well-matched to those estimated in the method of constant stimuli. After assessing validity of PEST method in chimpanzees, contrast sensitivity functions were obtained over the range of 0.5 - 8.0 c/deg using the Gabor patches. The contrast sensitivity was similar to that of humans, showing bandpass shape functions with both low and high frequency attenuation. These results suggest that humans and chimpanzees share the physiological mechanisms underlying spatial vision.

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H3 *809* Interaction between brightness and contrast of complex stimuli

Wei-Chung Cheng[1] (waynecheng@mail.nctu.edu.tw), Chain-Fu Chao[1]; [1]National Chiao Tung University, Taiwan

Purpose: Can reduced brightness of natural images be compensated by increasing luminance contrast?Method: Four human subjects were asked to match the brightness of complex stimuli by adjusting luminance contrast in a dark surround. Method of adjust was used to find the point of subjective isoluminance across 60% to 150% of brightness. A sigmoidal function was used to modulate the luminance contrast of natural images.Results: Consistent results for 70% to 110% of brightness were found among the four subjects. In this range, the luminance contrast is an inverse linear function of brightness with virtually identical constants for the four subjects. Beyond this range, however, the matching became difficult and led to diverse results.Conclusion: This finding can be applied to display design. For example, increasing contrast can enhance image quality when the luminance is reduced to save power consumption of portable electronic devices. The high-dynamic range algorithms can also employ this finding to increase the apparent contrast of natural images.

URL: http://color.eic.nctu.edu.tw

H4 *810* Luminance equilibrium of chromatic pairs at different eccentricities

Justin PLANTIER[1] (jplantier@imassa.fr), Jean Philippe AUBRY[1], Françoise VIENOT[2], Gérard OSSARD[3], Corinne ROUMES[1]; [1]Institut de Médecine Aérospatiale du Service de Santé des Armées, B.P 73- 91223 Brétigny-sur-Orge Cedex, [2]Muséum National d'Histoire Naturelle, CRCDG, 36 rue Geoffroy Saint-Hilaire, 75005 Paris, [3]3 Laboratoire de médecine aérospatiale, 91220 Brétigny-sur-Orge Cedex, France

In order to determine the chromatic contrast sensitivity function, the luminance equilibrium of chromatic pairs should be evaluated with the actual visualization display. This evaluation should be done at different eccentricities when the visual stimulations are DOGs (Difference Of Gaussians), because the spatial frequency variation modifies the spatial extent of the stimulation. The luminance equilibrium evaluation method of chromatic

pairs was based on the apparent motion paradigm (Anstis, Cavanagh 1983). We filled an annulus with two-colour radial sectors. When the colours differed in luminance, the stimulation looked like the wings of a windmill (Anstis, S. 2000). At equiluminance, the motion appeared to vanish. The experimental method was a constant stimuli method with ten values of luminance for one colour and eleven repetitions for each level. A two alternative forced-choice procedure (clockwise or counterwise rotation) was used. Four colour pairs were tested: red-green, yellow-blue (colour-opponent pairs), cyan-magenta, yellow-purple (cone-opponent pairs). Two eccentricities were studied: for each annulus, the inner and outer annulus diameters being respectively 0,4°-2,4° and 2,8°-5°. Tests were displayed on a flat CRT screen with a mean luminance of 16 cd.m-2 for the yellow-blue pair and 30 cd.m-2 for the others. Seeven colour-normal observers took part in the experiment.The results show that the luminance equilibrium is identical for the two sizes of annulus except for the yellow-blue pair. For this pair, the mean ratio: yellow luminance/blue luminance is equal to 1 for the smallest eccentricity and decrease to 0.8 for the largest.

H5 *811* Psychophysical evidence for long-range influence on foveal adaptation

Tobias Otte[1] (Tobias.Otte@zfn-brain.uni-freiburg.de); [1]Brain Research Unit, Department of Neurology, University Hospital, Freiburg, Germany

In 1985, Valberg, Lee, Tigwell & Creutzfeld showed that intensity-response curves of cells in the macaque geniculate nucleus are shifted to higher ranges when a white annulus is added around the adaptation field of the recorded cells. We found psychophysically that a flash-induced foveal afterimage appears light when the background is surrounded by a dark annulus of 8 deg inner radius, and dark when the surrounding annulus is light. We conclude that the annulus affects the afterimage by a long-range neural signal (Otte, Valberg & Spillmann, 2005). Results differ from the "periphery-effect" (McIlwain, 1964) and similar lateral effects. Whereas these effects are elicited by a strong motion signal, the polarity of the afterimage depends on the luminance in the surround.Afterimages elicited by a strong light are known to change their brightness in counter-phase to the background. Here I present a model demonstrating how the luminance in the periphery affects the brightness of a foveal afterimage, assuming that the surround signal alters the adaptation level of the foveal cells as suggested by Valberg et al. (1985). This model strengthens the correlation between the neurophysiological results by Valberg et al. and our psychophysical findings.

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H6 *812* A simple context-dependent and luminance-driven model of lightness perception

Piers Howe[1] (phowe@hms.harvard.edu), Margaret Livingstone[1]; [1]Harvard Medical School, Boston MA 02115

We have constructed a model of lightness perception that contains just five free parameters and comprises two components: one considers a surface's luminance and the other the context in which the surface is placed. The luminance component assumes that the surface with the highest luminance is white and estimates the lightnesses of all other surfaces in the visual scene by comparing their luminances to the highest luminance in the scene. The context component of the model modifies these lightness estimates by taking into account the contrast between a surface and its neighbors. Depending on the exact luminance relationships, the context component will sometimes predict the lightness difference between a surface and its neighbors to be exaggerated (i.e. the simultaneous contrast effect) and sometimes be understated (i.e. an assimilation effect). In this way the context component of the model is able to modify the lightness estimates of the luminance component of the model so that they are more in keeping with human perception. The model is able to explain a number of visual phenomena including the simultaneous contrast illusion, illumination dependent errors, the Gelb effect, White's effect, the Benary cross, the White-Todoroviæ illusion, the Koffka ring, the Craik-O'Brian-Cornsweet effect, a display containing multiple luminance steps as well as several important variations of the above displays.

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URL: http://mysite.verizon.net/vzeejf0b/

H7 *813* Spatiotemporal dependencies of brightness induction

Mark E McCourt[1] (mark.mccourt@ndsu.edu), Barbara Blakeslee[1]; [1]Center for Visual Neuroscience, North Dakota State University, Fargo, ND 58102

The brightness of a target region is modulated by the luminance of surrounding regions. Brightness induction is believed to be low-pass with respect to both spatial and temporal frequency, and to extend only to relatively low frequencies. However the methods used to measure induction magnitude to date have made accurate determinations of its temporal frequency response difficult. We exploit a novel technique in which we sinusoidally counterphase the inducing grating of a grating induction display to create a counterphasing induced grating within the test field. Adding a second (genuine luminance) counterphasing grating in spatial and temporal quadrature phase to the modulating induced grating leverages the induced brightness modulation into a traveling wave (motion), to which we are exquisitely sensitive. The quadrature sum moves leftward or rightward depending upon whether the temporal phase of the second luminance grating is plus or minus 90 degrees relative to the induced grating. Adding a third (genuine luminance) canceling grating into the test field permits a precise estimation of induction magnitude at manifold spatial and temporal frequencies, since when the canceling grating exactly nulls the induced grating motion energy within the test field is left/right balanced, resulting in 50:50% left/right judgments in a forced-choice motion direction task. Using this technique we have measured the spatiotemporal dependencies of brightness induction across a wide range of spatial and temporal frequencies. Brightness induction extends to much higher frequencies than have heretofore been thought possible.

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H8 *814* Human cortical responses to illusory and actual luminance variations

Huseyin Boyaci[1] (boyac003@umn.edu), Fang Fang[1], Scott O. Murray[2], Daniel J. Kersten[1]; [1]Department of Psychology, University of Minnesota, [2]Department of Psychology, University of Washington

We studied the cortical responses to illusory luminance variations induced by the Cornsweet effect, as well as actual luminance variations. Both the illusory and actual luminance variations were composed of two flanking territories and a contrast border between them. In the Cornsweet effect, two equiluminant flanking territories appear to have different luminances due to a region composed of two opposite sign luminance gradients and a contrast border between them. In the "actual" condition the luminance on both sides of the border were uniform and counter-phase modulated in time around the mean luminance (square-wave modulation, 0.5Hz). In the "illusory" condition, the luminance of the flanking territories remained constant while the gradients within the Cornsweet region reversed their signs in time (square-wave modulation, 0.5Hz.) This modulation induced the illusory percept of an animated luminance change across the flanking territories, which were the regions of interest. We measured reliable BOLD modulation in early visual cortical regions of interest, particularly in V2 and V3, in response to both illusory and actual luminance variations. The magnitude of the BOLD response to the illusory luminance variation was similar to the response to the actual luminance variation in those areas. Our results suggest that neurons in early visual cortex are sensitive to illusory luminance changes engendered by distant scene cues.We also addressed the role of perceived 3D configuration on the fMRI signal,

where the Cornsweet-like luminance pattern is induced either by surface pigmentation, or by surface curvature and spatial layout of light sources (Knill and Kersten, 1991).

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H9 *815* Simultaneous Contrast and White's Effect as a Consequence of a Biologically Plausible Model of Brightness Filling-in

Alex Ioannides[1,2] (alex.ioannides@ucl.ac.uk), Alan J Johnston[1,2], Lewis Griffin[3]; [1]CoMPLEX, University College London, [2]Psychology, University College London, [3]Computer Science, University College London

Simultaneous contrast and White's effect, as predicted by current models of brightness coding (Dakin and Bex, 2003; Blakeslee and McCourt, 1999), can be shown to be reliant on the non-linear amplification of low spatial frequency information, sampled continuously by large receptive fields (< 0.5cpd). However, the existence of receptive fields of this scale in V1 is controversial. Our goal is to predict both simultaneous contrast and White's effect only using filters of the scale typically found in V1. A model is presented, which is based on the proposition that V1 simple cells provide a measure of the 1st and 2nd order derivatives of a blurred version of the retinal image, and that this information is sampled at discrete intervals by overlapping receptive fields. An approximation of the Taylor series representation of the image, operating on the available differential information, is used to fill-in brightness in the regions local to each sampling point. Reconstruction of the 0th order term (the global brightness structure), is performed by enforcing continuity between neighboring regions of local brightness. This is achieved by shifting the absolute brightness level of each local region, and optimizing the shifts such that the variance in the differences in brightness within overlapping regions is minimized. This technique can effectively reconstruct natural scene images. Error in reconstruction of the global brightness structure by this method provides an account of simultaneous contrast and White's effect.

H10 *816* Probe disks reveal lightness computation in sunlight and in shadow

Ana Radonjic[1] (ana@psychology.rutgers.edu), Simone Whyte[1], Jennifer Faasse[1], Alan Gilchrist[1]; [1]Department of Psychology, Rutgers University, Newark

Fields of illumination exist in the external world, but to what extent are they represented in the visual lightness software? Cartier-Bresson's photograph *Trastevere* is sliced diagonally into adjacent regions of sunlight and shadow. We pasted identical gray disks onto a digital version of *Trastevere*, to probe the lightness computation at 12 locations in the scene. Separate groups of fifteen observers viewed the CRT image and made Munsell matches for each disk in 6 different conditions. For identical round disks, the disks in the shadowed region appeared 2.13 Munsell units lighter than those in sunlight, and lightness values were roughly homogeneous within each of these two regions, regardless of distance from the boundary. This effect grew significantly larger (2.67 units) when disk size and shape were made to conform to depicted perspective, and larger still (3.13 units) when disk boundaries were blurred to conform to photograph graininess. Viewed through a pinhole, known to enhance depth perception, the difference grew further to 4.07 units. When gray disks were pasted onto the glass CRT screen, the difference shrank to 1.49 units. This framework difference effect thus varies with the strength to which the disks appear to belong to their surrounding framework. Control conditions ruled out a local contrast explanation. Our manipulations affected only the disks in shadow, not those in sunlight. When the entire sunlit region of the image was blacked out, the disks appeared white. These results are consistent with predictions of anchoring theory, but difficult to reconcile with spatial filtering models.

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H11 *817* Lightness constancy in shadows: Evidence for high level inference.

James M Hillis[1] (jmhillis@psych.upenn.edu), David H Brainard[1]; [1]University of Pennsylvania, Department of Psychology

The perceived lightness of a focal stimulus depends on the context in which it is presented. In some cases these effects can be explained parsimoniously in terms of simple adaptive mechanisms, while in other cases such explanations are tenuous. Adelson's checkerboard illusion (http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html) provides an interesting example: two gray squares of identical intensity, one in a shadow and one not, have very different apparent lightness. We performed experiments to determine the nature of the mechanisms underlying this effect. Our working hypothesis is that consistency between context effects revealed by appearance and discrimination data is a signature of early mechanisms, while a dissociation between the two indicates the action of higher-level processes. We have shown that context effects induced by changes of uniform backgrounds (JOSA, 2005) and relatively unstructured contrast are common to both appearance and discrimination. Ten observers participated. Observers set lightness matches between stimuli presented at two locations in the checkerboard illusion (one in and one out of the shadow). We also measured discrimination thresholds for each observer at the two relevant locations. The same measurements were made for a control configuration where the appearance of shadow was eliminated from the checkerboard. The asymmetric matches revealed a large appearance effect in the illusion configuration, and almost no effect in the control configuration. The threshold measurements were unchanged between illusion and control configurations. In contrast with our results for simple context manipulations, lightness effects revealed by the checkerboard illusion cannot be explained by adaptive processes that mediate discrimination performance.

H12 *818* Lightness Judgments Made in Shadow and Highlight

James A. Schirillo[1] (schirija@wfu.edu), Alexander D. Logvinenko[2]; [1]Department of Psychology, Wake Forest University, Winston-Salem, NC 27109, [2]Department of Vision Sciences, Glasgow Caledonian University, Glasgow, UK

An object's lightness is known to be relatively constant when its illumination varies. Lightness constancy is usually measured when the target is in highlight (and matching chips are in shadow), and for an illumination range of not more than 10:1. We have measured lightness constancy for 16 naïve subjects using a symmetrical display, where on different trials the target was placed in both highlight and shadow. The ratio of illuminations was ~100:1. We found, first, a considerable difference between the results depending on the placement of the target (i.e., highlight vs. shadow). The Brunswick ratio when the target was in shadow (and matching chips were in highlight) was ~41% (Thouless ratio = ~80%). The Brunswick ratio when the target was in highlight (and matching chips were in shadow) was ~99.8% (Thouless ratio = ~97.8%). Second, when the target was in highlight near perfect lightness constancy was found, dramatically higher than ever reported.Hsia (1943), in the only other symmetrical display we know of, also has data suggesting this trend. However, his illumination ratio only gets as large as 4.3:1. Also, the maximum Brunswick ratio obtained in his study was ~53%. Thus, the dramatic effect we get using real papers and lights may be due to using such a large luminance ratio (~100:1). Y. Hsia, (1943). Whiteness constancy as a function of difference in illumination, Archives of Psychology 284, 5-63.

H13 *819* Lightness perception in scenes with motion-based shading cues to the spatial distribution of illumination

Katja Doerschner[1] (katja.doerschner@nyu.edu), Laurence T. Maloney[1,2]; [1] Department of Psychology, New York University , [2]Center for Neural Science, New York University

When a gray matte surface changes its orientation with respect to a collimated light source the intensity of the light reflected from this surface changes, varying with the angle between surface normal and light source direction. The luminance changes of the rotating patch are a cue to the spatial distribution of the illumination. We examine whether observers use this *motion-based shading cue* in estimating the albedo of a static test surface under the same illumination.**Methods:** Six observers viewed computer-rendered 3D scenes, each consisting of an array of smoothly rotating (100° partial rotation) matte rectangles of the same albedo. A punctate light source placed slightly above and far behind the observer illuminated the scenes. Observers adjusted the luminance of a static central test patch until its perceived albedo matched that of the rotating rectangles. On some trials, observers judged the albedo of the test patch at orientations that never occurred in the animated sequences (to preclude simple copying of the luminance of a rotating patch at the same orientation). In a second condition specular spheres were added to the scene to serve as additional cue to the properties of the illumination. **Results:** Observers partially discounted the spatial distribution of the light in estimating surface albedo of the static test patch, successfully utilizing the motion-based shading cue. But only when specular spheres were also present did observers' luminance settings approach veridical, suggesting that motion-induced shading is a relatively weak cue to the spatial distribution of the illuminant.

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H14 *820* Change in perceived lightness in a cue recruitment experiment

Julia Boltianski[1] (bjulia@sas.upenn.edu), Benjamin T Backus[1,2]; [1]Department of Psychology, University of Pennsylvania, [2]Institute for Neurological Sciences, University of Pennsylvania

Classical (Pavlovian) conditioning procedures can sometimes cause visual appearance to become dependent on a single new cue (Haijiang et al., 2005). Fiandt (1936) conducted a series of experiments in which perceived surface lightness was allegedly made dependent on new signals: a small bit of shadow, a button, or a tone (conditioned stimuli) were able to cause changes in lightness perception after being paired with a large cast shadow (which caused apparent lightening in a shaded part of a test display). Fiandt's finding has seldom if ever been cited after Brunswik (1956). Can his stimuli be used to demonstrate cue recruitment? We asked observers to report paint color for gray disks in shadow, by matching them to grayscale painted chips. Following Fiandt, the shadow's penumbra was mostly invisible, so light disks appeared as though painted dark gray (reverse Gelb effect). On training trials a small bit of penumbra (a "Schattenzunge") and a large red rectangle (cast by red cellophane) were visible; after the observer made her match, the shadow caster and cellophane were moved up and down together, which moved the shadow off the disk and caused it to appear lighter. On test trials the red rectangle was visible while the Schattenzunge was not. Preliminary results were that stimuli came to appear lighter on training trials, but not test trials. Thus the Schattenzunge, but not the rectangle, was necessary for the learned lightening effect. The more arbitrarily visual signal was not learned as a lightness cue in this experiment.

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URL: http://psych.upenn.edu/backuslab

H15 *821* A multiscale filtering model can explain brightness motion in single-field contrast asynchronies

Alice R. Shapiro[1] (ashapiro@bucknell.edu), Arthur G. Shapiro[1]; [1]Bucknell University

In simultaneous contrast demonstrations, two physically identical patches of light have different brightness levels when placed in different contexts. One current model of such phenomena is based on multiscale filtering of the visual image. Here, we use a single-field contrast asynchrony to test for the presence of multiscale spatial channels in brightness perception ("the barbell illusion"—see *Journalofvision.org/10/5/2*, figure 11b). The stimulus consists of a rectangular field, with one short end positioned next to a light field, and the other next to a dark field. As the luminance of the rectangle modulates in time, a veil of brightness appears to move back and forth across the rectangle (brightness motion). We present a model based on an array of rectified center-surround filters applied over time (in a X,t plot, the maximal filtered response drifts in synchrony with the brightness motion). The model predicts that if inner fields of opposite contrast are placed between the flanking fields and the modulating rectangle, then filters of different scales will produce motion in opposite directions. In our experiments, a small dot drifts back and forth along the length of the modulating rectangle. The observer adjusts the phase of the dot so that it matches the phase of the brightness motion. We manipulate contrast and size of the inner and outer flanks. We find that when the inner flanks are thin and of low contrast, the phase of brightness motion is determined by the contrast of the outer flanks, therefore supporting a multiscale model.

URL: www.shapirolab.net

H16 *822* The role of Michelson contrast in perceptual transparency

Marc K. Albert[1] (mka@soton.ac.uk); [1]School of Psychology, University of Southampton, UK

Singh and Anderson (2002) proposed that the perceived transmittance of a transparent filter seen in front of a sinewave background is determined by the ratio of its Michelson contrast to that of its background seen directly. In their experiment, observers matched the perceived transmittances of target and comparison filters by adjusting the comparison filter's luminance range, keeping its mean luminance constant. The two filters had different mean luminances, but identical backgrounds. Assuming that the visual system parameterized the filter and background image regions (sinewaves) in terms of mean luminance and contrast, then this setup meant that observers could only match on the basis of contrast. The possibility that mean luminance also influences perceived transmittance was not considered. Thus, observers might have simply been matching the best they could under the restriction that they could only adjust contrast.To address this issue, observers in my experiment matched perceived transmittance by adjusting the comparison filter's (simulated) physical transmittance. The target and comparison backgrounds had different mean luminances and Michelson contrasts, thereby unconfounding filter contrasts from filter-to-background contrast ratios. Also, adjusting the physical transmittance of the comparison filter changed both its mean luminance and contrast, so that their relative importance for matching perceived transmittance could be investigated.Both mean luminance and contrast strongly affected perceived transmittance, contrary to Singh and Anderson's theory. For example, their theory incorrectly predicts that all filters with zero reflectance will appear equally transmissive. Also, Singh's (2004) claim that their theory predicts lightness matching through transparency is incorrect.

H17 *823* Perceptual Transparency Determines Illusory Motion

Caterina Ripamonti[1] (c.ripamonti@ucl.ac.uk), Stephen Westland[2]; [1]Institute of Ophthalmology, University College London, [2]School of Design, University of Leeds

Aim. We present a new illusory motion generated by a pattern drifted diagonally with respect to its two components. The components consist of (i) a set of horizontal bars spatially superimposed on (ii) a square-wave vertical grating. When the pattern is drifted diagonally, the two components can either appear to separate and slide past each other (sliding percept, illusory motion), or remain together as a single plaid-like pattern drifting diagonally (diagonal motion). We have investigated the chromatic conditions that determine the illusory motion. We show evidence that illusory motion occurs when the pattern is compatible with the chromatic conditions that determine perceptual transparency. Specifically, these conditions are defined by the invariance of the cone-excitation ratios

(Ripamonti & Westland, 2003). That is, when a pair of surfaces (vertical grating) are viewed directly, then through a transparent filter (horizontal bars), the cone excitations for the pair of surfaces change, but the ratios of their excitations remain unchanged. **Method.** A series of horizontal bars (0.8deg) partially superimposed a square-wave vertical grating (0.8deg). The whole pattern moved diagonally at 10Hz and was viewed through a circular aperture (9.5deg). The cone-excitations of the grating and bars were manipulated in order to systematically vary the cone-excitation ratios. Observers responded whether the motion was sliding or diagonal. **Results and Conclusions.** When the two ratios approximated the invariance, observers perceived sliding motion. Moreover, the sliding percept was delayed due to the time taken for the colour and motion detecting mechanisms to interact.

H18 *824* Can the probability of occurrence of imperfect scission predict the extent of perceived transparency?

Simone Gori[1] (simone.gori@unipd.it); [1]University of Padua

In achromatic transparency, Beck and Ivry (1988) have found that color scission may be imperfect, i.e., observers may report that the color of the background seen through the transparent region differs from the color of the background seen directly. The present study tested whether the probability of occurrence of imperfect scission predicts the extent of perceived transparency. Experimental stimuli consisted of a bicolored rectangle with a transparent square placed on the center of the rectangle. Let P and Q be the luminances of the left and right halves of the transparent region and let A and B be the luminances of the left and right halves of the rectangle outside the square, respectively. Four values were used for each of these luminances. Of all possible combinations, those that satisfied the relation A < P < Q < B were used for the experimental stimuli. Subjects had the task to report whether the colors seen through the transparent region on the left and right halves of the background were equal or differed from the colors seen directly on the left and right halves of the background, respectively. Subjects also rated the extent of transparency of the transparent square on a 1-99 scale. All subject showed imperfect scission. It has been found that the extent of transparency was equal to the product of a proportionality constant multiplied by the arithmetic mean of the proportion of reports that scission was imperfect in the left and in the right parts of the transparent square.

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H19 *825* Corner salience varies parametrically with corner angle during flicker-augmented contrast

Xoana G Troncoso[1] (x.troncoso@neuralcorrelate.com), Stephen L Macknik[1], Susana Martinez-Conde[1]; [1]Barrow Neurological Institute, Phoenix, Arizona

When corners are embedded in a luminance gradient, their perceived salience varies parametrically with corner angle (Troncoso et al, Perception, 2005), as does corner-related BOLD activation in all human retinotopic areas (Troncoso et al, ECVP, 2005). However, the parametric relationship between corner angle and corner salience may not be solely restricted to corners within luminance gradients, but hold true for all types of corners in the world. To test this hypothesis, we developed a variant of the flicker-augmented contrast illusion (Anstis and Ho, 1998): we flickered solid (i.e. non-gradient) corners of different angles from black to white (50% luminance over time) against a black or a white background. Sharp corner angles generated a qualitatively stronger illusory effect than shallow corner angles. To objectively quantify this effect, we conducted a 2AFC experiment, where subjects had to indicate which of two stimuli was brighter: a Standard or a Comparator. The Comparator was a flickering corner with 14 possible angles: ±15°, ±30°, ±45°, ±75°, ±105°, ±135°, ±180°. The Standard was a non-flickering bar made of multiple luminance segments, pseudorandomly scrambled (each segment had one of 11 possible levels of luminance). Our results showed a parametric relationship between the strength of the flicker-augmented contrast illusion and the sharpness of the corner angle. We propose that this relationship between corner salience and corner angle is a general and fundamental principle of corner perception, with potentially crucial implications for the brain mechanisms underlying early visual processing of shape and brightness.

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URL: http://www.neuralcorrelate.com/smc_lab/

H20 *826* Surface reflectance properties and feel of object surface

Kazuhiko Yokosawa[1] (yokosawa@l.u-tokyo.ac.jp), Ataru Era[1]; [1]The University of Tokyo

In daily life, we are able to discriminate various materials by sophisticated feel of object surface. On the other hand, it has been considered that unique physical parameters like surface contrast and distinctness represent psychological attributes like gloss and smoothness, respectively (Fleming et al., 2001). Here, the suitability of this simple correspondency between physical parameters and psychological attributes was tested in two experiments. Contrast and distinctness were defined as the degree of specular and diffuse reflectance, respectively. We used spherical objects as stimuli, whose surface reflects natural scenes. Participants evaluate the degrees of gloss and smoothness. Greenish and monochrome surfaces were used in Experiments 1& 2, respectively. As a result, both gloss and smoothness could be explained regressively by two physical parameters of contrast and distinctness in high correlation. That is, both subjective evaluation, gloss and smoothness, were the result of interaction between two physical parameters at least. This means that these subjective attributes are not simple but might involve multiple factors. And different regression equations were provided by Experiments 1 and 2. This suggests that the color tone is also a determinant of gloss and smoothness.

H21 *827* Adding a veiling luminance is not sufficient to explain the effects of glare on simple reaction times

Rolando C Aguirre[1,2] (raguirre@herrera.unt.edu.ar), Jose F Barraza[1,2], Elisa M Colombo[1,2]; [1]Department of Luminotecnia, Luz y Visión - Facultad de Cs Exactas y Tecnología - Universidad Nacional de Tucumán - Tucumán - Argentina, [2]CONICET - Consejo Nacional de Investigaciones Científicas y Técnicas - Argentina

Purpose. The reduction of visual performance due to glare was traditionally modeled by adding to the stimulus a uniform veiling luminance (Lv), which reduces the effective contrast of the image. We investigate whether this model can account for the increase of simple reaction times obtained when a steady glare source is presented in the periphery of the visual field. Methods. We measured Simple Reaction Times (RT) of mesopic achromatic sinusoidal gratings as a function of contrast, for three levels of glare (0, 15, and 60lx) and four spatial frequencies (1, 2, 4, and 8c/deg). Results. When we plot RT as a function of the inverse of contrast, RT increases linearly for all levels of glare and spatial frequencies. The higher is the glare the steeper are these lines. This effect is stronger for low than for high spatial frequencies. We used the formula proposed by Plainis and Murray (Neuropsychologia, 2000), which relates RT with contrast, luminance, and spatial frequency and estimated the Lv that produces the best fit of the model to the experimental data. We now re-plotted the data as a function of the inverse of the effective contrast and found that, for low spatial frequencies, the reduction of effective contrast can explain the increase of slopes. However, this explanation does not hold for high spatial frequencies. Conclusion. The veiling luminance model, which is independent from spatial frequency, cannot account for the effect of glare on the Simple Reaction Times.

Action and Space Perception

H22 828 An influence of "warming up" on distance perception

Cedar Riener[1] (criener@virginia.edu), Dennis Proffitt[1]; [1]University of Virginia

Recent research by Proffitt and colleagues has indicated that the perception of distance is influenced by the state of the body. These studies demonstrate effects of physiological state on distance perception by inducing large changes in physiological state and observing differences in estimates of distance perception. The current study examines the influence of a more subtle change in physiological state, that of "warming up." Warming up before exercise prepares muscles for work and improves cardiovascular efficiency. Warming up therefore decreases the amount of effort required to traverse a certain distance, whereas fatigue increases the amount of effort required. Following the hypothesis that perceived distance is influenced by the predicted effort required to act on that distance, distances would appear closer to those observers who have warmed up, compared to those who have not. In the current study, two groups of participants first made several distance estimates to targets in a hallway as baseline measure. Then, one group of participants warmed up by riding slowly on a stationary bicycle for three minutes, while the other group sat down for three minutes. Finally each group made a second set of distance estimates. A ratio score was constructed by dividing the post-adaptation by the pre-adaptation estimates. The ratio scores were significantly lower (indicating a relative decrease) in the group that warmed up, compared to the group that sat. This result further supports the hypothesis that physiological state can influence the perception of distance.

H23 829 Effects of Effort and Intention on Perception: The Locus of the Effect

Jessica K. Witt[1] (jwitt@virginia.edu), Dennis R. Proffitt[1]; [1]University of Virginia

People perceive their environment in terms of the energetic costs associated with the actions that they intend to perform. For example, hills look steeper when people wear a heavy backpack (Bhalla & Proffitt, 1999) and targets look farther away when people throw heavy balls to them (Witt et al., 2003). Moreover, these effects are conditionalized by intention. Only effort associated with an intended action influences perception (Witt et al., 2004). These experiments demonstrate that non-visual information -- such as the energy expenditure required to perform an intended action -- influences perception. Several implications result from this research including the claim that perception is not a modular, informationally-encapsulated process. This research is often met with resistance and an alternative explanation that the effects are due to post-perceptual processes as opposed to an effect on perception itself. In a critical experiment, we examined the locus of these effects and demonstrated that effort and intention affect perception directly rather than influencing post-perceptual processes. Perception relates spatial layout, as specified by optical and ocular-motor information, to the energetic costs of intended actions.

H24 830 Effort Affects Perceived Distance to Objects Within Reach

Jonathan R Zadra[1] (zadra@virginia.edu), Sally A Linkegauger[1], Dennis R Proffitt[1]; [1]University of Virginia

Previous research demonstrates that distance perception is not solely a function of optical variables, but rather is also influenced by the perceiver's physiological state, intent to act on a distance, and the effort associated with such an action. Proffitt and colleagues have shown that perceived distance increases when the perceiver is wearing a heavy backpack (Proffitt, Stefanucci, Banton, & Epstein, 2003). This and other similar studies used distances beyond 4 meters. In the present studies, we examine the influence of effort on distance perception for objects within reach. Participants were seated at a table and a beanbag was placed before them at 40, 50, or 60 cm (four trials each). Participants were asked to imagine picking the bag up, then gave a distance estimate using a visual matching task, and finally reached for and picked up the bag. Effort was manipulated across two conditions, using either a light (<1 lb) or heavy (5 lb) beanbag. Participants who intend to pick up the heavy bag judge all three distances as greater than participants who intend to pick up the light bag. These results suggest that, similar to results from longer distances, our perception of distances within our reach is also influenced by effort.

H25 831 The Roles of Altitude and Fear in the Perception of Height

Jeanine K Stefanucci[1] (jks8s@virginia.edu), Dennis R Proffitt[1]; [1]University of Virginia

While the perception of distance on the ground has been extensively studied, the perception of vertical extents (or heights) is a relatively understudied aspect of spatial layout. In a series of experiments, we show that the perception of vertical extents are slightly overestimated when viewed from the ground, but largely overestimated when viewed from the top. The following three measures were used to assess the perception of vertical extents: 1) visually matched estimates of apparent distance, 2) visually matched estimates of apparent size, and 3) a triangulation by walking estimate. When viewing from the top, participants overestimated the distance to the ground by as much as 60%, the size of targets on the ground by 22%, and triangulated walking estimates by 13%. When looking up, participants only overestimated the distance by 23%, but size and triangulated walking estimates for targets viewed from below were accurate. Results obtained from both the real world and virtual reality will be discussed. Furthermore, a non-optical variable — fear — was positively correlated with participants' overestimation of height. We suggest that the overestimation of height that occurs when looking down from a high place is due to both the altitude and a fear of falling.

H26 832 Ease to Grasp an Object Affects Perceived Distance

Sally A Linkenauger[1] (sal3g@virginia.edu), Jessica Witt[1], Jeanine Stephanucci[1], Dennis Proffitt[1]; [1]University of Virginia

Recent research has shown that the ability to act affects perception of spatial layout. For example, as the effort to traverse a distance or climb a hill increases, people's perception of distance and slant increase as well (Proffitt et al., 2003; Bhalla & Proffitt, 1999). In addition, tool use decreases distance estimations to target objects presumably, because of the increased ability to interact with the object (Witt et al., 2005). In the present experiment, we manipulated participants' ability to grasp tools by changing the position of the tool's handle. Several tools were presented at a varying distances to the left or right of the observer. The objects were either placed in a position and orientation where they were easy to grasp or hard to grasp. Participants estimated the distances to the tool using a visual matching task. Participants estimated the distance to a tool as farther away when the tool was difficult to grasp than when the tool was easy to grasp. These findings support the notion that the ability required to grasp an object affects distance perception.

H27 833 Absolute egocentric distance judgments are improved after motor and cognitive adaptation within HMD

Betty J Mohler[1] (bmohler@cs.utah.edu), William B Thompson[1], Sarah H Creem-Regehr[2]; [1]School of Computing, University of Utah, [2]Psychology Department, University of Utah

In full-cue, real-world environments, people are accurate at visually-directed actions to targets on the ground. The same distance estimation tasks conducted in virtual environments using head-mounted display (HMD) systems show that people act as though the environment is smaller than intended. The explanation for this difference between actions in real and virtual environments is unknown. Our current study investigated influences of adaptation within the HMD on subsequent distance judgments. Two forms of feedback were evaluated using two distinctly different response measures. In a pre-test, subjects indicated egocentric distances to targets on the floor using one of two measures: blind walking

or verbal reports. In the adaptation period, they experienced one of two interventions. A visual-motor intervention involved the continuous visual and motor feedback of walking with eyes open to previously viewed targets. A non-visual-motor intervention involved walking with eyes closed until the subjects were told that they reached the previously viewed target. After this adaptation period, subjects completed a post-test in which they performed the same task as in the pre-test. Distances were underestimated in the egocentric distances by approximately 30% for both tasks during the pre-test, consistent with previous results. Notably, subjects became significantly more accurate at both blind-walking to targets and verbal reports of distance after both adaptation experiences. The results indicate that both cognitive and motor indications of distance can be recalibrated in the HMD and suggests that recalibration can be caused by effects other than the interaction of sensory modalities indicating the speed of travel.

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H28 *834* Individual differences in accuracy of blind walking to targets on the floor

Scott A. Kuhl[1] (skuhl@cs.utah.edu), Sarah H. Creem-Regehr[2], William B. Thompson[1]; [1]School of Computing, University of Utah, USA, [2]Department of Psychology, University of Utah, USA

Walking without vision to previously viewed targets is a task commonly used to measure the perception of absolute distance. Previous work indicates that subjects are accurate at this task in full cue real world environments to targets up to 20 meters (Loomis et al.,1992). We reexamined claims of accuracy while looking for evidence of individual differences and changes in performance over time by analyzing data pooled from previous studies in our laboratory. This data came from over 100 subjects and involved 1,200 direct blind walking trials to targets at distances up to 12 meters. We found that, on average, subjects walked 96% of the distance to the target. One sided t-tests ($p < .05$) indicate that approximately one third of the subjects walked significantly less than the global average and another third of the subjects walked significantly more than the global average. These two groups walked 83% and 108% of the way to the target respectively on average. These individual differences indicate that blind walking experimenters should not necessarily compensate for a small number of subjects by running more trials per subject. An analysis of the percent walked by individual subjects over trials supports the suggestion by Philbeck et al. (2004) that subjects become more accurate at blind walking as they complete more trials even when no feedback is provided. Similar analyses would be useful to perform on distance judgments within HMD-based virtual environments, in which systematic biases of underestimation of distance are typically found.

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H29 *835* The Effects of Optical Compression and Magnification on Distance Estimation

Jennifer L Campos[1] (camposjl@mcmaster.ca), Adrian S Brucker[1], Zeljka Vucetic[1], Hong-Jin Sun[1]; [1]McMaster University

When moving through space, both visual and non-visual information can be used to monitor distance traveled. It is important, although challenging to dissociate the relative contributions of each of these cues when both are available in natural, cue-rich environments. This study created a conflict between visual and non-visual distance cues by either magnifying (2x) or compressing (0.5x) the information contained in the optic array using spectacle-mounted lenses. The experiment took place in a long, wide hallway, relatively void of visual landmarks. Subjects (Ss) were required to view a static target in the distance (4, 6, 8, 10m) and reproduce this distance by walking. Ss experienced four optical conditions (2x, 0.5x, 1x, or no lenses) either during the visual preview (Exp 1) or during the walked response (Exp 2). In Exp 1, Ss viewed the target distance under each of the four optical conditions and produced their estimates by walking blindfolded. In Exp 2, Ss viewed the target distance without lenses and produced their estimate by walking under each of the four optical conditions. In Exp 1, when wearing the 2x lenses during visual preview, Ss produced estimates that were significantly shorter than those produced when wearing 1x or no lenses. The opposite was true when wearing the 0.5x lenses. In Exp 2, however, regardless of the optical manipulation, Ss' estimates remained essentially unchanged, thus suggesting a reliance on non-visual cues. Such findings may reflect the tendency for subjects to weigh more reliable cues higher in their final estimate.

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H30 *836* Effects of context on a 3D pointing task

Michelle J.A. Doumen[1] (m.j.a.doumen@phys.uu.nl), Astrid M.L. Kappers[1], Jan J. Koenderink[1]; [1]Helmholtz Institute, Utrecht University, The Netherlands

We examined the effect of external and internal references on the judgment of positions of objects in a visual scene. We used a 3D exocentric pointing task in which an observer had to direct a pointer toward a target with a remote control. We varied the positions of the observer, the pointer and the target. We measured deviations from veridical settings in the horizontal plane and in the vertical plane. We found that observers differed in dependence on certain references. Some people showed smaller deviations in the horizontal plane when the pointing-direction was parallel to one of the walls, others showed smaller deviations in the horizontal plane when the pointing-direction was in the frontoparallel plane, while a third group showed an interaction between these two effects. For the deviations in the vertical plane, we found no effect of the presence of a wall parallel to the pointing-direction. Frontoparallelity, however, influenced the settings of the observers. The deviations in the vertical plane are differently dependent on references than the deviations in the horizontal plane. Thus, our conclusion is twofold: first, the structure of the environment that is used for judging positions of objects is observer-dependent and second, visual space is anisotropic.

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3D Space

H31 *837* On the computational elements of visual surface perception

Hiroshige Takeichi[1,2,3] (takeichi@riken.jp); [1]RIKEN, [2]IML, the University of Tokyo, [3]KARC, NICT

The computation of visual surface perception is not well documented, mainly because of the complex interactions between its phenomenological components, such as illusory contour, transparency, occlusion, and stereopsis. Here it is hypothesized that these phenomenological elements for visual surface perception are compound phenomena that consist of three computational elements. 1. Contour delineation: If a set of features satisfy a relation that is invariant or preserved under projection, the features appear grouped, as they are likely to constitute the image of an object. Shape is a view-invariant and therefore intrinsic property of an object. Thus, recognizable shape features and elements should be preserved under projection. 2. Optics estimation: The optics estimation process is a scission or splitting of the intensity of a *pixel* into components. Components are surfaces, cast shadows, illumination, and cast lights. While shape is a view-invariant property in the contour delineation process, reflectance and transmittance are view-invariant properties in the optics estimation process. 3. Depth stratification: By detecting a multiple match or a binocularly-unpaired region, one identifies a *location* where multiple depth values must be assigned to one direction of sight. If the identified depths or local luminance contrasts are consistent along a contour, they lead to the perception of a visual surface. An advantage in the computational decom-

position is simplification of inter-module interactions. The adequacy of the hypothesis can be tested empirically through variations of the depth propagation effect (*Perception*, **21**, 177), and theoretically in ecological optics.

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URL: http://rarfaxp.riken.jp/~takeichi

H32 *838* The slant of the visual system's intrinsic bias in space perception and its contribution to ground surface representation

Jun Wu[1] (j0wu0001@louisville.edu), Zijiang J He[1], Teng Leng Ooi[2]; [1]University of Louisville, USA, [2]Pennsylvania College of Optometry, USA

The Sequential Surface Integration Process (SSIP) hypothesis posits that the visual system relies on its intrinsic bias and the external depth cues to construct the ground surface representation. We previously deduced that the intrinsic bias, revealed in the dark, takes the form of an implicit surface with its far-end slanted upward (Ooi et al, 2001). To investigate the slant of the intrinsic bias, we measured judged surface slant of a fluorescent L-shaped target in the reduced background(2x4 parallel array of fluorescent elements on the floor in the dark) and dark conditions. The L-shaped target was placed flat, either at the test(4m or 6m on the floor) or catch-trial locations. Observers performed three tasks: (i)aspect ratio matching; (ii)blind-walking to the remembered target location and gesturing its height and slant; (iii)adjusting by hand the slant of a palm-board to match the perceived target slant(while standing at the starting position). We found that for all three tasks, including the last two that directly measured the judged target slant, the L-shaped target was perceived as slanted upward in the dark condition. The perceived slant represents the intrinsic bias, since the ground surface is invisible in the dark. The L-shaped target was also perceived as slanted upward in the reduced background condition, although the perceived slant was significantly decreased compared to the dark condition. This suggests that with external depth cues, the ground surface representation is less influenced by the intrinsic bias, leading to a more veridical slant percept.

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H33 *839* Where's the floor?

Laurence R. Harris[1,2] (harris@yorku.ca), Richard T. Dyde[1], Michael R.M. Jenkin[1,3]; [1]Centre for Vision Research, York University, Toronto, Canada, [2]Dept. Psychology, York University, Toronto, Canada, [3]Dept Computer Science and Engineering, York University, Toronto, Canada

The floor of a room is the surface that is most likely to provide support. What is the contribution of the room's structural features to the perception of which surface this is? Using the Immersive Visual Environment at York (IVY) twelve subjects were placed in three simulated box-like rooms with no features. The rooms had a constant depth, a height-to-width ratio that varied from 1:1 to 1:3 and were presented at different roll orientations in an interleaved manner. The far wall was coloured purple and the other four visible surfaces were randomly assigned one of four colours on each trial and subjects indicated 'the floor' by pressing correspondingly coloured buttons on a game-pad. Each surface was described by its normal vector. The vectors of the chosen surfaces were summed to provide the average orientation of the perceived floor for each room orientation. We tested three models of how people determine the floor. Subjects might choose the surface (1) closest to orthogonal to gravity (flipping point of wall-to-floor at 45^o), (2) closest to orthogonal to gravity on each side of the room's diagonal (flipping point when diagonal of room vertical), or (3) based on a weighting function dependent on each surface's length and orientation. Contrary to expectations, subjects did not necessarily choose the surface closest to orthogonal to gravity. The weighted-surface model best described the data with each surface being weighted by its relative length raised to the power 1.25 ($r^2 = 0.9$).

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H34 *840* Change detection and primacy of the ground surface in scene organization

Zheng Bian[1] (bianz@ucr.edu), George, J Andersen[1]; [1]University of California, Riverside

We reported (2005, under review) a ground surface (compared to ceiling surface) advantage in determining perceived layout (a ground dominance effect). Here we report two experiments using a flicker paradigm to examine if change detection is easier for scenes containing a ground surface as compared to a ceiling surface. In Experiment 1 observers fixated a cross and were presented an original scene (containing a ground and a ceiling surface with randomized black-white checkerboard texture) and a modified scene (with the luminance of one block on a surface changed) for 250ms each in a sequence of A, A, A', A'. The two scenes were alternated until subject's detected a change. Control trials with no change were also included. We found that detecting a change on the ground surface was easier than changes on a ceiling surface. In Experiment 2 we examined if this advantage of the ground surface was due to its location in visual field. On each trial only one surface was presented and the surface was either in the lower visual field or in the upper visual field. We found a change on the ground surface easier to detect in the lower visual field but more difficult to detect in the upper visual field. These results, considered in light of recent ground dominance studies, suggest that the ground surface is of primary importance in the perceptual organization of scenes.

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H35 *841* Size-distance perception based on ocular convergence angle in 3- to 5-year-old children

Albert Yonas[1] (yonas@umn.edu), Carl E. Granrud[2], John Grittner[1]; [1]Institute of Child Development, University of Minnesota, [2]School of Psychological Sciences, University of Northern Colorado

Changes in convergence angle affect the perceived size and distance of objects whose actual size and distance remain constant. With increased convergence angle, observers consistently perceive decreased object size and distance. With decreased convergence angle, observers perceive increased object size and distance. Although these effects are well established in adults, they had not been investigated previously in children. This study tested 3- to 5-year-old children and college-aged adults. Participants viewed a stimulus object, whose size and distance remained constant, through a mirror stereoscope, whose mirrors could be rotated to manipulate convergence angle. Each participant received 8 trials: 4 in which convergence angle increased and 4 in which it decreased. Convergence angle had similar effects on perceived size and distance in children and adults. Participants in both age groups consistently reported that the object appeared to move closer and become smaller when convergence angle increased, and appeared to move farther away and grow larger when convergence angle decreased. In addition, magnitude of change in perceived size was similar in the two age groups. These results suggest that an unconscious inference-like process, that takes distance cues into account in perceiving size, operates in young children as well as in adults. Previous studies have found substantial differences between children and adults in size constancy performance. This study's findings are consistent with the hypothesis that the same perceptual mechanisms govern size perception in children and adults, and that age-related changes in size constancy performance result from cognitive, not perceptual, development.

H36 *842* Egocentric distance estimation requires eye-head position signals

Gunnar Blohm[1] (blohm@yorku.ca), J. Douglas Crawford[1,2]; [1]Centre for Vision Research, York University, 4700 Keele Street, Toronto, Ontario, M3J 1P3, Canada and Canadian Institutes of Health Research, Group for Action and Perception, [2]Departments of Psychology, Biology and Kinesiology & Health Sciences, York

University, 4700 Keele Street, Toronto, Ontario, M3J 1P3, Canada

In order to successfully reach to an object presented in the visual field, the brain must reconstruct the egocentric spatial location of this object from available retinal and extraretinal information. The retinal images from both eyes are merged to provide a unique (cyclopean) representation of object direction. Retinal disparity between eyes provides information about the object's distance from the cyclopean eye. The complex geometry of eye-in-head and head-on-body rotations suggests that retinal disparity information of a reach target may not be invariant with regards to gaze (cyclopean eye-in-space) direction. Here, we developed a 3-dimensional (3D) binocular model that incorporates the complete geometry of eye and head rotational positions. We show that different eye-head orientations produce distinct retinal disparities so that, given a target viewed at fixed retinal disparity and cyclopean retinal location, the brain cannot reconstruct target distance without knowledge of eye and head positions. Thus, extraretinal eye and head positions are needed, in addition to retinal disparity and vergence signals, to compute an estimate of distance. This represents the first theoretical evidence showing that the depth component of a desired reach can be accurately computed only if the brain takes into account the linkage geometry of the eye and head. This calculation thus requires a complete 3D visuo-motor reference frame transformation.

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H37 *843* The contribution of binocular disparity to depth perception in natural scenes

Samira Bouzit[1] (sb70@st-andrews.ac.uk), Paul B. Hibbard[1]; [1]School of Psychology, University of St Andrews, United Kingdom

The role of this study was to assess the role of binocular cues in the perception of 3D shape under natural viewing conditions. While studies of binocular vision often use simple stimuli in order to isolate binocular cues, in the natural world there are many, highly redundant sources of information regarding the 3D structure of the environment. It is important to establish the role of binocular cues in the perception of depth in this natural context. Binocular natural scenes were captured under controlled viewing conditions using two digital cameras. Participants were presented with monocular and binocular images in a dark room using a standard Wheatstone stereoscope at a distance of 50cm. Following Koenderink (1996), observers were shown a number of pairs of dots on the surface at different locations and were asked to discriminate the depth of these dots, i.e. to assess which point was the closer of the two. The dots were distinguished by their structure as a disk and a circle. Observers' responses were converted into depth inequalities and were used to determine (i) relief maps of perceived depth and (ii) the internal consistency of observers' local depth judgments. Contrary to the expectation from using simple stimuli, the pictorial relief maps could not be meaningfully generated for both viewing conditions. Observers' responses show good repeatability of responses to individual pairs of points. Responses were more consistent under monocular viewing. The current study shows little indication of the contribution of binocular cues to this process under natural viewing conditions.

H38 *844* Elucidating the Factors Influencing Judgments of Egocentric Distance in Immersive Virtual Environments

Victoria Interrante[1] (interran@cs.umn.edu), Lee Anderson[2], Brian Ries[1]; [1]Department of Computer Science, University of Minnesota, [2]Department of Architecture, University of Minnesota

Numerous experiments investigating egocentric distance perception in immersive virtual environments have found that distances are underestimated in virtual environments relative to in the real world. However we have recently discovered a notable exception to this rule: when the virtual environment represents an exact 3D replica of the occupied real environment, and when the participant is allowed to unambiguously verify this by viewing the real environment before donning the display on which the corresponding virtual environment is presented, distances are judged nearly equivalently in the virtual and real worlds. Two explanations are possible: 1) the accuracy of participants' distance judgments is related to their sense of 'presence' in the virtual environment, which increases when they have unambiguous evidence that the presented virtual environment corresponds to the occupied real environment; or 2) participants are able to use metric information gleaned from their prior exposure to the real space to calibrate the size of the corresponding space presented via the head mounted display. To disambiguate, we have designed a follow up experiment in which we surreptitiously vary the positions of the walls in the virtual environment so that the floor space (distances between opposing walls) is either slightly less or slightly greater in the virtual environment than in the real environment. If the first hypothesis holds, then we should not expect to see much degradation in the accuracy of participants' distance judgments as a result of these manipulations; however if the second hypothesis holds, then the accuracy of distance judgments should decline.

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URL: www.cs.umn.edu/~interran/full_pub_list.html

H39 *845* Spatial compression produced by a stationary telescope

H A Sedgwick[1] (hsedgwick@sunyopt.edu), Grace Tran[2]; [1]SUNY State College of Optometry, [2]Illinois College of Optometry

A telescope compresses optically specified distance. Shah and Sedgwick (2004), measuring perceived distance using a walking task with free head movements, found much less telescopic compression of perceived distance than was optically specified. They also found no significant difference in perceptual compression between a telescope and a plain tube having the same field of view. Our study measured the compression in depth of perceived shape while looking through a stationary telescope. A 2.75x telescope was mounted 40 cm above a tabletop patterned with receding stripes. The 11.6 degree field of view was centered on a series of rectangular stimulus cards lying flat on the table at a distance of 100 cm. Participants monocularly viewed each card through the telescope, or through a tube having the same field of view, and verbally judged the card's perceived length (in depth) relative to its width (in the frontal plane). Perceptual compression of shape was calculated by dividing the perceived proportion (length/width) by the actual proportion. The telescope and the tube both produced significant perceptual compression, but perception was significantly more compressed through the telescope (0.43) than through the tube (0.52). The perceptual compression produced by our stationary telescope matched the optically specified compression (0.43) that we calculated based on the telescope's magnification and viewing angle. In addition, monocular vision, restricted head movements, and a restricted field of view may have contributed to the compression in depth of perceived shape with both the tube and the telescope.

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H40 *846* The Use of Radial Outflow for the Perception of Depth In Remote Environments

Christopher C. Pagano[1] (cpagano@clemson.edu), Megan P. Smart[1], Thandi B. Blanding[1], Vilas K. Chitrakaran[1]; [1]Clemson University

Previous research has shown that self-produced head motions towards and away from a target serve as effective information about egocentric depth. We investigated depth perception of a remote target viewed via a camera attached to a robotic arm. The participants viewed the expansion and contraction of the target's image on a monitor as the camera was passively moved towards and away from the target with a consistent sinusoidal velocity profile. The task was to report the distance from the remote camera to the target. Eight subjects participated in three experimental sessions in a fixed order. The first session used familiar objects as stimuli (a

tennis ball, soda can, compact disk, etc.). This allowed participants to relate the images' expansion rate to the distances of objects of known actual size. The second and third sessions used plain white squares with image sizes controlled so as not to be related to depth. Visual feedback regarding error was given throughout the first and second sessions. No feedback was given in the third session. For all three sessions the actual distance of the target was a significant predictor of perceived distance. Results indicate that radial outflow produced by an oscillating camera can serve as effective information about depth in a remote environment. The results also show that after initial training this information can be used without feedback. These results have implications for the design of systems to aid depth perception for teleoperation.

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H41 *847* Manipulating prior assumptions about 3D stability

Andrew Glennerster[1,2] (a.glennerster@rdg.ac.uk), David McKean[2], Stuart J Gilson[2]; [1]Department of Psychology, University of Reading, UK, [2]Laboratory of Physiology, University of Oxford, UK

We have found that when a virtual room expands around an observer as they move through it, binocular and motion parallax cues fail to override the observer's assumption that the room is static, leading to gross errors in size constancy. Here, we investigated whether this assumption could be changed.Wearing a head mounted display in an immersive virtual reality system, subjects compared the size of an object visible only on the left side of a room (when the room was small) with one visible on the right (when everything in the room was 4 times larger and 4 times more distant) [condition A]. Subjects then repeated the experiment in a similar expanding room that contained constant-sized objects (human figures) [condition B]. Here, size judgements were much closer to veridical. After training, the improved size judgements persisted even without the human figures [A,B,A], showing subjects' prior assumptions had been changed.Other subjects repeated the experiment using a training stimulus in which texture elements on the walls and floor remained a constant physical size as the room expanded [condition C]. This gave a much stronger impression that the room changed size and more accurate size matches. However, it was less effective in changing subjects' size matches in the test phase [A,C,A]. Direct comparison in the same subjects [A,C,A,B,A] confirmed the greater effectiveness of condition B. Conclusion: Breaking subjects' assumption of a stable world is most effective when visual stimulation during the training phase is similar to that during the test phase.

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URL: http://virtualreality.physiol.ox.ac.uk/

H42 *848* The hidden scale of natural forms: a new cue to depth?

Erik Blaser[1] (erik.blaser@umb.edu); [1]Department of Psychology, University of Massachusetts Boston

Purpose: To determine if there exists a heretofore unknown cue to scale, and therefore depth, hidden in the patterns of natural materials. **Background**: Conventional wisdom holds that materials such as clouds, rock, and water are fractal and scaling-symmetric: they look the same no matter how far you zoom in. But it is also clear that physical forces place different constraints at different scales. Elephant-sized ants collapse; surface tension can only create small water droplets. **Hypothesis:** The structural legacy of these different constraints should be evident in the visual patterns of the materials - likely both reflectance and relief - and a resourceful visual system would exploit this cue. **Method:** Observers viewed images (rock formations in Utah) that lacked any known depth cues. Images were carefully vetted, filled the picture frame, and had no obvious relationship between spatial frequency power spectra and distance. These test images appeared on the left side of the monitor, while a full-cue measurement image of a standing woman appeared on the right. Observers zoomed in or out on the measurement image until it matched the distance of the test. **Results:** Ten naive observers were able to make distance judgments that were correlated with actual distances. Performance was only slightly degraded in conditions with inverted or grayscale test images. **Conclusion:** We take these results as an existence proof for an absolute cue to scale and depth in the visual structure of, at least, one natural material: rock. Our current work seeks to further isolate and formalize this cue.

Attention and Reward: Cortical Physiology

H43 *849* Posterior Cingulate Neurons Encode Visually and Motivationally Salient Events

Arwen B Long[1] (arwen@neuro.duke.edu), Allison N McCoy[1], Michael L Platt[1]; [1]Department of Neurobiology, Duke University

In monkeys performing delayed saccade trials, posterior cingulate (CGp) neurons respond to visual target presentation, after saccade onset, and following reward delivery. These responses are modulated by expected reward size, probability, and variance. Furthermore, response strength predicts saccade accuracy. These results suggest the hypothesis that CGp neurons signal visuospatial salience, thus contributing to biased attention and orienting. This hypothesis predicts that CGp neurons should respond to salient visual cues in the absence of saccades and, further, that these responses should vary with cue reward value. To test this prediction, we recorded from single CGp neurons in monkeys performing a visual fixation task while peripheral cues were presented in the neuronal response field. Cue color predicted the size of reward delivered for correct performance and, across blocks, color-reward pairings were reversed. A population of CGp neurons showed sustained responses to visual cues and for some neurons these responses reflected cue value. One question these data raise is whether CGp neurons respond to salient events in the absence of any visuomotor task. To address this question, we delivered rewards at unpredictable intervals while monkeys sat passively in the dark. Many CGp neurons responded to reward delivery under these conditions. These results suggest that CGp neurons encode both visually and motivationally significant events.

H44 *850* Microstimulation in Macaque Posterior Cingulate Cortex Biases Target Choice

Benjamin Hayden[1] (hayden@neuro.duke.edu), Heather Dean[1], Michael Platt[1]; [1]Department of Neurobiology, Duke University

The mechanisms by which the brain integrates knowledge about potential rewards with visualspatial information to guide saccades are poorly understood. Recent data from our lab suggest that posterior cingulate cortex (CGp) mediates this process. We have shown that neurons in posterior cingulate cortex (CGp) signal both the expected value of orienting to visual targets and the motivational consequences of orienting to those targets (McCoy et al. 2003). If CGp is the site of binding for rewards and visuospatial information, then microstimulation during the delay period in a free choice task should bias monkeys to choose the contralateral target. To test these hypotheses, we recorded choices made by monkeys when they were allowed to saccade to either of two spatial positions. (The two options were associated with equal rewards.) We stimuluated at sites in CGp on half the trials. We found that microstimulation during the delay period biases choices towards the contralateral target. Stimulation during the delay period also decreases saccade latency. These effects may represent a combination of stimulation-induced bias and a compensatory bias on trials with no stimulation. These results suggest that artificial activation of CGp neurons enhances the motivational salience of contralateral space, and that CGp participates in assigning value to spatial locations.

H45 *851* **LIP neurons encode both social and fluid value for visual orienting.**

Jeff T. Klein[1] (kleinjeff@neuro.duke.edu), Robert O. Deaner[1], Michael L. Platt[1,2,3]; [1]Dept. of Neurobiology Duke Univ. Med. Ctr., Durham, NC 27710, [2]2Center for Cognitive Neuroscience Duke Univ. Med. Ctr., Durham, NC 27710, [3]Dept of Biological Anthropology & Anatomy, Duke Univ. Durham, NC 27710

Recent studies suggest that neuronal activity in several brain areas reflects the expected value of fluid reinforcement associated with saccades. We sought to address the question of whether this activity is specific to particular reinforcers, or is more abstract. Monkey subjects therefore performed a choice task, in which saccades to one target (T1) were rewarded with juice, while saccades to the other target (T2) were rewarded with both juice and an image of the face or perineum of a familiar monkey. Varying the outcomes for orienting to T1 and T2 permitted us to estimate the value of orienting to social images in fluid units. We found that male subjects paid a fluid premium to view images of female perineums and the faces of dominant individuals, but were indifferent to images of subordinates. Moreover, social value was highly consistent across subjects and independent of particular images displayed. Next, we studied the activity of single neurons in area LIP and found that firing rate was modulated by both the juice value and the social value associated with T2 choices. Population analysis revealed correlations between firing rate and social value that mirrored correlations between firing rate and fluid value. We also permitted monkeys to perform single target trial blocks where social and fluid value varied independently. During single target blocks, LIP firing rate was not systematically correlated with juice or social value. These findings collectively suggest that parietal cortex carries an abstract representation of relative orienting value.

H46 *852* **Segregating the Effects of Motivation and Reflexive Visual Attention on Neuronal Activity in Area LIP**

Michael S. Bendiksby[1] (bendiksby@neuro.duke.edu), Michael L. Platt[1]; [1]Dept. of Neurobiology, Duke University Medical Center

Distinct neural systems process motivation and attention. At the behavioral level, however, both attention and motivation influence the reaction times of monkeys orienting to visual targets. Similarly, both attention and motivation enhance neuronal responses to visual targets in several visual and oculomotor brain areas in monkeys. Since both attention and motivation are conditioned by fluid rewards in such studies, the extent to which modulations in neuronal activity reflect attention or motivation remains unclear. Distinguishing these requires orthogonal manipulations of attention and reward. We attempted to distinguish motivational from attentional modulations in neuronal activity in area LIP in rhesus monkeys by training them shift gaze to visual targets while attention was manipulated exogenously and reward size was varied. Monkeys shifted gaze to a peripheral visual target 100-800 ms (SOA) after the illumination of a non-predictive visual cue either at the target location (valid condition) or diametrically opposed with regard to fixation (invalid condition). Small, medium, and large rewards were cued on each trial by the color and shape of the fixation stimulus. Saccade latencies were faster on valid than invalid trials, suggesting capture of attention by the peripheral cue; and also decreased with increasing reward, suggesting enhanced motivation. Importantly, there was no interaction between the effects of attention and motivation on reaction times. In preliminary neurophysiological data, the responses of LIP neurons were enhanced when validly cued targets appeared in their response fields and when saccade latency into the RF was decreased, but were only weakly modulated by reward size.

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H47 *853* **Modulation of cortical feedfoward dynamics by endogenous and exogenous attention**

Thomas Schmidt[1] (thomas.schmidt@psychol.uni-giessen.de), Anna Seydell[2]; [1]University of Giessen, Germany, [2]University of Goettingen, Germany

Single-cell recordings indicate that a visual stimulus elicits a wave of rapid neuronal activation that propagates so fast that it might be free of intracortical feedback. We traced the time-course of early feedforward activation by measuring pointing responses to color targets preceded by color stimuli priming either the same or opposite response as the targets. Effects of visual attention at the prime/target locations were studied by giving either an endogenous or an exogenous attentional cue, varying both the cue-prime and the prime-target SOA (stimulus onset asynchrony). Early pointing kinematics were time-locked to prime onset and independent of target onset, indicating that initial responses were controlled exclusively by the feedforward information elicited by the primes. However, early pointing dynamics were clearly modulated by attention at optimal cue-prime SOAs. Results indicate that visual attention modulates cortical feedforward dynamics in advance of critical stimuli.

H48 *854* **Attentional modulation of center-surround interactions in macaque area V4**

Kristy A Sundberg[1] (sundberg@salk.edu), Jude F Mitchell[1], John H Reynolds[1]; [1]System Neurobiology Lab, The Salk Inst., La Jolla, CA, USA

Directing attention to one of two stimuli placed within a neuron's classical receptive field (CRF) biases the neuron's response to more closely resemble the response evoked when the attended stimulus appears alone. It is not known, however, how attention modulates responses when one stimulus is positioned in the center of the neuron's CRF and the other is positioned within the surround. To examine this question we trained two monkeys to attentively track 2 out of 4 square wave gratings as they moved along separate trajectories through the visual field. In the middle of each trial the stimuli paused, with one grating in the CRF center, one in the surround, and the other two in the opposite hemifield. We have previously found that with attention directed away (to stimuli in the opposite hemifield), the surround stimulus strongly suppresses the response to the center stimulus. Here we report evidence that this suppression can be modulated by attention. We find that, in some neurons, directing attention to the surround stimulus can magnify surround suppression, and that attention to the center stimulus can reduce surround suppression.

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H49 *855* **Neural activity in areas LIP and MT during rapid covert shifts of attention**

Todd M. Herrington[1] (todd_herrington@student.hms.harvard.edu), John A. Assad[1]; [1]Harvard Medical School, Department of Neurobiology

How fast can visual selective attention be shifted in the absence of eye movements? We studied primate areas LIP and MT during covert shifts of attention between visual targets, while simultaneously measuring the behavioral time course of the attentional shift. Monkeys were trained to detect a 50-ms duration speed increase at one of two patches of coherently moving dots. A cue at the fixation point indicated which patch was more likely to change. The cue was valid on 85% of trials. Critically, on 40% of trials the cue switched at an unpredictable time to indicate that the previously uncued patch was now cued. Detection performance at the cued patch was characterized by improved accuracy (67% vs. 37%, $p << 0.0001$) and decreased reaction times (462 vs. 474 ms, $p << 0.0001$). On switch trials, the monkey rapidly switched attention around the time of the switch cue. Surprisingly, this behavioral switch was first evident for speed changes occurring immediately before the switch cue itself, consistent with visual buffering of the target stimuli akin to iconic memory. The responses of LIP and MT neurons were enhanced by attention. In both neural populations the attentional modulation switched at ~200 ms after the switch cue. Comparing the neuronal attentional switch time with the visual response to the target speed change, we observed that the attentional switch was sufficiently fast to interact with a simultaneously presented speed change. This may represent a neural correlate of the behaviorally evident visual buffer.

H50 *856* **Effects of Frontal Eye Field Microstimulation on the Discriminabilityof Visual Responses in Area V4**

Katherine M Armstrong[1] (karmstro@stanford.edu), Tirin Moore[1]; [1]Department of Neurobiology, Stanford University School of Medicine, Stanford, CA 94305

The source of the perceptual and neurophysiological enhancements observed during selective attention is largely unknown. Recent work has implicated the frontal eye field (FEF), an oculomotor area in the frontal lobe, in the modulation of visual responses in extrastriate cortex. Subthreshold FEF microstimulation enhances responses of retinotopically overlapping V4 neurons in passively viewing monkeys. This effect depends on the stimulus presented to the receptive field (RF): more enhancement is observed for effective than for ineffective stimuli, consistent with the effect of voluntary attention on visual responses. In this study, we examined whether the graded enhancement following microstimulation actually improves the ability of V4 neurons to discriminate different RF stimuli. We used signal detection theory to quantify how well V4 responses could distinguish between two oriented-bar stimuli. Receiver-operator-characteristic (ROC) curves, computed for each neuron's responses, provided a measure by which to examine the impact of FEF stimulation on stimulus discriminability. Several hundred milliseconds after visual stimulus onset, response adaptation had markedly reduced the discriminability of V4 responses to different RF stimuli. However, we found that microstimulation at this point in the trial could transiently increase the area of ROC curves, and thus improve the ability of V4 neurons to discriminate visual stimuli. This suggests that oculomotor signals can improve the stimulus discriminability of neural responses in visual cortex that encode impending saccade targets, or covertly attended stimuli.

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Perceptual Organization: Grouping & Segmentation

H51 *857* **Activity in late visual areas correlates with surface perception**

Seth E Bouvier[1] (sbouvier@ucla.edu), Kristen S Cardinal[2], Stephen A Engel[3]; [1]UCLA Neuroscience Program, [2]UCLA Department of Neurology, [3]UCLA Department of Psychology

The neural mechanisms that allow a percept of a single surface to be formed from noncontiguous regions of an image remain largely unknown. We used fMRI to measure the responses of visual areas to ambiguous patterns that could be perceived as either a coherent surface or as unconnected fragments. Subjects viewed a dynamic array of small adjoining elements that were randomly assigned as either surface or noise every 100 ms. On each trial the color of the surface elements was identical and the color of each noise element was randomly sampled. Prior to scanning, each subject's threshold was defined as the proportion of elements assigned to surface when the subject perceived a surface on half of the trials. Each subject in the fMRI experiment viewed stimuli at their individually measured threshold as well as values above and below this threshold. Neural responses to each condition were estimated as the linear kernels that best fit the event-related timecourse from each of many visual areas. Early visual areas (V1,V2) responded most strongly during trials with a high proportion of noise elements while later visual areas responded most strongly during trials with a low proportion. Furthermore, in later visual areas responses to threshold stimuli were 33% higher during trials in which the subject perceived a surface than during trials in which the subject did not. Early visual areas did not show this pattern. Later visual areas likely contain neurons whose activity correlates with coherent surface perception on a trial-by-trial basis.Supported by NIH EY11862

H52 *858* **Figure-ground effects in V1 measured with functional MRI**

Erin M. Harley[1] (harley@psych.ucla.edu), Seth E. Bouvier[1], Genevieve M. Heckman[1], Stephen A. Engel[1]; [1]UCLA Department of Psychology

Cells in V1 show increased spiking when texture elements within the neuron's receptive field belong to a figure compared to when those same elements belong to the background (Lamme, 1995). We examined whether figure-ground signal enhancement could be measured in a population of neurons in human V1 with fMRI. Previous fMRI work found no evidence of V1 signal enhancement for figures defined by 2nd-order texture contours, but a demanding fixation task may have prevented figures from being perceived (Schira et al., 2004). In the present study subjects viewed oriented line-segment displays (19^o x 19^o) while BOLD fMRI data were acquired using a rapid event-related design. Ground stimuli were composed of parallel lines at one of two orientations. Figure stimuli were identical to ground but also contained two figure regions (6^o x 6^o, opposite sides of fixation with inner edges at 2^o eccentricity) in which line orientation was orthogonal to the background. To control attention across conditions subjects detected infrequent oddball stimuli in which the line segments were of slightly higher density. Separate localizer scans were used to find voxels in V1 responsive to figure but not background regions (V1 ROIs). We averaged data within the V1 ROIs and computed conditional hemodynamic timecourses using standard linear methods. Data from four subjects revealed a 13% increase in BOLD response in the V1 ROIs to figure compared to ground stimuli. This result provides evidence that figure-ground segregation results in increased neuronal activity in human V1 that is detectable with fMRI.

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H53 *859* **An Effect of Figure-Ground Assignment: Perceptual Enhancement**

Joshua D. Cosman[1] (joshua-cosman@uiowa.edu), Lauren N. Hecht[1], Shaun P. Vecera[1]; [1]University of Iowa Department of Psychology

Several cues influence figure-ground assignment, including area (Rubin, 1958) and convexity (Metzger, 1953). In addition, top-down input such as attention (Vecera et al., 2004) or familiarity (Peterson, 1994) also influence figure-ground assignment. Although much is known about the factors that affect, or control, figure-ground assignment, little attention has been given to possible consequences, or effects, of this process. The subjective salience enjoyed by figural regions could be caused by at least two effects, either a perceptual enhancement of figures or to figures being given processing priority over grounds. We attempted to distinguish these effects of figure-ground assignment by using a perceptually demanding spatial resolution task. In Experiment 1, observers viewed figure-ground displays in which two features appeared in the figure or ground region; features appearing on figures were discriminated more accurately than those on grounds, consistent with an enhancement effect. In Experiments 2 and 3, the regions were presented separately to rule out stimulus effects on target discrimination. No differences in target discrimination were found between the regions, supporting the enhancement effect seen in Experiment 1. Experiment 4 tested a strong prediction made by an enhancement process, namely that targets on figural regions would be discriminated more accurately than targets on figurally neutral regions. As predicted, targets appearing on figures were discriminated more accurately than those appearing on either ground regions or on neutral stimuli. Taken together, these results suggest that figures are perceptually enhanced compared to grounds.

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H54 *860* **Figure-ground assignment in pigeons: Smaller area and longer pre-exposure enhance figural advantage**

Olga F. Lazareva[1] (olga-lazareva@uiowa.edu), Leyre Castro[1], Shaun P. Vecera[1], Edward A. Wasserman[1]; [1]University of Iowa

Four pigeons discriminated whether a target spot appeared on a colored figural shape or on a differently colored background by first pecking the target and then reporting its location: on the figure or the background. We recorded three dependent variables: target detection time, choice response time, and choice accuracy. In a previous study, we found that pigeons were faster to detect the target, to report its location, and to learn the correct response on figure trials than on background trials; we also found that the pigeons were not using local display properties to perform the figure-background discrimination (Lazareva et al., in press). Here, we investigated the effects of changes in size and in display pre-exposure. Pigeons' accuracy on both figure and background trials increased as the size of the figure decreased. Both target detection time and choice reaction time were faster on figure trials than on background trials: this figural advantage increased as the size of the figure decreased. When the display containing the figure and background was shown 1, 2, or 4 s before onset of the target, target detection times were faster on both figure and background trials compared to the simultaneous presentation of the display and the target; as well, the disparity between figure and background trials increased with longer pre-exposure. A similar, but less pronounced, trend was found for choice reaction time. These results suggest that figure-ground segregation in people and pigeons is similarly affected by both geometrical and temporal variables.

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H55 *861* Reference Frames in Figure-Ground Organization

Jessica S. Thierman[1] (thierman@berkeley.edu), Shaun P. Vecera[2], Stephen E. Palmer[3]; [1]Cognitive Science Program, UC Berkeley, [2]Department of Psychology, University of Iowa, [3]Department of Psychology, UC Berkeley

Within what reference frames do orientation-related factors of figure-ground organization operate: retinal, environmental/gravitational, or object-based? Previous research showed that the bias toward lower regions is based on retinal directions: Observers whose heads were upside-down perceived the retinally lower (and thus gravitationally upper) region as figural (Vecera, 2004). We extended this line of inquiry to include all known figure-ground cues that have an orientation component: lower-region (Vecera, Vogel, & Woodman, 2002), wider base (Hulleman & Humphreys, 2004), horizontal-vertical orientation (Rubin, 1921), symmetry (Bahnsen, 1928), and familiarity (Peterson, 1994). Observers viewed black/white figure-ground displays with their heads either upright or at an angle for which differences in reference frame should be evident (45, 90, or 180 degrees from upright, depending on the particular factor). Once the observer saw one region as figural, a probe dot was presented, and he/she indicated whether it was on the figural region or not. The results indicate that retinal directions clearly dominate for lower region and wider base, but object-based directions dominate for familiarity and symmetry. The results are discussed as indicating that at least some figure-ground organization cues (e.g., lower region and wider base) operate before orientation constancy. This fact is interesting because the ecological rationale for these figure-ground cues is based on gravitational rather than retinal considerations. Because the world is normally viewed with the head upright, however, retinal directions also support the ecological validity of retinal versions of these factors. (http://socrates.berkeley.edu/~plab/projects.htm)

URL: http://socrates.berkeley.edu/~plab/projects.htm

H56 *862* A dynamic cue for figure ground assignment: Advancing vs. receding

Jean M. Vettel[1] (jvettel@alumni.cmu.edu), Elan Barenholtz[1], Michael J. Tarr[1]; [1]Brown University

Past research on figure ground assignment to contours has largely considered static contours. Here we report a simple and extremely robust dynamic cue to figural assignment, based on whether the bounding region of a contour is advancing or receding. Subjects saw a straight or jagged contour moving behind a virtual aperture; after a brief time, a probe appeared slightly offset from the contour and the subject had to report whether the probe was 'on' or 'off' the moving 'surface', effectively assigning figure and ground to the two sides of the moving contour. Subjects showed a strong preference (~95-98%) to assign figure so that the surface that the contour was bounding was growing larger within the aperture (advancing) rather than smaller (receding). This was true regardless of the direction of motion of the contour and regardless of the initial/ending size of the bounded regions (i.e. the motion cue served to override the conventional cue of smaller area). This is a somewhat surprising result in that a moving object produces both receding and advancing motion within different regions of the visual field. This finding highlights the importance of dynamic factors in figure/ground assignment and perceptual organization, as well as suggesting a possible link between figure-ground assignment and motion perception.

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URL: www.tarrlab.org/vss2006

H57 *863* SIMULTANEOUS ACCELERATION IS KEY IN GROUPING BY VISUAL SYNCHRONY

Stéphane J. Rainville[1] (Stephane.Rainville@ndsu.edu); [1]Center for Visual Neuroscience, Department of Psychology, North Dakota State University

PURPOSE: Perceptual grouping is highly sensitive to temporal synchrony between moving Gabor elements. Here I tested whether grouping by synchrony depends on instantaneous carrier position, velocity, or acceleration.

METHODS: Observers discriminated the synchrony of Gabor pairs oscillating at 5 Hz in a 2AFC task. The phase of each Gabor's carrier evolved according to its own independent time-varying function $\ddot{o}(t) = k_1 + k_2 t + k_3\cos(\grave{u}t + k_4)$. The k_1 and k_2 terms acted as position and speed pedestals while the k_3 and k_4 terms determined the oscillation's amplitude and phase lag respectively. Similarity between the k_4 terms of the two Gabors determined their degree of synchrony.

RESULTS: Synchrony thresholds were immune to mismatches either in instantaneous carrier position or speed between the two Gabors.

CONCLUSION: The position and speed pedestal terms (k_1 and k_2) do not appear in the second derivative (i.e. acceleration) of time-varying phase profiles. Results therefore imply that simultaneous acceleration between Gabor elements – not simultaneous position or speed – drives grouping by visual synchrony. Newton's second law ($F = ma$) states that forces involved in scene dynamics are only reflected in acceleration. Findings from this study lead to the simple yet remarkable conclusion that grouping by simultaneous acceleration can succeed where lower-derivative grouping rules such as good continuation (0th time derivative) or common fate (1st time derivative) necessarily fail.

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H58 *864* Binocular disparity facilitates correct binding of color and motion

Hae-Rim Son[1] (gpflatm@hanmail.net), Hyung-Chul O. Li[1]; [1]Department of Industrial Psychology, Kwangwoon University, Seoul, Korea

Despite some neurophysiological findings concluding that visual features such as color and motion are processed in separate regions of the brain, all visual features appear to be bound together in an object. At what level of process does binding occur and what could serve as the linkage for the binding? One possibility is that visual features are bound together based on each feature's depth information. We examined this possibility using the paradigm employed by Wu, Kanai and Shimojo (2004). Basically, two

sheets of random dots were manipulated so as to move in opposite directions. The central dots were red and the peripheral dots were green on the upward moving sheet, but were reversed on the downward moving sheet. The observers reported on whether the majority of the peripheral red dots were moving up or down while gazing at the central part of the stimulus. The proportion of peripheral red dots moving upwards and the direction of the central red dots were manipulated. When the two sheets were not separated by depth, the observers' responses were modulated by the direction of the central red dots and misbinding of color and motion occurred. When they were separated, however, the responses were modulated only by the physical characteristics of the motion of the peripheral red dots and misbinding did not occur. This implies that color and motion are bound together based on each feature's depth information and that binding occurs after binocular disparity is processed.

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H59 *865* Binocular composition of monocular signals in perceptual grouping

Oren Yehezkel[1] (upolat@sheba.health.gov.il), Michael Belkin[1], Dov Sagi[2], Uri Polat[1]; [1]Goldschleger Eye Research Institute, , Tel Aviv University , Tel Hashomer, Israel, [2]Department of Neurobiology, Brain Research, The Weizmann Institute of Science, Israel

Bias in perceived grouping was examined in conditions where the two eyes receive different spatial external distortion. Stimuli, 10x10 dots matrix with Horizontal and Vertical spacing defining the direction of grouping (V/H), were presented, in random order either to both eyes (B), or only to one (M) while the other exposed to background luminance. Cylindrical lens were used to introduce a constant distortion along one direction. Bias and reaction times (RT) were measured under three Dichoptic conditions: (1) Binocular and Monocular without distortion (2) orthogonal distortions between the eyes presented simultaneously or in different trials, (3) as in (2) but with M distortion to one eye. Task was to distinguish between H/V groupings without feedback. (1) a) without induced distortion subjects show no bias, with sharp transitions between V/H groupings, b) at the transition, RT increased, with B being slower than M by 108ms (2) orthogonal distortions between the eyes showed no B bias but large M bias (3) M distortions showed a bias in the treated eyes while untreated eyes showed orthogonal bias. B-RT was slower than the M-RT by 116ms. The bias with the dichoptic presentation was found to be the average of the two opposite M groupings. The finding that the RT of the B level is slower (~100ms), and that M distortions bias the response of the untreated eye, suggest the existence of mutual interactions between the B and M processes.

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H60 *866* Grouping in random-dot patterns

Michael Kubovy[1] (kubovy@virginia.edu), Martin van den Berg[1]; [1]University of Virginia

We investigated the spontaneous perception of structure in random dot patterns (RDPs) and the role of the grouping principles of proximity, collinearity, and good-continuation. In three experiments observers reported the perceived organization in RDPs by either circling the groups they perceived or by clicking on the dots that appeared to belong to the same groups. We analyzed these reported organizations were analyzed within-subject and between-subject consistency, and they were used as the foundation for a quantitative model. This model uses graph-theoretic techniques to determine the neighborhoods of dots in the random dot patterns. Within these neighborhoods it computes the strengths of grouping by proximity, collinearity and good-continuation. In a computer simulation the model performed multiple trials with the experimental stimuli and, in a stochastic process, predicted grouping frequencies. Our data were accurately accounted for by a model based on grouping by proximity and good-continuation that computed neighborhoods in a global fashion. In a fourth experiment we tested this model in a new context and investigated the time-course of perceptual organization in RDPs. The predictions of the model captured the observers' performance in this experiment; display duration did not affect the responses. We interpret the results of these experiments and the model-fitting as evidence that the perceptual organization of RDPs is an early, automatic, and global process.

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H61 *867* Local Grouping in Glass Patterns: Chromatic and Luminance Tuning

Chien-Chung Chen[1] (c3chen@ntu.edu.tw); [1]Department of Psychology, National Taiwan University

Glass patterns consisted of randomly distributed dot pairs (dipoles) whose orientations were determined by a geometric transform. To perceive the structure in a Glass pattern, an observer needs to perform local grouping to find dipoles and global grouping across dipoles to get overall shape. We explored the mechanism for local grouping by studying its chromaticity and luminance tuning. Each dipole contained two 5.4' square dots separated by 27'. The randomly distributed dipoles covered 2% of the image. The coherence of a Glass pattern was defined as the proportion of dipoles oriented tangent to a spiral global form. The task of the observers was to judge whether the spiral was clockwise or counter-clockwise. In each dipole, one dot had its chromaticity on one of the cardinal axes (L-M, S, and isochromatic) in DKL color space and a contrast 10 times the detection threshold while the other dot varies in chromaticity and luminance. When two dots in a dipole had the same chromaticity, the coherence threshold (measured at 75% percentage correct level) was 30-40% for all axes. The coherence threshold increased to 75% when the chromaticity of the varying dot were about 45 degree from the S axis, 20-25 degree from the the L-M axis and more than 60 degree from the isochromatic axes. The chromatic tuning for local grouping is narrow on the isoluminance plane while broad about the isochromatic axis. The local grouping is constrained by separate mechanisms with distinct chromatic and luminance tuning.

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H62 *868* Modulation of contrast detection threshold by the configuration and contrast of the context

L. Jingling[1] (l.jingling@ucl.ac.uk), L. Zhaoping[1]; [1]Department of Psychology, University College London

Our previous experiments showed that the strength of facilitation to the detection of a target bar by collinear, bilateral, flanking bars first decreases and then increases with the contrast of the contextual bars, making an U-shaped curve of detection threshold vs. contextual contrast (Jingling and Zhaoping, 2005, Applied Vision Association Meeting, Aston, UK). Here, we further explore the effect of the spatial configuration in this contrast-dependent modulation by contextual bars. The detection threshold of a vertical target bar is measured with a staircase method by a two temporal-interval alternative-force-choice procedure. The target bar is always at the center of the screen, and the contextual bars are of the same shape and orientation as the target. Four contrast values, 0%, 1%, 5%, and 20%, of the contextual bars are used. We found that the detection of the target could be facilitated by the contextual bars when they form a regular pattern with the target (e.g., a collinear or parallel array of bars, or two arrays crossing into a X shape, or a regular texture of bars). This is not due to uncertainty reduction of the target location, since replacing the context by four dots around the target does not facilitate detection. In addition, when contextual bars in the regular configurations are not collinear to the target, the detection threshold varies monotonously (rather than U-shaped) with the contrast of the contextual bars. We suspect that the spatial configuration-dependent modulation by the context is beyond the known mechanism in the primary visual cortex.

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H63 *869* **The influence of perceptual segmentation on the perceived orientation of dot clusters**

Manish Singh[1] (manish@ruccs.rutgers.edu), Elias H. Cohen[2], Laurence T. Maloney[3]; [1]Dept. of Psychology and Center for Cognitive Science, Rutgers University - New Brunswick, [2]Dept. of Vision Sciences, SUNY, College of Optometry, [3]Dept. of Psychology and Center for Neural Science, New York University

Estimation of any visual property typically involves pooling information over an extended image region, but such pooling is useful only if the region selected is appropriate. Successful estimation thus depends critically on perceptual segmentation. Previous work has demonstrated that the perceived orientation of dot clusters is predicted by their principal axis. We investigated the interaction of perceptual segmentation and the perceived orientation of dot clusters that could potentially be segmented into two sub-clusters. **Methods.** Stimuli were dot clusters formed by the union of a large sub-cluster (uniformly sampled within an ellipse) and a small circular sub-cluster. Variables manipulated were: distance of the small sub-cluster from the main axis of the ellipse; dot density; and radius of the small sub-cluster. Dot clusters were presented for 1sec and masked. Observers adjusted the orientation of a pattern consisting of multiple parallel lines, to match the perceived orientation of the dot cluster.**Results.** As the separation of the sub-clusters increased, perceived orientation shifted gradually from the global principal axis (of both sub-clusters merged) to that of the larger sub-cluster alone. Thus with increased separation---hence increased likelihood of segmentation---the dots within the smaller sub-cluster are given systematically lower weights in the principal axis computation. Moreover, the shift occurred sooner for higher dot densities---consistent with the expectation that these require smaller separations to be reliably segmented. The visual system thus employs a strategy of robust statistics, wherein data points are weighted differentially based on the probability that they arose from a separate generative process.

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H64 *870* **Is perception of a degraded figure resistant to spatial context at short exposure?**

Michael R. Scheessele[1] (mscheess@iusb.edu); [1]Indiana University South Bend

Introduction: When a degraded figure is displayed with short exposure duration, do surrounding visual display elements provide spatial context that influences perception of the figure?

Method: Each stimulus contained a black figure against white ground. Each figure comprised 4 rectangles. White square distractors degraded a figure, while black square distractors served as noise. There were 3 conditions - figures presented with: all small square distractors, all large square distractors, and a third mixed condition. In the mixed condition, the figure was presented within an imaginary window (larger than the figure yet smaller than the image). The inside of this window contained all small square distractors, while the outside contained all large squares. Total distractor area was constant across conditions. On each trial, a subject's task was to respond whether the figure was displayed in its upright or reflected orientation. Exposure duration was 100 ms. Prior results showed that performance in the all-small distractor case is better than in the all-large distractor case. In the mixed distractor condition, if a subject processes only the part of the image inside the imaginary window, performance should be comparable to that in the all-small distractor condition. Otherwise, performance should be comparable to that in the all-large distractor condition.

Results: There was no significant difference between performance in the mixed distractor and the all-small distractor conditions.

Conclusion: The results suggest that visual display elements beyond a small window have little influence on perception of a degraded figure when exposure duration is brief.

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H65 *871* **Perceptual singularities in Smooth Orientation-Defined Textures: Segregation without feature contrast**

Ohad Ben-Shahar[1] (ben-shahar@cs.bgu.ac.il); [1]Department of Computer Science, Ben-Gurion University, Israel

A central notion in the study of texture segregation is that of *feature gradient* (or feature contrast). In *orientation-based* texture segregation (OBTS), where the dominant (and sometimes sole) feature of consideration is local orientation, *orientation gradients* have indeed played a key role in explaining behavioral results (Nothdurft, 1985,1991; Landy&Bergen, 1991; Mussap&Levi ,1999). However, in this paper we present clear evidence that orientation contrast does not account for all OBTS phenomena. We first demonstrate how orientation-defined textures (ODTs) of *constant* orientation gradient exhibit salient perceptual singularities (i.e., boundaries between perceptually coherent regions). More generally, we study *smoothly varying* ODTs that exhibit salient perceptual singularities despite having *no* outstanding orientation contrasts. While our psychophysical investigation proves these singularities robust and consistent across observers, we show that they defy not only popular texture segregation theories, but virtually all neural models (e.g., Li, 2000) and computational segmentation methods, either local (e.g., Malik&Perona, 1990) or global (e.g., Shi&Malik, 2000). To better understand this hitherto neglected aspect of texture segregation, which possibly confounds all previous studies with varying ODTs, here we first analyze the (differential) geometry underlying general ODTs and derive multiple ODT curvatures, and then we show psychophysically that unlike orientation gradients, these curvatures fully predict the perceptual singularities reported. Given the central role of feature gradients in early vision, the significance of our findings extends well beyond OBTS, and here we establish links to segregation/grouping based on other visual features and to the perception of 3D-shape from texture, shading, and surface contours.

H66 *435* **Prior experience affects amodal completion in pigeons**

Yasuo Nagasaka[1] (yasuo-nagasaka@uiowa.edu), Olga F. Lazareva[1], Edward A. Wasserman[1]; [1]The University of Iowa

Many earlier studies have failed to find evidence that pigeons complete partially occluded objects, although positive results have been reported for other birds. We investigated amodal completion in pigeons by analyzing the errors they committed while learning a 3-alternative simultaneous discrimination task.Pigeons were trained to discriminate among occluded, complete, and incomplete stimuli. The occluded stimulus comprised two colored shapes, one of which occluded the other (e.g., blue triangle occluded by red circle); the complete and incomplete stimuli comprised a single shape that had been partially covered in the corresponding occluded stimulus (e.g., whole triangle, or partial triangle, respectively). The correct response was to select the occluded stimulus and the dependent measure was the proportion of errors made to the complete stimulus. Pigeons were trained until they reached criterion with one set of stimuli; novel sets of the stimuli were repeatedly introduced.At the beginning of training, the proportion of errors to the complete stimuli was equal to the incomplete stimuli and did not differ from chance (50%). After repeated training with different shapes, the proportion of errors to the complete stimulus increased above chance. Moreover, when the pigeons were re-exposed to the initial set of training stimuli, they committed 70% of their errors to the complete stimulus. These results suggest that pigeons came to view the complete stimulus as being more similar to the occluded stimulus than the incomplete stimulus. Extensive experience with two-dimensional images may facilitate amodal completion of partially occluded objects in pigeons.

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Object Tracking, Enumeration, and Individuation

H67 *872* "Attentional high-beams" in tracking through occlusion

Jonathan I Flombaum[1] (jonathan.flombaum@yale.edu), Brian J Scholl[1], Zenon W Pylyshyn[2]; [1]Yale University, [2]Rutgers University

A considerable amount of research has uncovered several heuristics that the visual system employs to keep track of objects through frequent periods of occlusion. Relatively little work, by comparison, has investigated the on-line mechanisms that implement and support these heuristics. We explored how attention is distributed throughout a display when featurally identical objects become momentarily occluded during multiple object tracking (MOT). Observers tracked three targets among three distractors as they moved haphazardly during 10 second trials. All objects periodically became occluded when they passed behind two visible static 'walls'. During tracking, observers also had to detect small probes that appeared sporadically on targets, distractors, occluders, or empty space. Though occlusion did not impair MOT, probe detection rates for these categories confirmed the earlier finding that detection on nontargets was worse than on targets or in empty space and also revealed two novel effects. First, probe detection on an occluder's surface was much greater when either a target or distractor was currently occluded in that location, compared to when no object was behind that occluder. Thus object-based attention can still be active in a display even when the attended object is not visible. Second, and more surprisingly, probe detection was always better when objects were occluded (vs. unoccluded) for both targets and distractors. This *attentional high-beams* effect indicates that the apparently effortless ability to track through occlusion actually requires the active allocation of additional resources, and the current experiments demonstrate a new way that such effects can be discovered and quantified.

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URL: http://www.yale.edu/perception/

H68 *873* The distribution of attention within moving objects is affected by spatial probabilities

Cary S. Feria[1] (c.feria@morehead-st.edu), Maureen Doyle[1]; [1]Morehead State University

Alvarez and Scholl (in press) found that when several moving objects are tracked, attention is concentrated at the center of each object. Other literature has shown that the visual system attentionally prioritizes spatial locations based on the probabilities of stimuli appearing at each location (e.g., Geng & Behrmann, in press). Here we hypothesize that when tracking several moving objects, attention focuses on the most strategically advantageous locations, which may be the centers of objects or other locations. In a multiple object tracking task, observers tracked several long moving lines among identical distractors. Small circular probes appeared briefly on target lines, and observers' performance at detecting probes was used to measure the distribution of attention. The probability of a probe occurring at different locations was manipulated. When probes were most likely to appear on the centers of lines, probe detection was much more accurate at centers than near the ends of lines. However, when probes were most likely to appear near one of the endpoints of each line, detection was more accurate near those endpoints than at the centers, although this difference in detection rates was smaller. This suggests that when tracking several moving objects, there is an attentional bias toward centers of objects, however the attentional distribution is also affected by strategic factors such as spatial probabilities. Regarding findings that spatial locations are attentionally prioritized based on their probabilities of containing stimuli, our results suggest that these attentional prioritizations can move along with a continuously moving object.

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H69 *874* Which way did it go? Measuring trajectory information in multiple object tracking

Skyler S Place[1] (skyler@search.bwh.harvard.edu), Todd S Horowitz[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

In multiple object tracking (MOT) experiments, observers are capable of tracking 3-5 targets among identical distractors. What information about target trajectories can the visual system use in this task? We present a new method, which allows us to measure the precision of observers' information about object motion direction in MOT. In Exp. 1, we measured directional information for targets. Observers tracked 4 of 8 moving disks for 5 seconds. At the end of the trial, a green arrow appeared on one target disk. The arrow was presented at an angle (±15°, ±30°, ±±45°, or ±90°) to the target's actual direction of motion. The task was to make an unspeeded response indicating whether the green arrow was rotated clockwise or counterclockwise relative to the true direction. The 70% accuracy threshold was approximately 30°.In Exp. 2, we compared directional accuracy for targets and non-targets. Since the directional task probed non-targets as well as targets, we introduced two incentives for observers to track targets. First, on 20% of trials, a single disk turned blue, and observers made an unspeeded 2AFC decision as to whether the blue disk was a target; directional data were collected on the remaining trials. Second, we introduced more non-targets than targets (observers tracked 3 of 8). Accuracy for target direction was 86%, while non-target responses were near chance. The visual system has access to coarse information about target trajectories in MOT. This information is only available for attended objects.

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H70 *875* The 'Effective' Number of Trajectories Tracked in Amblyopic Vision

Srimant P Tripathy[1] (s.p.tripathy@bradford.ac.uk), Dennis M Levi[2]; [1]Dept. of Optometry, University of Bradford, Richmond Road, Bradford BD7 1DP, United Kingdom, [2]School of Optometry, University of California, Berkeley, CA 94720-2020

The 'effective' number of trajectories that can be tracked when detecting deviations in multiple trajectories depends on the angle of deviation, varying between one for a ±19° deviation and four for a ±76° deviation (Tripathy, Narasimhan & Barrett, 2005, *Perception(Suppl.)* **34** p. 12; also see Tripathy & Barrett, 2004, *Journal of Vision* **4** 1020-1043). Is this 'effective' number of tracked trajectories compromised in amblyopic vision?The stimuli were linear, non-parallel, left-to-right trajectories moving at 4°/s. The number of trajectories (*T*) was varied (1-10). One trajectory deviated clockwise/anti-clockwise at the screen's mid-line. Deviations were blocked at ±76°, ±38° or ±19°. The proportions of correct identifications of deviation direction were determined for each *T* for the amblyopic and non-amblyopic eyes of strabismic and anisometropic amblyopes. The 'effective' number of tracked trajectories (*A*) was estimated from the hypothetical machine that matched the human observer's performance by perfectly tracking *A* of the trajectories and ignoring the remaining trajectories. In another experiment *T* was fixed (10, 8 or 6), and the number of deviating trajectories (*D*) was varied between 1 and *T*. For each combination of *D* and *T* the value of *A* was estimated.The effective numbers of trajectories tracked by the non-amblyopic eyes of amblyopes were comparable to numbers previously reported for normally-sighted observers (Tripathy *et al.*, 2005, *op. cit.*) and were either the same as, or marginally higher than, the numbers for the fellow amblyopic eye. Resolution is not a primary factor limiting tracking performance when detecting large deviations in multiple trajectories.

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Monday Posters

H71 876 Multiple Object Tracking and Attentional Capture

Jeffrey R.W. Mounts[1] (mounts@geneseo.edu), Brian S. Amos[1], Monica A. Moschetta[1], Eric C. Page[1]; [1]SUNY Geneseo

Observers susceptibility to attentional capture during multiple object tracking was examined. Observers tracked 3-6 target objects as they moved within an array of identical, moving distractor objects for a period of 6 seconds. At the end of the tracking period, observers selected the objects believed to be the targets. On half of the trials, a new item (an abrupt onset) appeared suddenly within the display during the tracking period. These abrupt onsets disrupted tracking performance, as target identification accuracy was lower for onset trials compared to no onset (control) trials. Further analysis revealed that the abrupt onsets mainly disrupted tracking performance when they appeared near one of the targets (i.e., within 2 degrees). This disruption in tracking performance was confined to the target(s) near the abrupt onset; performance was equivalent to that in control trials for targets that were distant from the abrupt onset. Results are discussed in terms of the distribution of attention during multiple object tracking and the spatial resolution of attention.

H72 877 Exploring the effects of crowding in multiple object tracking using a dual-task paradigm

Michael N Tombu[1] (mike.tombu@vanderbilt.edu), Adriane E Seiffert[1]; [1]Vanderbilt University

A dual-task paradigm was employed investigating the attentional demands of crowding in multiple object tracking (MOT). Subjects tracked four of eight randomly moving dots. At some point a tone sounded, requiring a speeded response based on pitch. Previous research indicates that this tone task demands attentional resources. In Experiment 1, MOT difficulty was manipulated by having all dots either briefly attract one another, causing increased crowding, or continue to slightly repulse one another, causing no increase in crowding. We hypothesized that increasing crowding would make the tracking task more difficult and that it would demand increased attentional resources. If our crowding manipulation demands attentional resources in MOT, then the effect of crowding should be larger when it occurs temporally close to the tone (short SOA) as compared to when it occurs after tone processing is complete (long SOA). Results confirmed this hypothesis; increasing crowding had a significantly larger effect at the short SOA compared to the long SOA. Experiment 2 aimed to demonstrate a manipulation that would increase tracking difficulty while not increasing attentional demands. Dot contrast was briefly manipulated, either at a short or a long SOA relative to the tone. The effect of contrast was additive with SOA indicating that reducing contrast increases tracking difficulty, but does not increase attentional demands. These results indicate that increased crowding and reduced contrast both lead to worse MOT performance, however, only increasing crowding causes tracking to become more attentionally demanding.

H73 878 An Electrophysiological Measure of Multiple Object Tracking

Trafton Drew[1] (vogel@darkwing.uoregon.edu), Edward K. Vogel[1]; [1]University of Oregon

Numerous studies have shown that we are capable of tracking 4 or 5 moving objects simultaneously. In this study we examined an electrophysiological measure in humans that appears to reflect the tracking of multiple objects "online" during a trial. Subjects were shown a bilateral display of multiple moving objects and were asked to track the objects in a single hemifield for an occasional brief flicker of one of the tracked objects. We time-locked the ERPs to the onset of the moving objects and recorded throughout the trial. Approximately 400ms following the onset of the movement, we observe a sustained negative wave at electrode sites that were contralateral with respect to the hemifield the subject was tracking. This wave persisted throughout the entire trial and its amplitude increased as a function of the number of items the subject was tracking on a given trial (1, 2, or 4 items). Together, these results suggest that this activity reflects a neural mechanism for tracking multiple objects.

H74 879 Attentive tracking of multiple objects modulates neuronal responses in area V4 of the macaque.

Jude F Mitchell[1] (jude@salk.edu), Kristy A Sundberg[1], John H Reynolds[1]; [1]The Salk Institute

Human observers can attentively track multiple stimuli as they move along independent random trajectories among distracter stimuli (Pylyshyn and Storm, 1988; Sears and Pylyshyn, 2000). We developed a multi-object tracking task suitable for monkeys and recorded single units and LFPs in area V4 as tracked or untracked stimuli entered a unit's receptive field. Each trial began with fixation of a central point, after which 4 identical stimuli appeared at equally eccentric peripheral positions. Either one or two of these stimuli were briefly flashed, identifying them as targets for tracking. All stimuli then moved along random independent trajectories for 2-3 seconds while the monkey maintained fixation. The trajectories were constrained such that one of the stimuli entered and left the receptive field of an isolated V4 neuron. All stimuli terminated motion at equally eccentric positions that were unpredictable from their initial positions. Monkeys were rewarded only if they made a saccade to each target and to no distracters. We found that V4 single unit responses evoked by a tracked stimulus were on average ~20% stronger than the responses evoked by the same stimulus when it was not being tracked. The magnitude of the modulation did not differ significantly depending on whether the monkey was tracking a single target or two targets, suggesting that attending to one target did not reduce attention to the other.

Acknowledgment: NIH Training Grant in Cognitive Neuroscience

H75 880 Implicit Multiple Object tracking without an explicit tracking task

Harry H Haladjian[1,2] (haladjian@ruccs.rutgers.edu), Zenon W Pylyshyn[1]; [1]Rutgers Center for Cognitive Science, New Brunswick, NJ, [2]Department of Psychology, Rutgers University, New Brunswick NJ

We have previously used a probe detection task with Multiple Object Tracking and showed that in MOT probes are detected better on targets than on nontargets (VSS 2005) - a result we interpreted as showing that nontargets are inhibited. Here we ask whether the difference between probe detection performance on targets and nontargets is due to the explicit multiple object tracking task that requires observers to keep track of and report targets at the end of a trial, or whether flashed targets are primed and implicitly tracked merely because they are cued by being flashed - in other words, whether a target-nontarget difference in probe detection might be observed when no tracking is explicitly required. We used a modified version of MOT, in which observers were instructed merely to monitor for a probe while some objects moved in their field of view and were occasionally flashed to distract them. In this task no tracking of flashed items was required. We found evidence for better probe detection on flashed than on nonflashed items suggesting that flashed items are implicitly tracked even when there is no explicit requirement for tracking and reporting the cued items.

Acknowledgment: Supported by NIMH Grant 1R01-MH60924 to ZWP

H76 881 Are items encoded into VSTM when they are selected for tracking in MOT?Explorations with simultaneous and sequential cue presentations

Carlos Montemayor[1,2] (montemayor@philosophy.rutgers.edu), Zenon W Pylyshyn[1]; [1]Rutgers Center for Cognitive Science, New Brunswick, NJ, [2]Department of Philosophy, Rutgers University, New Brunswick NJ

Hung, Wilder, Curry & Julesz (1995) used sequential and simultaneous presentations to distinguish the encoding and storage limitations of visual short term memory. They found that simultaneous presentation led to better recall than sequential presentations and that with sequential presentations a slower rate of presentation (SOA of 50 ms) led to better recall than faster rates of presentations (SOAs of 33 ms and 17 ms). They argued that information is encoded differently from sequential and simultaneous

visual presentation and that with sequential presentation sufficient time is required to encode each incoming item. Here we apply the Hung et al methodology to test whether the process of *selection*, as opposed to the process of *encoding*, follows the same pattern. We used Multiple Object Tracking (MOT) as a measure of whether visually cued items had been selected under various conditions of temporal presentation. In contrast to the Hung et al findings with item recall, we found that item selection was better when the items were sequentially cued (as shown by better MOT performance) than when they were simultaneously cued, while there was little difference at the different presentation rates in the SOA range used in the Hung et al study. This finding further supports our earlier claim that selection and tracking may not involve memory because items' properties are not encoded into VSTM in the course of selecting and tracking objects in MOT (Scholl, Pylyshyn & Franconeri, ARVO1999).

Acknowledgment: Supported by NIMH Grant 1R01-MH60924 to ZWP

H77 *882* Selection and enumeration of moving objects

Carly J. Leonard[1] (carly@jhu.edu), Rachel Pierson[1], Melanie Palomares[1], Howard E. Egeth[1]; [1]Johns Hopkins University

Subitizing, the rapid and accurate enumeration of up to 3-4 items, is often thought to result from parallel access to multiple items in a display. This same limited capacity may mediate the 3-4 item limit in Multiple Object Tracking (MOT). If so, the subitizing limit should remain the same when the enumeration task is made more similar to a tracking task by including item motion and distractors. In order to test this, we had participants enumerate between 0 and 9 moving target items among distractors, with a fixed number of total elements. Each display was presented for 200ms. We measured sensitivity for each number and found a decreasing linear function, showing no evidence of a distinction between small (up to 3-4 items) or large (>4 items) displays. This enumeration task required the acquisition of moving items that matched the target color within the limited presentation time. Limits on this selection process could have impeded efficient enumeration, even in the subitizing range. Expt. 2 removed the distractors during the movement phase. Sensitivity was improved for all numbers of items and showed a shallow slope for 0-3 items, declining more sharply thereafter, as in typical enumeration tasks. Because display duration was not long enough for attentional shifts, Expt. 2 suggest participants are able to efficiently individuate several moving items in a display. However, Expt. 1 shows that a simple feature property cannot be used to segregate several moving target items from distractors for enumeration within 200ms.

H78 *883* The role of object properties in item individuation: The effects of item heterogeneity and change

Lana M. Trick[1] (ltrick@uoguelph.ca), Elizabeth Orr[1]; [1]Dept. of Psychology, University of Guelph

Item individuation is the ability to consider an item as an individual, and it is necessary if a person is to attend, foveate, or touch a specific item among others. At present it is unclear what role (if any) object properties play in item individuation. One way to investigate individuation is to use the visual enumeration task. Enumeration (determining how many items there are) requires individuation because accurate response requires that each item be considered once and only once. It has long been known that there are differences between enumerating small and large numbers of items. Specifically, when there are 1-4 items, a rapid (40-100 ms/item), accurate, effortless, process called subitizing is used. In contrast, when there are larger numbers of items, a slow (200-350 ms/item), effortful, error-prone process called counting is employed. In a series of studies, the role of object properties in individuation was evaluated by having participants enumerate 1-9 items of various types. In the first, participants enumerated items that were either homogeneous or heterogeneous in their properties. In the second, participants enumerated 1-9 items, but the items constantly changed their properties, their position, or both while being enumerated. Item heterogeneity and property change have different effects depending on the number of items. This effect was interpreted as it relates to recent theories of visual-spatial enumeration and Pylyshyn's (1989) FINST hypothesis.

H79 *884* Area and Element Size Bias Numerosity Perception

Miles Shuman[1] (mshuman@fas.harvard.edu), Elizabeth Spelke[1]; [1]Department of Psychology, Harvard University

Most recent work in numerical cognition has focused on the representational level. The consensus view is that symbolic numbers (e.g. Arabic digits) and non-symbolic numerical stimuli (e.g. dot arrays) alike engage an 'analog magnitude' representation system; the debate has largely moved to questions such as innateness and neural localization. Here, we take a step back to examine the perceptual mechanism that enables us to extract a numerical representation from a set of elements. The most prominent current models propose that this mechanism is iterative, individuating and tagging each element (sequentially or in parallel,) then summing to obtain a numerical magnitude. The observed variability in judged number (e.g. variability proportional to N in estimation tasks) is attributed to the representational system, rather than the perceptual mechanism. An alternative possibility is that the mechanism for numerosity perception is holistic, involving (e.g.) a 'calculation' of element density x 'envelope' area, and that variability in the perceived magnitudes of these continuous quantities is an important contributor to variability in represented numerical magnitude. We tested whether parametric variation of 'continuous quantity' variables – element size and envelope area – would systematically bias judgments of numerosity. We found a very strong effect of envelope area (with larger, lower density arrays judged more numerous) and a significant (though smaller in magnitude) effect of element size (with arrays of *smaller* elements judged more numerous.) These results pose a serious challenge to iterative models of numerosity perception, and suggest that perception may be an important source of noise in numerical cognition.

H80 *885* Numerical processing of visual arrays in the brains of adults and four-year-old children

Jessica F Cantlon[1,2] (jfc2@duke.edu), Elizabeth M Brannon[1,2], Kevin A Pelphrey[1,3]; [1]Department of Psychological & Brain Sciences, Duke University, [2]Center for Cognitive Neuroscience, [3]Brain Imaging & Analysis Center

Adult humans, human infants, pre-school children, and non-human animals appear to share a system of approximate numerical processing for non-symbolic stimuli such as arrays of dots or sequences of tones. Behavioral studies of adult subjects implicate a link between these non-symbolic numerical abilities and symbolic numerical processing in humans however, neuroimaging studies have remained inconclusive on the neural basis of this link. The intraparietal sulcus (IPS) is known to selectively respond to symbolic numerical stimuli such as Arabic numerals (see Dehaene et al., 2003 for review) however, two recent studies have arrived at opposite conclusions regarding the role of the IPS in processing non-symbolic, numerosity arrays (Piazza et al., 2004; Shuman & Kanwisher, 2004). Using functional magnetic resonance imaging (fMRI) at 4-Tesla and an event-related adaptation paradigm, we found that adult subjects showed a greater IPS response to visual arrays that deviated from standard stimuli in their number of elements than to stimuli that deviated from standards in local element shape. These results suggest a neurophysiological link between non-symbolic and symbolic numerical processing in adulthood. We hypothesized that the IPS may also be an important substrate for numerical processing early in human development, before sophisticated symbolic numerical skills develop (e.g., Spelke, 2002). We tested four-year-old children with the same fMRI-adaptation paradigm as adult subjects and found that the IPS responded to numerical deviants similarly in four-year-old children and adults. Thus the fundamental substrate of numerical cognition appears to be present early in development.

H81 *886* **Adults' and children's assessments of discrete and continuous quantity with nonsolid substances**

Hilary C. Barth[1] (hbarth@wesleyan.edu), Lacey Beckmann[2], Elizabeth S. Spelke[2]; [1]Wesleyan University, [2]Harvard University

In previous studies exploring adults' ability to aggregate area information across large sets of elements, participants saw rapidly presented pairs of large dot arrays and were asked to choose the one with the greater aggregate continuous amount (summed area), regardless of discrete number, under a range of experimental conditions. They were unable to assess total continuous amount across large sets accurately; discrete number drove their choices instead, even when choosing the larger number yielded a much smaller total amount, suggesting that systems of discrete number representation are critical to tasks requiring both continuous and discrete quantity estimation in large sets. The current study attempts to answer two follow-up questions. Does this pattern of performance hold for assessments of quantity with physical substances rather than objects? Do children also use discrete number as a cue to continuous quantity in large sets? For each trial, two side-by-side boards were presented, each covered with an array of colored paint blobs. Participants (college students or preschool children) were asked to identify the board containing *more paint* or (in a separate trial block) *more blobs*. As in previous studies using computer-generated stimuli, adults' judgments of the total continuous amount present in blobs of a physical substance was heavily influenced by the number of blobs present. Though easy familiarization trials showed that young children understood the task, they showed the same pattern of performance: numerical quantity dominated judgments of continuous amount. Potential implications for theories of quantity representation will be discussed.

Acknowledgment: This work was supported by a NSF-ROLE grant to E. Spelke.

H82 *887* **Children's amodal addition and subtraction of large sets**

Lacey Beckmann[1] (lacey@wjh.harvard.edu), Hilary Barth[2], Elizabeth Spelke[1]; [1]Harvard University, [2]Wesleyan University

Adults and preschool children integrate numerical information across visually and aurally presented sets, comparing dot arrays to sound sequences based on the number of elements in each set. Previous studies (Barth, La Mont, Lipton, & Spelke, PNAS 2005) suggest that amodal representations of approximate number mediate these operations. Adults can also perform across-modality arithmetic operations as easily as within-modality operations, adding dots to sounds and comparing the sum of the elements to a third dot array. Is this ability due to adults' experience with arithmetic? Four experiments tested kindergarten children's ability to add sounds and dots, or to subtract sounds from dots, in auditory sequences and visual arrays, respectively. The (never seen) result of the arithmetic operation was compared to the number of dots in a final array (these quantities differed by ratios of 4:7, 4:6, or 4:5, with comparison dots more numerous on half the problems). Performance was compared to a baseline comparison task with the same initial numerical value as the sum/difference, using a closely matched procedure that required no adding or subtracting. Participants were successful at all tasks; accuracy depended on the comparison ratio. Children, like adults, are equally accurate on addition and comparison tasks and less accurate on subtraction tasks. The present experiments provide evidence that abstract, non-symbolic representations of number support operations of arithmetic in the absence of symbolic number knowledge.

Acknowledgment: NSF REC-0196471 to E. Spelke

H83 *888* **Enumeration of Objects and Substances in Non-Human Primates: Experiments with Brown Lemurs (*Eulemur fulvus*)**

Jennifer L Barnes[1] (jennifer.barnes@yale.edu), Neha Mahajan[1], Marissa C Blanco[1], Laurie R Santos[1]; [1]Yale University

Adult humans, human infants, and non-human primates share the capacity to visually track small numbers of objects across time and occlusion. Previous studies have examined the limits of the object file system in human adults. Here, we explore whether non-human primates' object tracking abilities are subject to the same constraints as that of adult humans. Specifically, we examine whether object tracking in one prosimian species, the brown lemur (*Eulemur fulvus*), is affected when the objects to be tracked behave either non-rigidly or non-cohesively. We presented lemurs with a series of expectancy violation studies involving simple 1+1 addition events in which we varied the properties of the objects involved. Lemurs successfully enumerated the two objects when those objects were rigid cohesive individuals, but failed to enumerate similar looking non-rigid piles of sand. However, lemurs successfully enumerated non-cohesive objects that broke into multiple pieces. These results are discussed in light of recent theories about object processing in human infants and adults.

H84 *889* **Does subitizing require attention?**

Melanie Palomares[1] (paloma@jhu.edu), Loandra Torres[1], Carly Leonard[1], Howard Egeth[1]; [1]Johns Hopkins University

Simultaneous enumeration of items seems to have two components. Subitizing is the fast and accurate enumeration of 1-3 items while counting is the slow and inaccurate enumeration of more than 3 items. As subitizing seem automatic and effortless, many have posited that it operates preattentively (Trick & Pylyshyn, 1993; Sathian et al., 1999). To directly test this idea, we asked observers to identify a letter (Target 1) and to enumerate dots (Target 2) within a rapid serial visual presentation (RSVP) stream. We varied the number of dots from 0 to 9 and the temporal lag between Target 1 and Target 2 from 0 to 400 ms. If subitizing is preattentive, then enumeration within this range should be immune to the attentional blink, which is the decrease in Target 2 accuracy when the temporal lag between Target 1 and 2 is short (Joseph, Chun and Nakayama, 1997). Interestingly, there was no attentional blink for enumerating 0 or 1 items. More importantly, however, there were small but significant attentional blinks within the subitizing range (2-3 items) as well as within the counting range (4-9 items). Our results suggest that detecting the presence or absence of a single item is preattentive, while enumeration of multiple items within both subitizing and counting range requires attention.

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H85 *890* **Decreasing visual subitising performance with age**

Mridhula Kumar[1] (mkumar@berkeley.edu), Roger W Li[1,2], Dennis M Levi[1,2], Sandy W Chat[3], Manfred MacKeben[4]; [1]School of Optometry, University of California-Berkeley, Berkeley, California, USA, [2]Helen Wills Neuroscience Institute, University of California-Berkeley, Berkeley, California, USA, [3]School of Optometry, The Hong Kong Polytechnic University, Hong Kong, China, [4]The Smith-Kettlewell Eye Research Institute, San Francisco, California, USA

Subitising, the ability to quickly and intuitively enumerate small numbers of items, is likely to be mediated by parallel processing. The purpose of our study was to ask whether visual subitising performance changes with age.

We recruited 17 "junior" observers (21-30 years), and 14 "senior" observers (60-85 years). All had normal visual acuity. On each trial, a number (N) of black circular dots was presented on the monitor screen for 200 ms against a gray background (40 cd/m^2). N ranged from 1-10 dots; the dots were randomly positioned in a 10 x 10 square (1 deg x 1 deg). Observers were asked to enumerate the number of dots as quickly and accurately as they could. Response latency was measured using the time it took to say the number into a microphone.

The mean subitising thresholds were 7.08+-0.30 and 4.73+-0.36 dots for the junior and senior age groups, respectively. There was a statistically significant difference between the two means (unpaired t=5.08; df=30; p<0.0001). Response latencies for the stimuli up to 7 dots were about the same in both

groups. Latencies were about 500 ms for 1 to 3 dots, and thereafter increased linearly at the rate of about 300 ms/dot.

We found that the subitising performance deteriorates with advancing age. Control experiments using artificial pupils and reduced stimulus luminance show that subitising losses cannot be explained by the optical changes or by reduced retinal illuminance. Our findings support the hypothesis that parallel processing may be affected by age.

H86 *891* Staying in bounds: A critical role of closure for object files

Jason T Arita[1] (jason.arita@duke.edu), Stephen R Mitroff[1]; [1]Center for Cognitive Neuroscience, Department of Psychological and Brain Sciences, Duke University

As we move around the world, and the world around us, we must continually track objects as being the same entities from one moment to the next. But, over what sorts of entities can such 'object persistence' be computed? Previous work with adults and infants has shown that one of the most important principles for determining objecthood is *cohesion*: objects must have and maintain a unified boundary. For example, rarely do real objects suddenly split in two. But what happens if that boundary does not exist in the first place? Here we directly explore one particular aspect of cohesion; the role of *closure*: must objects have a continuous, single boundary? We examined this by contrasting objects defined by illusory contours (i.e., a Kanizsa square) with objects defined by physical contours. While both conditions involve subjective objects, only one adheres to the principle of closure. We explored the effects of closure on 'object file' representations by measuring 'object specific preview benefits' (OSPBs) wherein a preview of information on an object leads to a speeded response when that information later reappears on the same object (compared to when it reappears on a different object), beyond display-wide priming. A significant OSPB was found for objects defined by physical contours, but not for objects defined by illusory contours (and the conditions were significantly different from one another). This suggests that closure, per se, may play an especially important role in object persistence.

Tuesday Talk Sessions

Tuesday, May 9, 2006

Attention: Benefits of Selection and Modulation (892-897, 712), Biological Motion (898-903, 1147), Scene Perception (905-909), Spatial Interactions and Crowding (910-915), Object Recognition (916-921), Binocular Rivalry (922-927), Attention: Neural Mechanisms and Models (928-933), Binocular Vision/Stereopsis (934-939)

Attention: Benefits of Selection and Modulation

8:00 - 9:45 am

Hyatt Ballroom North

Moderator: Alex Holcombe

8:00 *892* **Progressively poorer perceptual precision and progressively greater perceptual lag:Tracking the changing features of one, two and four objects.**

Christina Howard[1] (howardcj@cardiff.ac.uk), Alex O Holcombe[1]; [1]School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff, CF10 3AT, UK

Approximate measures indicate a four-object capacity limit for tracking the changing positions of objects. More precise measures suggest a gradual decline in perceptual precision with number of objects tracked. Indeed, performance can decline substantially as load is increased from one to two (e.g. Tripathy and Barrett, 2004, Journal of Vision, 4, 1020 - 1043). Performance in continuous tracking of features other than position remains underexplored. Here we investigate the effect of attentional load on tracking smoothly changing orientations and spatial frequencies. Method: Five Gabor patches constantly changed orientation or spatial frequency in a smooth and random manner. To vary attentional load, one, two or four of these were indicated as the targets for tracking. After a random interval all Gabors disappeared and one target was indicated. To report the final state of this probed Gabor, observers adjusted the orientation or spatial frequency of a sample. Results: Tracking two Gabors yielded substantially greater error magnitudes than tracking one. Indeed, the distribution of orientation errors was not much better than that of a worst-case model wherein only one orientation is tracked at any time. Capacity thus appears very limited. A different analysis revealed that responses were more similar to previous states of the probed Gabor than to its final state. This lag increased with attentional load. The increase may represent either attention visiting each item less often with the increase in number attended, or a load-induced increase in consolidation time for visual short-term memory.

URL: http://www.cf.ac.uk/psych/holcombea/research/HowardVSS06/

8:15 *893* **Feature-based attention is not object-based**

Jianwei Lu[1] (jianweil@usc.edu), Laurent Itti[1]; [1]Computer Science Dept and Neuroscience Program, University of Southern California, Los Angeles, California, USA

Feature-based attention was revealed as global enhancement of attended visual features throughout the visual cortex. Object-based attention was shown as better performance when concurrently discriminating two features of same object compared to features of different objects. We used fMRI to investigate whether feature-based attention is object-based, i.e, is cortical enhancement of attended features influenced by the objectness the stimulus features appear? The stimuli were two fields of random dots presented bilaterally to central fixation cross. Subjects performed luminance discrimination using two-interval forced-choice paradigm on one side and ignored the stimulus on the other side. The ignored stimulus was always red dots and the attended stimulus was overlapped red and green dots. Subjects performed luminance discrimination on either red dots or on green dots. We compared visual cortical enhancement of the ignored stimulus when subjects attended on the other side to either identical(red) or different(green) stimulus in two conditions: either the dots stimuli on both sides appeared to belong to same object (both fields displayed in the same grey box appearing on top of a textured background, with cast shadows effects around the box), or as two separate objects (each field displayed in a separate box with the same background and shadows). Results showed both in single-object condition and in two-object condition the two subjects consistently had significant enhancement of the ignored stimulus in early visual areas(V1 to V4). Hence it indicated feature-based attentional enhancement exists even between two stimuli which belong to two different objects, suggesting a very early mechanism.

8:30 *894* **Interactions between space- and object-based attention revealed through ERP studies**

Marlene Behrmann[1,2] (behrmann@cnbc.cmu.edu), Dwight Kravitz[1,2], Nick Yeung[1,2]; [1]Department of Psychology, Carnegie Mellon University, Pittsburgh, [2]Center for the Neural Basis of Cognition, Pittsburgh

Recent functional MRI studies have demonstrated that regions of early visual cortex whose receptive fields overlie locations occupied by a cued object show increased activation, providing a possible neural basis for the behavioral facilitation observed for information appearing within these locations (Muller & Kleinschmidt, 2003). However, the timecourse of this effect is obscured by the poor temporal resolution of fMRI. In this set of experiments, we used ERPs to investigate the neural timecourse of object-based attention using a well-established object-based attention paradigm (Egly, Driver, & Rafal, 1994). We found time-specific modulation of the N2 component in parietal, occipital, and temporal electrodes for within- versus between-object trials. We next extended the paradigm to include targets in the surround of the cued object. This allowed us to ascertain the dynamics associated with benefits that accrue not only to the cued object but also to objects in the spatial surround of the cued object (Kravitz & Behrmann, in press). Taken together, these results indicate a close coupling between spatial and object representations, whereby information from both interacts to determine the distribution of attentional facilitation throughout a visual scene. These results are consistent with an account of a general attention mechanism in which information is distributed across multiple levels of representation and in which these representations interact to form an attentional gradient.

Acknowledgment: This work was supported by a grant from NIH to MB.

8:45 *895* **Visual search has no foresight**

Jeremy M Wolfe[1,2] (wolfe@search.bwh.harvard.edu), Todd S Horowitz[1,2], David E Fencsik[1,2], Stephen J Flusberg[1]; [1]Visual Attention Lab, Brigham & Women's Hospital, Boston, MA, [2]Dept. of Ophthalmology, Harvard Medical School

During an extended visual search task (e.g. search for T among Ls, "TvL"), does sensitivity to target identity accumulate gradually or are targets identified swiftly, but only once they are selected by attention? We used a novel, event-related technique that allowed us to measure signal strength at different times prior to the end of search. Os searched for horizontal Ts among rotated Ls and reported target orientation. Stimuli were scaled to be peripherally identifiable. Mouseclicks produced very brief glimpses of the display. Click positions served as confidence ratings scaled from "highly confident left" to "highly confident right". A final mouseclick, localizing the target, ended the trial. Ratings were averaged as a function of number of frames prior to final response. Ratings were used to generate ROCs for each frame relative to response. Just two frames prior to finding the target, d' was near zero for most Os, even though they had searched for many frames. We compared these data to two control conditions: assessment of a gradual random walk toward a boundary (guaranteed slow accumulation of information); and TvL search with small stimuli that required foveation (guaranteed step function from no signal to perfect identification). TvL search data mimicked the mandatory eye movement condition, rather than the slow accumulation control. There was no evidence for gradual accumulation of information in this search task. Os have no explicit information about the location or identity of targets in TvL search task until attention selects the target.

Acknowledgment: Supported by AFOSR

URL: search.bwh.harvard.edu

9:00 *896* **Change detection has no foresight: Measuring advanced knowledge of changes across displays**

David E Fencsik[1,2] (fencsik@search.bwh.harvard.edu), Todd S Horowitz[1,2], Stephen J Flusberg[1], Jeremy M Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

In a visual change detection task, observers search for a change between two displays presented in alternation. When do observers have knowledge about the presence of a change? Does knowledge accumulate gradually, or is the change detected swiftly, but only after the changed region is selected by attention? While several researchers have reported evidence of awareness of a change prior to or in the absence of explicit report ("implicit change detection" or "mindsight"; e.g., Rensink, PsychSci, 2004), others have found contrary results (e.g., Mitroff & Simons, VisCog, 2002). We applied a new, event-related signal detection method in order to supply converging evidence. Observers viewed alternating displays repeatedly in brief exposures ("frames"). Following each frame, observers indicated their confidence along a rating scale ranging from "highly confident same" to "highly confident different". Each trial ended when the observer indicated response certainty by pressing a button. Ratings were averaged across trials after being aligned relative to the final response frame. From these data, we generated ROCs for each frame relative to the time of response. This procedure has produced evidence for gradual increases in sensitivity in control tasks (e.g., simulated diffusion; motion coherence detection). In change detection, however, we observed a step function. Stimulus sensitivity was high for the final response, but near zero just two frames prior to response. Observers have no information about the presence of a change prior to directing attention to the region that is changing across displays.

Acknowledgment: Supported by grants from NIMH (MH56020) and AFOSR to JMW, and a NEI NRSA Fellowship to DEF.

9:15 *897* **Attention alters the appearance of motion coherence**

Stuart Fuller[1] (sgf208@nyu.edu), Taosheng Liu[1,2], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, New York, NY, [2]Center for Neural Science, New York University, New York, NY

Background: Selective attention enhances visual information processing, as measured by behavioral performance and neural activity. However, little is known about the effects of attention on subjective experience. Here we studied the effect of transient (exogenous) attention – automatic and short-duration preferential processing at a given location – on the subjective appearance of visual motion, using a psychophysical procedure that directly measures appearance and controls for response bias (Carrasco, Ling & Read, 2004). Method: Observers viewed briefly presented (150 ms) pairs of dot patterns (5° diameter, 8° eccentricity on the horizontal meridian), and reported the motion direction of the more coherent pattern. In each trial, one pattern had 50% coherence and the other varied randomly between 10% and 90%. Uninformative peripheral cues presented 80 ms before stimulus onset directed transient attention to one of the stimulus locations. To rule out response bias, in a control experiment, we increased the time interval between the cue and the stimuli to 450 ms, such that the effect of transient attention would expire before stimulus presentation. Results: We found that directing attention to a stimulus location increases its perceived coherence level and improves discrimination performance. In the control experiment, the cues had no effect on apparent coherence or discrimination. Our results are consistent with physiological studies showing that attention modulates motion processing and provide evidence of a subjective perceptual correlate of attention with a concomitant effect on performance.

9:30 *712* **Greater response conflict from weaker visual signals**

Yuko Yotsumoto[1,2] (yuko@nmr.mgh.harvard.edu), Aaron Seitz[1], Yuka Sasaki[2], Shinsuke Shimojo[3], Toshimasa Yamamoto[4], Masao Kogure[4], Masamichi Sakagami[5], Takeo Watanabe[1]; [1]Boston University, [2]Martinos Center for Biomedical Imaging, Massachusetts General Hospital, [3]California Institute of technology, [4]DENSO IT Laboratory, [5]Tamagawa University

It is generally thought that strong conflicting signals have greater negative impacts on task performance than relatively weaker conflicting signal. Here we show that this is not necessarily the case for visual-motor contingencies. We used a novel procedure where subjects judged the color (blue or green) of a visual stimulus by making a color-contingent leftward or rightward motion. In the background, a certain percent of coherently moving dots was presented with leftward or rightward direction, but which was irrelevant to the task. In half the trials, the direction of the "correct" motor response was the same as the direction of motion-stimulus (ie congruent trials), whereas in the other half of trials, the correct response direction was opposite to the coherent motion direction (ie incongruent trials). The coherent motion percentage was randomly chosen for each trial and ranged from 0-100%. Interestingly, we found a non-monotonic relationship with a significant dip in performance at around 25% motion coherence with recoveries of performance on either side. Reaction times trended higher at 25% coherence, opposite to the prediction of a reaction-time/accuracy trade-off. The generality of this effect was confirmed with tasks using different motor responses, such as saccadic eye movements and steering wheel operations. These results are at odds with the model that stronger irrelevant signals more severely interfere with a task performance. One possible explanation is that visual signals that are too weak to be "noticed" and suppressed can directly interfere with a motor response as conflicting motor signals.

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Biological Motion

8:00 - 9:45 am

Hyatt Ballroom South

Moderator: Maggie Shiffrar

8:00 *898* **From point-lights to virtual skeleton: biological-motion representations revealed by dynamic classification images**

Hongjing Lu[1] (hongjing@psych.ucla.edu), Zili Liu[1]; [1]Psychology Department, UCLA

Human observers readily recognize complex actions based on impoverished visual inputs, such as point-light biological motion. How is point-light biological motion represented by the visual system? We used techniques of classification images to provide a pictorial answer. Observers discriminated a point-light human who was walking either forward or backward (moonwalk). The two stimulus movies were identical except that one of them was played backward. The point-light human was embedded in dynamic white noise.We developed a new method for constructing classification images by computing trial-by-trial correlations between noise pixels and an observer's responses. The resulting correlation map revealed statistically significant correlations at all point-light locations, i.e., dynamic "templates" of the forward and backward walkers. We further computed a semipartial correlation map, using multiple regression to increase the power of the analysis in order to reliably detect small but nonzero correlations between noise pixels and responses. Classification movies were created using the resultant semipartial correlation map, in which noise pixels located along the "virtual skeleton" (lines connecting point-light joints according to the structure of a human body) yielded significant correlations with observers' responses. In a control analysis, lines linking up symmetrically corresponding point-light joints (e.g., the left and right hands) yielded non-significant correlations.Our findings indicate that the internal representation used to discriminate dynamic point-light walkers includes not only joint positions (conveyed by the physically-presented point-lights), but also the "skeleton" that was never physically present in the stimulus signals.

8:15 *899* **Predicting point-light actions in real-time**

Markus Graf[1] (markus.graf@cbs.mpg.de), Bianca Reitzner[1], Martin Giese[2], Antonino Casile[2], Wolfgang Prinz[1]; [1]Max PIanck Institute for Human Cognitive and Brain Sciences, [2]University Clinic Tübingen, Laboratory for Action Representation and Learning

Evidence has accumulated for a mirror system in humans which simulates actions of conspecifics (Wilson & Knoblich, 2005). One likely purpose of such a simulation system is to support action prediction. We focused on the time-course of action prediction, investigating whether the prediction of actions involves a real-time simulation process.We motion-captured a number of human actions and rendered them as point light action sequences. In the experiments, we presented brief videos of human actions, followed by an occluder and a static test stimulus. Both the occluder duration (SOA of 100, 400, or 700 ms) and the distance of the test stimulus to the endpoint of the action sequence (corresponding to 100, 400, or 700 ms) were varied independently. Subjects had to judge whether the test stimulus depicted a continuation of the action in the same orientation, or whether the test stimulus was presented in a different orientation in depth as the previous action sequence.Prediction accuracy was best when SOA and distance to the endpoint corresponded, i.e. when the test image was a continuation of the sequence that matched the occluder duration. This pattern of results was destroyed when the sequences and test images were inverted (flipped around the horizontal axis). In this case, performance simply deteriorated with increasing distance to the end of the sequence. Overall, our findings suggest that action prediction involves a real-time simulation process. This process can break down when the actions are presented under viewing conditions for which we have little experience.

8:30 *900* **Brain activity evoked by perception of novel 'biological motion'**

John A. Pyles[1] (jpyles@uci.edu), Javier O. Garcia[1], Donald D. Hoffman[1], Emily D. Grossman[1]; [1]Department of Cognitive Sciences, University of California, Irvine

Purpose: Contemporary research in biological motion perception has generally been confined to point-light animations of human movement. Our experiments examine whether perception of novel, coherent motion sequences depicting animate creatures evokes similar neural responses as perception of human motion. **Method:** A new stimulus set ('creatures') was created using 3-D artificial evolution software ('Framsticks', http://www.frams.alife.pl). These stimuli depict animate beings, each with unique body configurations and unique manners of locomotion. Results from a rating experiment demonstrate that observers perceive point-light versions of these creatures as 'alive'. Two blocked fMRI experiments compared neural activity for viewing moving creatures versus human motion. In a first experiment, observers viewed fully-illuminated animations of creatures and humans. In a second experiment observers viewed point-light animations of creatures, point-light animations of humans, and scrambled point-light animations motion-matched to the human animations. **Results:** Fully-illuminated animations of human movement produced greater BOLD response in STSp and ITS brain areas than creatures. The BOLD response in FFA did not differentiate between the two type of animations. Despite being rated as 'alive', point-light animations of creatures resulted in BOLD activity similar to that of scrambled sequences in areas selective for biological motion. **Conclusions:** These results suggest that perceived animacy is insufficient for optimally driving neural activity within brain areas selective to biological motion. Poorly selective neural responses for point-light creatures suggests that knowledge of body structure may be an important factor for activating these areas.

8:45 *901* **Learning and perceiving informative spatio-temporal components from emotional body expressions**

Martin Giese[1] (martin.giese@uni-tuebingen.de), Lars Omlor[1], Claire Roether[1]; [1]ARL, Dept. of Cognitive Neurology, Hertie Institute for Clinical Brain Research, Tuebingen, Germany

Humans are able to communicate emotions through their posture, and through the dynamics of their body movements. Features that convey critical information about specific emotions have only rarely been studied, typically based on perceptual ratings (e.g. Montpare et al., 1987; Meijer, 1991; Wallbott, 1998). A more accurate characterization of informative features can be obtained by a statistical analysis of trajectories of emotional body movements. Studies on image statistics have shown that Independent Components Analysis (ICA) allows to extract highly informative features for the perception of natural images and faces. This motivates the question whether related approaches allow to extract informative spatio-temporal components for the visual perception of emotional body expressions. METHOD: Our analysis was based on motion capture data from actors performing actions with different emotional affects. This data was analyzed with existing ICA methods, and applying a new algorithm that combines non-negative ICA with feature extraction by sparse regression. We extracted spatio-temporal components that contributed maximally to the approximations of trajectories with different emotional styles. In a psychophysical experiment, we tested the relevance of these components for the visual emotion categorization. RESULTS: Opposed to standard ICA, the new algorithm extracts a small number of spatio-temporal components that are specific for individual emotions. These components seem to correlate with features that are important for the categorization of emotional body expressions. Informative features for visual recognition might thus reflect distinctive components in motor patterns that cannot be extracted with basic algorithms, like PCA or standard ICA.

Acknowledgment: Supported by HFSP, DFG, and the Volkswagenstiftung.

9:00 *902* **Identity perception with and without a body.**

Sapna Prasad[1] (prasad@psychology.rutgers.edu), Michael Kozhevnikov[1], Maggie Shiffrar[1]; [1]Rutgers University-Newark

Perception-action theories suggest that observers use their own action control systems to perceive the actions of others. If so, then observers must be able to overlook form differences between their body and the bodies of other people. Furthermore, observers should be able to recognize their actions in the absence of body form cues. To test these ideas, two psychophysical studies of identity perception were conducted. Observers demonstrate the greatest visual sensitivity to their own movements in point light displays (Loula et. al, 2005). Form cues are reduced in point light displays, but are not absent. Optic flow patterns are devoid of bodily form cues. In Experiment 1, naïve participants walked along a hallway with a head mounted camera. The resultant optic flow stimuli were edited into 5 sec movies. One month later, participants viewed the optic flow stimuli that they and another person had generated. In a 2AFC task, participants differentiated their own flow patterns from those of another person at above chance levels, suggesting that identity perception can occur independently of body form. To extend this result, Experiment 2 tested whether participants can identify their own actions even when those actions are presented on someone else's body. Participants' actions were recorded with a motion capture system and superimposed onto different bodies. One month later, participants identified the actor in each movie. Performance in this identity discrimination task depended upon motion but not body shape. Together, these findings support motor theories of action perception that emphasize actions over bodies.

Acknowledgment: NIH grant EY012300

9:15 *903* **A Pedestrian Courtship: Attractiveness and Symmetry of Humans Walking**

Javid Sadr[1] (sadr@wjh.harvard.edu), Nikolaus F. Troje[2], Ken Nakayama[1]; [1]Dept. of Psychology, Harvard University, Cambridge, MA, [2]Dept. of Psychology, Queen's University, Kingston, ON

People are more than faces, and much of our perception of others derives from visual appraisal of bodies and their movement -- rich sources of information as to gender, identity, etc. We find that, even ignoring overt courtship displays (eg, dancing), the mere act of walking, a ubiquitous human activity, provides observers a compelling percept of attractiveness. Previously, we demonstrated the influence of sexual dimorphism and prototypicality on attractiveness of human gait; here we extend this to examine the role of symmetry.To do so, we obtain attractiveness ratings for motion-captured women, displayed as point-light walkers, and for their perfectly symmetric counterparts. Our results show that making symmetric an individual's body and movement can indeed increase attractiveness, although this benefit might not be seen for less attractive individuals. Moreover, a key feature of our approach (Troje, 2002) is the ability to independently manipulate the symmetry of either the body or its movement and thus investigate the contribution of each to attractiveness. Whereas previously examined anatomical asymmetries may be quite small and difficult to measure and to perceive visually, we propose that asymmetries in movement may be more readily observed and salient. Our results thus far indicate that, at least for more attractive individuals, symmetry of movement has a greater bearing on attractiveness than does anatomic symmetry.In conclusion, we suggest that explicitly and independently manipulating anatomic and kinematic symmetry (and sexual dimorphism, prototypicality, etc) of motion-captured individuals provides an important complement to existing correlational and video-based methods in the study of person perception.

Acknowledgment: J. Sadr and K. Nakayama were funded in part by an NSF grant in Human and Social Dynamics. N. Troje was funded by the Volkswagen Foundation and the Canada Foundation for Innovation.

9:30 *1147* **Does the Perception of Speed Influence the Perception of Animacy?**

Paul A. Szego[1] (szegopa@mcmaster.ca), M.D. Rutherford[1]; [1]Psychology, Neuroscience and Behaviour, McMaster University

The ability to perceive objects as alive is a fundamental ability that begins early in infancy, has dedicated neural circuitry, and serves as a building block for later social perceptual development. Previous research has shown that one cue to an object's animacy is its speed: Relatively faster moving objects are more likely to be perceived as animate, all else equal. Our goal was to test whether the perception of animacy could be influenced by an illusory difference in speed, in the absence of any actual difference in speed. In a two-alternative forced choice task, participants viewed dots moving one at a time across the two equally-sized central circles of the Ebbinghaus-Titchener illusion. In this illusion, an apparently smaller central circle is surrounded by larger inducing circles, and an apparently larger central circle is surrounded by smaller inducing circles. On each trial, participants saw two dots, one at a time, traveling an equal distance across each of the central circles at one of three constant speeds. Participants judged which of the two dots appeared to be alive. Results showed that of two dots traveling at the same speed across circles of equal diameter, one was perceived as animate significantly more often if moving across an apparently larger circle, for all speeds tested. These results suggest that the perception of animacy can be influenced by the apparent extent of motion in the absence of any actual speed differences.

Acknowledgment: National Sciences and Engineering Research Council of Canada (NSERC)

Scene Perception

11:00 - 12:30 pm

Hyatt Ballroom North

Moderator: Russel A. Epstein

11:00 *904* Abstract withdrawn.

11:15 *905* **The Roles of Amplitude and Local Phase Information in Scene Gist Recognition and Masking**

Lester C. Loschky[1] (loschky@ksu.edu), Amit Sethi[2], Daniel J. Simons[3], Tejaswi N. Pydimarri[4], Nicholas Forristal[1], Jeremy Corbeille[1], Katie Gibb[1]; [1]Dept. of Psychology, Kansas State University, [2]Dept. of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, [3]Dept. of Psychology, University of Illinois at Urbana-Champaign, [4]Dept. of Computer & Information Science, Kansas State University

How is scene gist recognized? We investigated the roles of the amplitude spectra and local relative phase of scenes in both scene gist recognition and masking. We hypothesized that the information most useful for scene gist recognition also produces the strongest scene gist masking. Previous results (Loschky, et al., Psychonomics, 2005) showed that masks having the amplitude spectra of scenes but random phase spectra produced stronger masking than white noise masks, but weaker masking than scene image masks. We tested the further hypothesis that masks sharing both similar amplitude spectra to scenes and similar local relative phase information would produce stronger scene gist masking than masks sharing only the amplitude spectra of scenes. We compared scene gist masking produced by 1) synthesized textures (Portilla & Simoncelli, 2000) based on scenes, and 2) phase-randomized scenes using the RISE algorithm (Sadr & Sinha, 2004). Results confirmed our hypothesis. Scene categories also varied in necessary and sufficient information for gist. Similar patterns were found for both the gist recognition threshold of phase randomization, and for synthesized texture images: forests and mountains were the most recognizable. Furthermore, compared to masking by an image from a differ-

ent scene category, scenes masked by either their fully phase-randomized versions or their synthesized texture versions showed the same across-category pattern: forests and mountains were more recognizable than other categories under conditions of target/mask integration. Thus, some categories are more recognizable based on amplitude and local relative phase information, while others require more information (e.g., global relative phase—'layout').

Acknowledgment: SR Research: provision of Experiment Builder software & technical support

11:30 *906* Effect of adaptation suggests role of low-level processes in rapid scene categorization

Daniel Kaping[1] (dkaping@gwdg.de), Tzvetomir Tzvetanov[1], Stefan Treue[1]; [1]Cognitive Neuroscience Laboratory, German Primate Center, Göttingen

The human visual system has a remarkable ability for rapid recognition and categorization of visual scenes. This perceptual speed might strongly rely on low-level feature dissimilarities, such as different spatial frequency contents between man-made and natural scenes (Torralba & Oliva, Network, 2003). Here we set out to test the contribution of such early visual processes during rapid categorization by using an adaptation paradigm. We hypothesized that adaptation to spatial frequency distribution matched to that of man made scenes might modify the perception of a subsequently viewed real world image.We presented grayscale images of natural and man-made scenes for 12 ms terminated by a mask. The images were preceded by an adaptation sequence of rectangles approximating the statistical properties of man-made scenes. Observers were either asked to rapidly detect the location of a single man-made scene amongst two or four simultaneously presented scenes or asked to rapidly localize the single natural scene amongst the presented images. Following the adaptation, observers' performance (reaction time and percent correct) in localizing the natural image among distracting images did not change significantly while the localization of man-made images was severely impaired. We suggest that this results from a recalibration of the visual system to the spatial frequency profile of the adapter, allowing detection of statistical deviations from this mean during rapid categorization. Our findings present strong evidence for an important role of low-level processes in fast image categorization because they could recover the "gist" of the visual input.

Acknowledgment: This study was supported by the SensoPrim EU Marie Curie Early Stage Training Program

11:45 *907* Looking at scenes while searching for numbers: Dividing attention multiplies space

Helene Intraub[1] (intraub@udel.edu), Karen K. Daniels[1], Todd S. Horowitz[2], Jeremy M. Wolfe[2]; [1]University of Delaware, [2]Brigham and Women's Hospital and Harvard Medical School

After memorizing photos of scenes, viewers tend to remember having seen beyond the edges of views ("boundary extension": BE). During normal scene perception, we don't try to memorize layout: we attend to common tasks. Is BE elicited when attention is diverted from the scene? Photographs (n=48) were presented for 750 ms. Superimposed on each were red 2s and 5s. Os (N=108) performed a search task (SEARCH-ONLY), a BE task (MEMORY-ONLY) or both (SEARCH-MEMORY). In the search task, Os counted 5s (0, 1, 2). In the BE task, Os rated test pictures on a 5-pt scale ("same", "a little or a lot closer or wider angle"). In the SEARCH-MEMORY condition, Os performed both tasks giving search priority. Search accuracy was well above the 33% chance level and did not differ significantly between SEARCH-ONLY (58.6%) and SEARCH-MEMORY (55.0%) conditions. Mean ratings revealed significant BE in both memory conditions. Interestingly, BE was greater when attention was divided (SEARCH-MEMORY). Was BE constrained by focused attention or did MEMORY-ONLY Os use a strategy (e.g., "Tree 5 mm from edge")? To thwart this, a replication was run (N=72). The BE-task was presented as an unexpected, incidental test at the end of a 12-trial series. Results were the same. These data show that layout extrapolation automatically occurs in scene representation. Indeed, extrapolation was greater when attention was diverted to search. Thus BE is available to facilitate integration of views during scene perception even when the observer's attention is devoted to other tasks.

Acknowledgment: NIMH MH56020

12:00 *908* Boundary Extension: Filling-out scene layout information in human parahippocampal cortex

Soo Jin Park[1] (soojin.park@yale.edu), Helene Intraub[2], David Widders[1], Do-Joon Yi[1], Marvin M. Chun[1]; [1]Yale University, [2]University of Delaware

A central question in visual cognition is how we perceive a seamless world despite physiological constraints in vision. Here, we report functional magnetic resonance imaging (fMRI) evidence for *boundary extension* (BE: Intraub & Richardson, 1989), the extrapolation or "filling-out" of scene layout beyond what was physically presented. FMRI adaptation reveals whether a particular neuronal population treats two stimuli as the same or different (Grill-Spector et al., 1999; Kourtzi & Kanwisher, 2001). We used fMRI adaptation to measure whether the parahippocampal place area (PPA), important for scene layout perception (Epstein & Kanwisher, 1998), would respond to extrapolated layout. In the two critical conditions, close-up and wide-angle views of the same scene were presented in one of two different orders: close-wide, or wide-close. If the PPA activity reveals BE and responds to the filled-out layout of the scene representation, then we should observe attenuation in the close-wide condition but not in the wide-close condition. FMRI revealed boundary extension for close-wide scene pairs in the PPA. As a control, we also measured responses in the lateral occipital complex (LOC), which processes object information. No BE is predicted in the LOC because behavioral work suggests that extrapolation does not occur for object representations alone. Indeed, fMRI adaptation did not reveal any extrapolation of object representations in the LOC. Thus, scene layout representations are extrapolated beyond the confines of the perceptual input selectively in the PPA. Such filling-out may facilitate perception of a continuous world from discontinuous, constrained views.

Acknowledgment: Supported by NIH grant EY014193.

12:15 *909* Parahippocampal and retrosplenial involvement in two kinds of scene recognition

Russell A. Epstein[1] (epstein@psych.upenn.edu), J. Stephen Higgins[1,2]; [1]Dept. of Psychology, University of Pennsylvania, [2]Dept. of Psychology, University of Illinois

Complex real-world scenes can either be identified at the basic level ("a store") or as specific places with specific locations in the world ("the Penn Bookstore at 36th and Walnut St."). We used fMRI to test whether these two recognition tasks engage the same or different neural systems. In each trial of Exp. 1, subjects saw a verbal label followed by a briefly presented and masked photograph and reported whether the label matched the photograph. In *location identification* trials, stimuli were names and photographs of familiar locations around the Penn campus, while in *category identification* trials, stimuli were names and photographs of easily categorizable unfamiliar scenes ("kitchen", "parking lot"). Scene-responsive voxels in the parahippocampal place area (PPA) and retrosplenial cortex (RSC) responded much more strongly during location identification than during category identification. Exp. 2 was a control experiment that replicated these results in a new set of subjects and demonstrated that they could not be accounted for by stimulus differences. Exp. 3 and 4 demonstrated different roles for the PPA and RSC during location identification, with the PPA supporting a representation of the local scene that can be activated by either visual or verbal stimuli and the RSC supporting processes that may facilitate the placement of the local scene within a larger spatial framework. These results are consistent with the claim that PPA and RSC are preferentially involved in localization rather than categorization of scenes and point to the existence of distinct neural systems involved in these two tasks.

Acknowledgment: This research was supported by a grant from the Whitehall Foundation.

Spatial Interactions and Crowding

11:00 - 12:30 pm

Hyatt Ballroom South

Moderator: Susana Chung

11:00 *910* Neural correlates of letter crowding in the periphery

A. Cyrus Arman[1] (aarman@usc.edu), Susana T. L. Chung[3], Bosco S. Tjan[1,2]; [1]Neuroscience Graduate Program, University of Southern California, [2]Deparment of Psychology, University of Southern California, [3]College of Optometry, University of Houston

PURPOSE: In the periphery, a letter target larger than the size of the observer's acuity can become unrecognizable when flanked by other letters. This "crowding" phenomenon is a vivid demonstration of the nonlinear nature of the deficits in form vision in the periphery. We used a combination of psychophysics and functional-imaging to determine the neural loci of crowding.

METHODS: Subjects performed a four-alternative-forced-choice letter identification task in the lower-right periphery at 5° eccentricity. The target-letter (Sloan Letters K, V, N, S) appeared for 100ms in four conditions: target-alone, or with letter flankers at 1.25x, 2x, and 3x letter height center-to-center separation.

RESULTS: Subject's psychophysical performance ranged from 50% in the crowded condition (1.25x separations) to near perfect in the non-crowded conditions (3x separation and 'target-alone'). In early visual areas (V1, V2, V3) there was little or no difference in the peak amplitude of the BOLD response across conditions. However, in V4 there was a suppression in the crowded condition compared to the non-crowded conditions. This pattern of activity was reversed in anterior regions of LO and in the vicinity of IPS.

CONCLUSION: Our findings suggest a bottom-up origin of crowding: crowding impedes the formation of high-level features somewhere between V1 and V4, resulting in impoverished inputs to LO, which then recruits more spatial-attention to enhance and process the input. In essence, it does not appear to be a lack of attention that causes crowding; instead, crowding impedes bottom-up feature integration and increases attentional demands.

Acknowledgment: Supported by: NIH/NEI R03-EY016391 (BST) and R01-EY12810 (STLC)

11:15 *911* Feature Integration Maps during crowding as revealed from covariance analysis of classification images

Anirvan S. Nandy[1] (nandy@usc.edu), Bosco S. Tjan[1,2]; [1]Department of Psychology, University of Southern California, [2]Neuroscience Graduate Program, University of Southern California

In the periphery, a letter target can become unrecognizable when flanked by other letters. This "crowding" phenomenon is largely absent in the fovea. Is crowding associated with changes in the features extracted by the visual system? Standard classification-image methods cannot reveal low-level features because it cannot distinguish conjunctive from independent use of features. Even if a clear template is revealed, it does not follow that all parts of the template are utilized as a whole. In this study, we investigated feature utilization by applying a pixel-wise covariance analysis to the noise fields from the error trials of a letter-identification experiment ("o" vs. "x"), run with four conditions: foveal vs. peripheral viewing, with or without flankers. The results were visualized as maps of correlation coefficients between pairs of pixels. In the fovea, the elementary features were found to be curved segments for "o", and bipolar bar segments for "x", of roughly the full letter size. The presence of flankers led to stronger inhibition zones without affecting feature shape or size. In the periphery, the features were bar fragments (vertically oriented for "o", diagonally for "x"), roughly half the letter size. The presence of flankers further reduced the feature size by 1/3, and although the features retained similar shapes, they were surrounded by stronger and tighter inhibition zones. These findings suggest that, compared to the fovea, the features utilized in the periphery are smaller fragments of the target. Their sizes are further reduced by the presence of flankers, which leads to crowding.

Acknowledgment: Supported by: NIH/NEI R03-EY016391

11:30 *912* Crowding between first- and second-order letter stimuli

Susana T.L. Chung[1] (schung@optometry.uh.edu), Roger W. Li[2], Dennis M. Levi[2]; [1]University of Houston, [2]University of California at Berkeley

Evidence abounds that the detection of first- and second-order visual stimuli is processed by separate pathways. This study asked whether first- and second-order stimuli remain independent at the stage of processing where crowding occurs. We measured thresholds for identifying a first- or second-order target letter in the presence of two second- or first-order flanking letters, for various letter separations. For comparison, we also measured thresholds when the target and flanking letters were all first- or second-order. Contrast of the flankers was 1.6x their respective contrast thresholds. First-order letters were defined by a luminance difference between the letter and its background. Second-order letters were defined by a differential noise contrast between the group of pixels that made up the letter and the group of pixels that made up the background. Measurements were obtained for each eye of four amblyopes, and at 10° lower field of four normally sighted observers. As expected, across all observers and for both eyes of the amblyopes, threshold elevation (magnitude of crowding) was maximal at the closest letter separation, and decreased as letter separation increased. Threshold elevation was greater for second- than first-order target letters, independent of the order type of flankers. Substantial threshold elevation occurred even when the target and flanking letters were of different order type. Our finding of substantial interaction between first- and second-order stimuli suggests that the processing of these stimuli is not independent at the stage of processing at which crowding occurs.

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11:45 *913* Target-Flanker Binding Releases Crowding

Sing-Hang Cheung[1] (shcheung@stanford.edu), Gordon E. Legge[2], Susana T. L. Chung[3], Bosco S. Tjan[4]; [1]Stanford University, [2]University of Minnesota, [3]University of Houston, [4]University of Southern California

Purpose. The interfering effect of letters on the recognition of adjacent letters is known as crowding. According to an Attention explanation, crowding occurs when visual attention cannot individualize the target. Alternatively, according to a Feature-integration explanation, the bottom-up interference among features of the target and the flankers results in crowding. Both explanations predict a release from crowding when the target and flankers touch, and are perceived as a single object. We tested this counter-intuitive prediction with target-flanker-touching and non-touching conditions. **Methods.** Three normally-sighted observers performed an orientation-judgment task with a 2-deg "T", presented at 8 deg in the right visual field, flanked by four similar T's. The flankers were oriented with the leg of the T pointing away from the target. The target was always darker than the background. Flankers were either darker than the background in the same-polarity condition or brighter in the opposite-polarity condition. Center-to-center distances between the target and the flankers were 2 deg (touching) or 2.5 deg (non-touching). Task accuracy was assessed with 200 trials at each of the seven contrast levels from 3% to 100%. **Results.** Compared with the non-touching condition, the touching condition yielded better accuracy (mean difference: 4.19 ± 1.84%) in the same-polarity condition, but worse accuracy (mean difference: -6.71 ±

0.84%) in the opposite-polarity condition. **Conclusions.** Reduced crowding was found in the touching condition, only when both target and flankers have the same contrast polarity. Release from crowding occurs when the visual system interprets the target and flankers as a single object.

Acknowledgment: Supported by NIH grants R01-EY02934 (GEL), R01-EY12810 (STLC) and R03-016391 (BST).

12:00 *914* **The time course of contrast masking reveals two distinct mechanisms of human surround suppression**

Yury Petrov[1] (yury@ski.org), Matteo Carandini[1], Suzanne P. McKee[1]; [1]Smith-Kettlewell Eye Research Institute

When a target in the periphery is surrounded by a matching mask, contrast sensitivity is suppressed, producing elevated thresholds. We explored the time course of this suppression and found clear evidence for two distinct mechanisms: one strong, transient, and monocular, the other weaker, sustained, and dichoptic. We measured thresholds for a 1.3 cpd Gabor target at 8 deg eccentricity surrounded by a large annulus of matching spatial frequency and orientation. We found that surround suppression is very strong (threshold elevated by up to 600%), but that it decreases by about three-fold when stimuli last longer than ~100 msec. The strong transient component occurs almost instantaneously (< 1 frame delay, 12 msec) irrespective of the separation between target and surround. The transient suppression differs from the sustained suppression in two remarkable ways. First, it does not transfer dichoptically. Second, it occurs even when the surround is of much lower contrast than the target. Both suppression components are tightly tuned to orientation, peaking at target orientation, but not tuned to spatial phase. These results indicate that there are two distinct kinds of surround suppression in human vision. The properties of the weaker sustained mechanism suggest a cortical origin. The neural substrate of the strong transient suppression is much less evident: the absence of dichoptic transfer suggests a subcortical origin, yet the strong orientation selectivity indicates cortex.

Acknowledgment: Supported by NIH/NEI 06644 (SPM) & NIH/NEI NRSA award (YP)

URL: http://www.ski.org/SPMcKee_lab/yury

12:15 *915* **Segmentation counteracts masking**

Preeti Verghese[1] (preeti@ski.org), Elliot Freeman[2]; [1]Smith Kettlewell Eye Research Institute, San Francisco CA 94115, U.S. A., [2]Institute of Cognitive Neuroscience, University College London, London WC1N 3AR, U.K.

We examined whether segmentation can alleviate the effect of a superimposed mask. We measured contrast increment thresholds for a horizontal static test grating (2 cpd, 30% contrast) under three conditions: 1) the test grating presented alone; 2) with a similar-sized superimposed mask grating of orthogonal orientation, creating a plaid; 3) with a superimposed mask having twice the diameter of the test. We hypothesized that this large mask condition might facilitate segmentation of the test. Masks had fixed contrast of 30%. The stimuli were presented at fixation and observers were asked to detect an increment of variable contrast on the test grating in a 2AFC task.For two out of four observers, thresholds were elevated by a factor of two in both superimposed mask conditions relative to the grating-alone condition, consistent with cross-orientation masking. For the other two observers, however, only the smaller mask produced this elevation, while the large mask reduced thresholds to the level of the grating-alone condition. This suggests the test grating could be effectively segmented from the compound stimulus.The segmentation effect was more robust with drifting stimuli: all four observers showed no threshold elevation in the large-mask condition, while their thresholds were elevated two-fold in the small-mask (plaid) condition. Peripheral presentation, in particular, appeared to enhance segmentation. By contrast, brief foveal presentations precluded segmentation, inducing the full masking effect regardless of spatial extent. Thus it appears that visual organization has a profound impact on early processes that determine contrast sensitivity.

Acknowledgment: This work was supported by funds from Smith Kettlewell Eye Research Institute

Object Recognition

2:00 - 3:30 pm

Hyatt Ballroom North

Moderator: Mary Bravo

2:00 *916* **Representation of possible and impossible objects in infancy.**

Sarah M. Shuwairi[1] (sms425@nyu.edu), Scott P. Johnson[1]; [1]New York University

The human visual system is well equipped to inform us about whether an image depicts a possible viewpoint of a structurally coherent 3-D object. Adult observers can readily classify simple 2-D line drawings as depicting "possible" or "impossible" 3-D objects. Our previous work demonstrated that 4-month-olds showed a strong novelty preference (i.e., significantly longer looking times) for impossible relative to possible object displays (Shuwairi et al., 2005). Therefore, the capacity to detect irregularities in global object structure is available early.To investigate the perceptual mechanisms that support this capacity, we recorded eye movements as 4-month-olds viewed structurally matched line drawings of possible and impossible cubes. We reasoned that infants would provide evidence of active comparison of specific local regions in which depth order of junction parts was reversed in impossible relative to possible object displays and that "critical regions" in impossible cubes would recruit increased visual attention.Dwell times were reliably longer within critical regions in impossible relative to possible cubes ($p < .01$). Within each impossible cube, dwell times were longer in the critical region inconsistent with global coherence relative to other regions ($p < .05$). These results further document the ability of young infants to discriminate between possible and impossible objects, and extend our initial findings by providing insights into the mechanisms responsible for the effect. By 4 months of age, infants allocate attentional resources appropriately to register critical junctions, compute local relative depth of surfaces, and represent global 3-D object coherence.

2:15 *917* **Using an interest point detector to find potential fragments for recognition**

Mary J Bravo[1] (mbravo@crab.rutgers.edu), Hany Farid[2]; [1]Rutgers-Camden, [2]Dartmouth College

Inspired by recent computer vision models for object recognition in clutter, we are developing a model of human object recognition based on local, distinctive fragments. The first stage of such models typically involves the selection of a large pool of potential image fragments using an interest point detector. In subsequent stages, this large pool is reduced to a smaller set of distinctive fragments. In developing a model for humans, our first step has been to determine whether the pool of fragments selected by the most common interest point detector, the Harris Detector (HD), includes the fragments humans find distinctive. Our test images were randomly rotated photographs of 12 common tools. We applied an HD to these images and collected fragments with a wide range of interest ratings. The scale of the HD determined the size of the fragments (8-pixel radius, 1-2% of the whole object). These fragments were then used as the stimuli in a recognition experiment. After a brief training period with whole tools, observers identified the tool fragments. Overall, observers were remarkably good at recognizing these tiny fragments. We then compared the recognition results with the interest ratings of the HD. Many fragments that were recognizable to observers were not given high interest ratings by the HD, which responds best to locations with large luminance gradients in multiple directions (e.g., corners). In addition to recognizing such frag-

ments, observers also recognized fragments with subtle or one-dimensional gradients.

2:30 *918* **Dissociating viewpoint costs in mental rotation and object recognition**

William G Hayward[1] (whayward@psy.cuhk.edu.hk), Guomei Zhou[2,3], Isabel Gauthier[4], Irina Harris[5]; [1]University of Hong Kong, [2]Chinese University of Hong Kong, [3]Chinese Academy of Sciences, [4]Vanderbilt University, [5]University of Sydney

In mental rotation, participants must determine whether two stimuli match when one undergoes a rotation in 3D space relative to the other. The key evidence for mental rotation is the finding of a linear increase in response times as objects are rotated further apart. This signature increase in response times is also found in recognition of rotated objects, which has led many theorists to postulate mental rotation as a key transformational procedure in object recognition. A number of recent studies, however, have reported inconsistencies between performance on mental rotation and object recognition tasks. These results led us to reexamine the similarity of viewpoint costs in mental rotation and object recognition. Following Gauthier et al. (2002), we conducted tasks which were identical except that mental rotation required a judgment of object handedness (whether it was mirror-reflected before rotation) whereas object recognition required an identity judgment. In each task, two stimuli were shown in succession, and might be rotated in depth by up to 165°. Mental rotation costs increased linearly with rotation, but object recognition costs increased only over small rotations, and then were reduced as rotations approached 165°. These results show that viewpoint costs can be dissociated between mental rotation and object recognition. When taken in conjunction with the brain-imaging results of Gauthier et al. (2002), our results suggest that whereas mental rotation requires internal 3-D rotations, object recognition requires feature matching of view-specific representations.

Acknowledgment: This research was supported by a grant (CUHK4260/03H) from the Hong Kong Research Grants Council

2:45 *919* **Magnocellular contributions to top-down-facilitation of object recognition**

Kestas Kveraga[1, 2] (kestas@nmr.mgh.harvard.edu), Jasmine Boshyan[1], Moshe Bar[1,2]; [1]Massachusetts General Hospital, [2]Harvard Medical School

Most research on object recognition has focused on hierarchical, bottom-up processing along the ventral visual stream. However, emerging evidence suggests that top-down processes play a key role in facilitating object recognition. A recently proposed model of such top-down facilitation posits that a coarse, low spatial frequency image of a stimulus is rapidly projected to the orbitofrontal cortex (OFC), where it activates a prediction about potential object matches (Bar, 2003). A subsequent top-down projection from the OFC to the inferior temporal cortex narrows the object search-space by biasing the bottom-up process toward the most likely representations. We predicted that these facilitatory projections would rely on the magnocellular (M) pathway, known to convey low spatial frequency information, compared with the complementary parvocellular (P) pathway. We studied humans with fMRI, using stimuli designed to engage the M or the P pathways selectively. The P stimuli were isoluminant, chromatic line drawings, and the M stimuli were luminance-defined, low-contrast drawings. We hypothesized that despite the greater visibility of the P stimuli, the M stimuli would be recognized faster, and activate the OFC more. Conversely, the P-biased stimuli would require more processing in the inferior temporal cortex because of the lack of top-down facilitation. Our results support these predictions, in that the M stimuli resulted in shorter recognition times and greater activity in the OFC compared with the P stimuli. These findings lend strong support to the top-down facilitation model by showing that magnocellular projections play a critical role in triggering top-down facilitation of object recognition.

Acknowledgment: This research was Supported by the James S. McDonnell Foundation 21st Century Science Research Award in Bridging Brain, Mind and Behavior #21002039, NINDS R01 NS044319 and NS050615, NCRR P41RR14075, and the MIND Institute.

3:00 *920* **A tale of two agnosias: functional differences between integrative and visual form agnosia.**

M. Jane Riddoch[1] (M.J.Riddoch@bham.ac.uk), Glyn W. Humphreys[1], Martyn Bracewell[1]; [1]University of Birmingham, Birmingham B15 2TT UK

The performance of two patients with visual agnosia is compared across a number of tests examining visual processing. The patients are distinguished by having dorsal and ventral extrastriate lesions. Clear differences emerge such that inanimate objects are disadvantaged for the patient with a dorsal extrastriate lesion, while animate items are disadvantaged for the patient with the ventral extrastriate lesion. The patients also show contrasting patterns of performance on the Navon Test: the patient with a dorsal extrastriate lesion processing at a local level while the patient with a ventral extrastriaite lesion processing at a global level. We propose that the dorsal and ventral visual pathways may be characterised at an extra-striate level by the differences in local relative to more global visual processing, and that this can link to visually-based category-specific deficits in processing.

3:15 *921* **Effects of spatiotemporal object continuity on repetition attenuation in human fusiform gyrus**

Do-Joon Yi[1] (dojoon.yi@yale.edu), Nicholas B. Turk-Browne[1], Jonathan I. Flombaum[1], Brian J. Scholl[1], Marvin M. Chun[1]; [1]Department of Psychology, Yale University, New Haven, CT, USA.

A central task in vision is to represent objects as the same persisting individuals even through visual interruptions such as occlusion. Previous research in several areas of cognitive science has identified a powerful principle in such processing: objects must trace continuous paths through space and time. Here, we report novel fMRI evidence for the neural consequences of spatiotemporally continuous vs. discontinuous motion. We measured fMRI adaptation to reveal whether the fusiform face area treats two faces as the same or different (Grill-Spector et al., 1999; Kourtzi & Kanwisher, 2001). The initial display on each trial contained two vertical columns spanning fixation. One face appeared from behind a column, moved to fixation, turned back, and disappeared behind the original column. Immediately afterwards, a second (same or different) face made a similar movement from either the same column (which would be consistent with its being the same reappearing object) or the other column (which would necessarily be a new object, even if it was featurally identical). We hypothesized that two identical faces from the same column would be treated as the same persisting object, resulting in fMRI adaptation. In contrast, we predicted that two identical faces from different columns would be treated as separate objects, reducing fMRI adaptation. Significant fMRI adaptation occurred only when two identical faces were linked as a single object via spatiotemporal continuity. These results provide a novel demonstration of how spatiotemporal cues to object persistence can influence neural processing of object identity in mid-level visual cortical areas.

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Binocular Rivalry

2:00 - 3:30 pm

Hyatt Ballroom South

Moderator: Sheng He

2:00 *922* BINOCULAR RIVALRY BETWEEN TWO INDUCED COLORS

SANG WOOK HONG[1] (swhong@uchicago.edu), STEVEN K. SHEVELL[1]; [1]Visual Science Laboratories, University of Chicago

PURPOSE: An open question in color rivalry is whether alternation between the two colors is caused by a difference in receptoral stimulation or a difference in the neural representation of color appearance. This question was examined with binocular rivalry between physically identical lights that differed in appearance due to chromatic induction. METHODS: Perceptual alternation was measured between gratings of the same chromaticity, presented on patterned inducing backgrounds. The patterned inducing backgrounds caused the gratings, one to each eye, to appear different in color because of chromatic induction. The gratings were dichoptically presented with binocular disparity so the grating appeared in front of the background. In a control condition, perceptual alternation was measured between two physically different chromaticities on a uniform equal-energy-white background. These chromaticities matched the appearance of the identical gratings on their patterned inducing backgrounds. RESULTS: Perceptual alternation was found for the two physically identical chromaticities that appeared different due to chromatic induction. Stereoscopic depth was also perceived, indicating binocular neural combination despite color rivalry (cf. Treisman, 1962). DISCUSSION: These results show that color rivalry is resolved after color appearance is affected by chromatic context. Thus color rivalry does not require competing unequal cone excitations; the results suggest rivalry depends on the neural representation of color appearance. Further, color rivalry within a grating that appears in a different depth plane than the background corroborates separate processing of color and stereoscopic depth, with subsequent neural binding.

Acknowledgment: Supported by NIH grant EY-04802.

2:15 *923* STEREOSCOPIC DEPTH DURING BINOCULAR RIVALRY

Timothy J. Andrews[1] (t.andrews@psych.york.ac.uk); [1]Department of Psychology, University of York, York YO10 5DD

The mechanism underlying binocular single vision is generally thought to involve a unification of information from each eye into a common stream that eventually leads to perception. However, the phenomenon of binocular rivalry shows that binocular vision does not always involve integration of the two eye views. One explanation for how the visual system deals with monocular signals in such different ways is that rivalry only occurs when binocular correspondence cannot be solved. A prediction of this model is that stereopsis should not be possible during binocular rivalry. In this study, subjects viewed a stimulus comprised of three vertically arranged grating patches. The top and bottom patches were given equal and opposite horizontal disparities such that one or other was in front of fixation during the stereo presentation. The grating patches in the two eyes differed in their spatial frequency, spatial phase, orientation or direction-of-motion. The task of the subjects was to press a button to indicate which grating patch (top or bottom) was closest. Immediately after their stereo judgment, subjects were asked to indicate the perceptual appearance of the gratings. The results show that stereopsis is possible even when the form from one eye is suppressed from awareness during binocular rivalry. These findings are consistent with the idea that the integration of information from the two eyes can occur independently for different aspects of vision.

2:30 *924* Successive rivalry does not occur without attention

Patrick Cavanagh[1] (patrick@wjh.harvard.edu), Alex O. Holcombe[2]; [1]Harvard University, [2]Cardiff University

The role of attention in rivalry remains controversial (Mitchell et al, 2004; Meng &Tong 2004; Paffen et al, 2005). To test whether rivalry can occur without attention, we used an array of 8 rivaling gratings, each flickering out of phase between eyes to create successive rivalry (at 3 to 4 Hz, O'Shea & Crassini, 1984), arranged in a circle around a central fixation point. In a control condition, observers reported 1) changes in dominance when attending to a single patch and 2) the pattern of dominance across multiple patches attended at the same time. Result: approximately equal dominance durations of the two rivaling patterns and an absence of any obvious synchrony across patches. However, moving attention rapidly from one patch to the next around the array (guided by a pointer) gave a completely different outcome. Alternation slowed or stopped entirely and one or the other pattern was strongly dominant (average of 90% of the time). If rivalry was occurring on the unattended locations, then the dominance of each location would be sampled by attention and should show relatively random alternation from location to location. This would be true even if the alternation at each patch had stopped in the absence of attention, leaving the dominance frozen on one pattern or the other. These results suggest that the mutual inhibition underlying rivalry (at least of the successive variety) does not occur in the absence of attention. The competing patterns have not just stopped alternating, they have stopped competing.

2:45 *925* Invisible images can influence saccadic eye movements

Chengzhi Feng[1,2] (psyfeng@gmail.com), Yi Jiang[2], Sheng He[2]; [1]Department of Psychology, Soochow University, 50 Donghuan Rd., Suzhou, China 215021, [2]Department of Psychology, University of Minnesota, 75 E. River Rd., Minneapolis, MN 55455

We recently demonstrated that visual information rendered invisible through interocular suppression could still guide the distribution of spatial attention (Jiang et al., VSS 2005). In the current study, we further investigated whether invisible information could influence the direction of saccadic eye movements. Two images, one intact and one scrambled, were presented to the left and the right side of a fixation point. However, this pair of images was only presented to the observers' non-dominant eye while high contrast dynamic random Mondrian patterns were presented to their dominant eye at corresponding retinal locations. Identical Mondrian patterns were presented on both sides of the fixation point and remained dominant throughout each trial so that observers were completely unaware of which side of the fixation point received the intact test image. Images with different levels of valence (e.g., erotic images, emotional and neutral faces) were used as test stimuli. We recorded the position and movement of the suppressed eye while observers viewed the dichoptic visual stimuli. Even though observers were not aware of which side the intact image was located, their eyes were more likely to move towards the side containing the intact image. The influence on eye movements was stronger for erotic pictures than for emotional faces, with neutral faces generating the weakest effect. Apparently, pictures with high arousal value, even when invisible, were still effective in attracting saccadic eye movements towards them. The results suggest that eye movements, as well as visual spatial attention, are influenced by invisible information.

Acknowledgment: This research was supported by an award from the James S. McDonnell foundation and a National Institutes of Health Grant R01 EY015261-01.

3:00 *926* **Minimal Physiological Conditions for Binocular Rivalry**

Hugh R. Wilson[1] (hrwilson@yorku.ca); [1]Centre for Vision Research, York University, Toronto, Canada

Binocular rivalry entails a perceptual alternation between incompatible stimuli presented to the two eyes. A minimal explanation for binocular rivalry involves strong competitive inhibition between neurons responding to different monocular stimuli to preclude simultaneous activity in the two groups. In addition, strong self-adaptation of dominant neurons is necessary to enable suppressed neurons to become dominant in turn. Here a minimal nonlinear neural model is developed incorporating inhibition, self-adaptation, and recurrent excitation. The model permits derivation of an equation for mean dominance duration as a function of the underlying physiological variables. This dominance duration equation incorporates an explicit representation of Levelt's second law. The same equation also shows that introduction of a simple compressive neuronal response nonlinearity can explain Levelt's fourth law. Finally, the model generates a simple form of perceptual memory with properties related to rivalry memory.

Acknowledgment: Supported in part by NSERC

3:15 *927* **Cross-orientation suppression occurs before binocular summation: Evidence from masking and adaptation.**

Daniel H Baker[1] (bakerdh@aston.ac.uk), Tim S Meese[1]; [1]School of Life and Health Sciences, Aston University, Birmingham, B4 7ET, UK

The threshold elevation produced by a grating mask with very dissimilar orientation from a target is sometimes called cross-orientation suppression (XOS). Once thought to be a single process within visual cortex, recent single-cell studies suggest earlier processes specific to eye of origin (e.g. Li et al. 2005, J Neurophysiol, 94(2), 1645-1650). Here, we investigate interocular XOS psychophysically using 1c/deg horizontal test gratings and cross-oriented masks. Masking functions for monoptic and dichoptic masks did not superimpose when plotted against contrast (0%-45%@200ms; Experiment 1) or duration (25-400ms@45%; Experiment 2). For example, monoptic XOS decreased and dichoptic XOS increased, as functions of duration. These results reject models in which XOS occurs only after binocular summation because such models predict that dichoptic and monoptic masking are identical. An unexpected finding was that a monoptic + dichoptic mask condition produced less masking than the dichoptic mask alone, suggesting interocular suppression of the mask components prior to dichoptic XOS. In Experiment 3, we found that dichoptic, but not monoptic, masking was reduced by adapting to the mask, consistent with cat physiology and a cortical locus for dichoptic masking. We propose a quantitative model of all our data where XOS is: (i) non-adaptable (and possibly precortical) for the monoptic case and (ii) adaptable (and presumably cortical) for the dichoptic case. This model also explains the finding that binocular XOS does not adapt (Foley & Chen, 1997, Vis Res, 37(19), 2779-2788) because in that condition, the adaptable contribution to XOS is negligible due to the interocular suppression described above.

Acknowledgment: Supported by EPSRC Grant Reference: GR/S74515/01

Attention: Neural Mechanisms and Models

4:30 - 6:00 pm

Hyatt Ballroom North

Moderator: Andrew Rossi

4:30 *928* **THE ROLE OF MT AND THE PARIETAL LOBE IN VISUAL TRACKING STUDIED WITH TRANSCRANIAL MAGNETIC STIMULATION**

Lorella Battelli[1,2] (Battelli@wjh.harvard.edu), George Alvarez[3], Thomas Carlson[4,2], Alvaro Pascual-Leone[1]; [1]Laboratory for Non-Invasive Brain Stimulation, Beth Israel Hospital, Boston, MA USA, [2]Department of Psychology, Harvard University, MA, USA, [3]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [4]Helmholtz Institute, Psychonomics Division, Universiteit Utrecht, The Netherlands

Recent psychophysical and patient work suggests there are independent attentive tracking systems for the left and right visual hemifields. Although neuroimaging has identified cortical regions involved in tracking (e.g., MT and IPS), it remains unclear how these areas contribute to the hemifield effects observed in psychophysical and patient studies. To address this issue, we used fMRI to localize area MT and the area of parietal cortex that is active during tracking (IPS), then used 1Hz repetitive transcranial magnetic stimulation (rTMS) to temporarily suppress activity in area MT or in IPS while observers tracked moving objects. Method: 8 discs moved around (4 in each hemifield). In the unilateral condition, observers tracked 2 items on the left or 2 items on the right. In the bilateral condition, observers tracked 4 items (2 left and 2 right). Unilateral Results: Following rTMS to either MT or IPS, tracking accuracy was relatively worse for targets in the contralateral hemifield than for targets in the ipsilateral hemifield. Bilateral Results: Following rTMS to IPS, the pattern of results was in the same direction as in unilateral condition, but the difference was larger. However, following rTMS to MT, accuracy was greater in the contralateral hemisphere than in the ipsilateral hemisphere. Conclusion: At least two areas within the network underlying attentive tracking (IPS and MT) show robust hemifield effects. Moreover, area MT and IPS are differently involved in tracking; there was a dramatic, qualitative difference between unilateral and bilateral conditions for MT, but only a magnitude difference for IPS.

Acknowledgment: supported by NEI EY15960 to LB

4:45 *929* **Deficits in Covert Attention After Temporary Inactivation of Macaque Frontal Eye Field**

Robert M. McPeek[1] (rmm@ski.org), Naomi Takahashi[1]; [1]The Smith-Kettlewell Eye Research Institute

The pre-motor theory of attention posits that oculomotor regions like the frontal eye field (FEF) are involved in shifts of attention, as well as eye movements. This idea has gained support from behavioral and neuroimaging studies in humans, as well as from microstimulation and recording experiments in monkeys. We reasoned that if the FEF is involved in controlling covert attention shifts, then performance in an attentionally-demanding task should be selectively impaired following FEF inactivation. To test this, we trained monkeys to discriminate the orientation of a briefly-presented target stimulus during fixation. Performance was measured before and after temporary muscimol inactivation of the FEF. In some experiments, the attentional load of the task was manipulated by presenting the discrimination target either alone (low load condition) or with distractors (high load condition). In other experiments, the target was always presented with distractors, and we used valid and invalid spatial precues to manipulate attention. After FEF inactivation, when the discrimination target was presented at the location corresponding to the injection

site, performance was impaired in the high attentional load condition, but not in the low load condition. Furthermore, the effectiveness of spatial precues was reduced when the precues were presented in the inactivated field, but not elsewhere. Control experiments show that these effects are not due to simple sensory or motor impairments. Thus, our results indicate that, in addition to its role in controlling eye movements, the FEF plays an important functional role in controlling covert shifts of spatial attention.

Acknowledgment: Supported by NIH R01-EY014885

5:00 *930* Bridging the Gap Between Monkey and Man: Macaque Event-Related Potentials Reveal Similarities to Human Indices of Visual Attention

Geoffrey F. Woodman[1] (geoff.woodman@vanderbilt.edu), Min-Suk Kang[1], Andrew F. Rossi[1], Jeffrey D. Schall[1]; [1]Vanderbilt University, Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt Center for Integrative & Cognitive Neuroscience

Nearly a half-century's worth of research has established the existence of a number of human event-related potential (ERP) components that measure a host of different operation during visual cognition. Surprisingly, almost nothing is known about whether nonhuman primates exhibit such electrophysiological signatures of cognition. We report findings from a new technique for recording ERPs from macaque monkeys. During visual search monkeys exhibit ERP components corresponding to those described in human studies. These include several early visual components sensitive to sensory processing demands and attention-directing lateralizations similar to the human N2pc. These findings serve to bridge the gap between the disparate literatures using electrophysiological measurements to study visual processing in the brains of humans and nonhuman primates.

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5:15 *931* NEURAL DECODING OF SEEN AND ATTENDED MOTION DIRECTIONS FROM HUMAN CORTICAL ACTIVITY

Frank Tong[1] (frank.tong@vanderbilt.edu), Yukiyasu Kamitani[2]; [1]Psychology Department, Vanderbilt University, Nashville, TN, USA, [2]ATR Computational Neuroscience, Kyoto, Japan

In recent fMRI studies, we have shown that ensemble activity in human visual cortex contains robust information that allows for accurate decoding of seen and attended visual orientations (Kamitani & Tong, Nature Neuroscience, 2005). By pooling weak feature-selective information from many voxels, we can obtain robust measures of ensemble feature selectivity. Here, we investigated whether ensemble activity patterns in human visual areas contain reliable information about seen and attended motion directions. fMRI activity was monitored while subjects viewed random dots drifting in 1 of 8 directions. A linear decoder was trained to classify activity patterns induced by different motion directions, then tested on independent test data. Ensemble activity from individual areas (V1-V4, MT+) led to reliable decoding of seen motion direction. In comparison, orientation-decoding performance was highly precise for V1 and V2 but at chance level for MT+. Next, we tested if it is possible to decode which of two overlapping motion directions is the focus of the subject's attention. The decoder was trained on single motion directions (clockwise or counterclockwise), then tested with ambiguous displays containing both overlapping directions while subjects performed a speed discrimination task on one of the two sets of moving dots. Direction-selective ensemble activity from all visual areas was reliably biased towards the attended motion direction, and reliable for individual areas V1, V2, and MT+. Our results indicate that human visual areas are sensitive to different motion directions, and their activity can be reliably biased by feature-based attention.

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5:30 *932* Bottom-up visual attention to salient proto-object regions

Christof Koch[1] (koch@klab.caltech.edu), Dirk Walther[1]; [1]Computation and Neural Systems Program, 216-76 California Institute of Technology, Pasadena, CA, 91125, USA

Perceiving natural scenes with multiple objects presents a serious challenge to any visual system. Selective visual attention provides a mechanism for serializing the visual information in order to perceive one object at a time. If no prior knowledge or expectation about the scene is available, attention will be guided from the bottom up by salient image features, computed from low-level image properties. In previous models of saliency-based visual attention from our lab (Koch & Ullman 1985; Itti, Koch & Niebur 1998), attention was guided to salient image locations by a winner-take-all (WTA) neural network operating on a saliency map. However, in order to effectively attend to objects one at a time, it is necessary to know their approximate size and extent before they are recognized. We developed a new version of our model that estimates the approximate extent of attended proto-objects. After computing the saliency map and the most salient location, feedback connections in the hierarchy of maps leading to the saliency map identify the most salient feature at the attended location. The corresponding feature map is segmented around that location using a network of linear threshold units. Our model performs well on natural images, and we present results of successfully using the model to learn and recognize individual objects in highly cluttered scenes. The entire saliency code is available to the community as a Matlab toolbox (http://www.saliencytoolbox.net).

URL: http://www.saliencytoolbox.net

5:45 *933* Feature congestion: A measure of visual clutter

Ruth Rosenholtz[1] (rruth@mit.edu), Yuanzhen Li[1], Zhenlan Jin[2], Jonathan Mansfield[1]; [1]Dept. of Brain & Cognitive Sciences, MIT, Cambridge, MA, USA, [2]Dept. of Psychology, Northeastern University, Boston, MA, USA

Visual clutter concerns designers of user interfaces and information visualizations. This should not surprise visual perception researchers, since excess and/or disorganized display items can cause crowding, masking, decreased recognition performance due to occlusion, greater difficulty at both segmenting a scene and performing visual search, and so on. Given a reliable measure of the visual clutter in a display, designers could optimize display clutter. Furthermore, a measure of visual clutter could help generalize models like Guided Search (Wolfe, 1994) by providing a substitute for "set size" more easily computable on more complex and natural imagery. We present a first cut of a measure of visual clutter (Rosenholtz et al, SIGCHI 2005), which operates on arbitrary images as input. This Feature Congestion measure of visual clutter is based on the analogy that a display or scene is more cluttered the more difficult it would be to add a new item which would reliably draw attention. Our Statistical Saliency Model for visual search suggests that this difficulty is proportional, locally, to the covariance of certain key features. We demonstrate that this measure correlates well with subjective assessments of visual clutter for a wide range of stimuli, and also that it correlates well with search performance in complex imagery, particularly on target-absent trials. This includes the search-in-clutter displays of Wolfe et al (2002) and Bravo & Farid (2004). We explore the use of this measure as a stand-in for setsize in visual search models.

Acknowledgment: Supported by ONR Grant N00014-01-1-0625, and NSF Grant BCS-0518157

URL: http://web.mit.edu/rruth/www/Papers/RosenholtzEtAlCHI2005Clutter.pdf

Binocular Vision/Stereopsis

4:30 - 6:00 pm

Hyatt Ballroom South

Moderator: Paul Hibbard

4:30 *934* **Is the Disparity-gradient Limit a Byproduct of Local Cross Correlation?**

Heather R Filippini[1] (hrose@berkeley.edu), Martin S Banks[2,3]; [1]Department of Bioengineering, UC Berkeley, CA, USA, [2]Vision Science Program, UC Berkeley, CA, USA, [3]School of Optometry, UC Berkeley, CA, USA

The visual system can estimate binocular disparity in a wide variety of viewing situations. Disparity estimation breaks down, however, when the disparity gradient (the rate at which disparity changes with changes in spatial position) is high. This breakdown has been called the disparity-gradient limit. There is considerable physiological and psychophysical evidence that disparity estimation is done by computing local correlations between the two eyes' images. When the two eyes' images are quite different, as they are when the disparity gradient is high, local correlation becomes low. We investigated the possibility that the disparity-gradient limit is a byproduct of estimating disparity by local cross-correlation. We examined observers' ability to extract a disparity signal as a function of the disparity gradient and compared that to the performance of a local cross-correlator. The stimulus was a disparity-defined sawtooth grating presented in a volume of noise elements. Observers indicated whether the relative phase of the grating stimulus was -90 or 90 deg. Threshold was defined by the proportion of noise that yielded 71% correct performance. We also varied the stimulus distance, which changes the perceived slant but not the disparity gradient. Variation in threshold was systematically related to the disparity gradient and not to spatial frequency, disparity amplitude, or perceived slant. The model exhibited the same behavior as observers. Correctly creating vertical disparities in the stimulus had little effect on the results. We conclude that the disparity-gradient limit is a consequence of estimating disparity by local cross-correlation.

Acknowledgment: NIH EY12851

4:45 *935* **A New Slant on Orientation Disparity: Evaluating Orientation Disparity as a Cue for 3D Surface Slant Perception**

Hal S. Greenwald[1] (hgreenwald@bcs.rochester.edu), David C. Knill[1]; [1]Center for Visual Science, University of Rochester

Purpose. We quantified the information provided by the outputs of biologically-plausible mechanisms sensitive to orientation disparity to determine the usefulness of this cue for estimating surface slant. **Method.** Using a modified disparity energy model tuned to orientation disparity, we computed responses to simulated surfaces textured with random mean-vertical or broadband noise and slanted away from the viewer about the horizontal axis. Based on the responses of our cell population, we estimated the slant of each surface using a Naïve Bayes decoder that compared the mean response levels with expected activity based on distributions for surfaces at a wide range of slants, and we compared this performance to estimates of the separability of different slants using linear discriminant analysis with gradient descent. To verify that the information used in the estimates were based on orientation disparity and not purely local orientation, we repeated the Naïve Bayes analysis using an energy model with monocular input. **Results.** The Naïve Bayes estimator and the linear discriminant analysis produced similar results with standard deviations ranging from 2-6 degrees, which is within the range of normal acuity for slant from stereo. The estimates from the monocular control were uninformative for the broadband noise textures and produced standard deviations that were more than 4 times larger for the oriented noise textures, indicating that the information was carried by orientation disparity. **Conclusion.** Given the performance of our model, orientation disparity appears to be a plausible source of information for estimating 3D surface orientation.

5:00 *936* **On seeing transparent surfaces in stereoscopic displays**

Inna Tsirlin[1] (inna@cs.yorku.ca), Robert S. Allison[1], Laurie M. Wilcox[1]; [1]York University, Toronto, Canada

Transparency presents an extreme challenge to stereoscopic correspondence and surface interpolation, particularly in the case of multiple transparent surfaces in the same visual direction. In this experiment we manipulate density, separation in depth, and number of transparent planes within a single experimental design, to evaluate the constraints on stereoscopic transparency. We use a novel task involving identification of patterned planes among the planes constituting the stimulus. The results show that, under these conditions, (1) subjects are able to perceive up to five transparent surfaces concurrently; (2) the transparency percept is impaired by increasing the texture density; (3) the transparency percept is initially enhanced by increasing the disparity between the surfaces; (4) the percept begins to degrade as disparity between surfaces is further increased beyond an optimal disparity, which is a function of element density. Specifically, at higher texture densities the optimal disparity shifts to smaller values. This interaction between disparity and texture density is surprising, but it can account for discrepancies in the existing literature. We are currently testing extended correlational and feature-based models of stereopsis with our stimuli. This will provide insight into our psychophysical results and a basis for quantitative evaluation of existing computational models.

5:15 *937* **Cooperative processing of spatially distributed disparity signals in macaque V1**

Jason M. Samonds[1] (samondjm@cnbc.cmu.edu), Brian Potetz[1], Tai Sing Lee[1]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA

Although there has been substantial progress in understanding the neurophysiological mechanisms of stereopsis, many questions remain about how the brain solves the correspondence problem. To gain insight into how horizontal disparity signals are spatially integrated and might solve the correspondence problem, we simultaneously recorded from multiple neurons in V1 of awake, alert macaques while displaying dynamic random dot stereograms. Physical distances between neurons ranged from 1 to over 3 mm, and receptive field separation ranged from partially overlapping to 2°. We quantified the functional connectivity among neurons using the correlation coefficient integrated from normalized cross-correlograms for ±25 ms lag times. The functional connectivity between disparity tuned neurons depended on the disparity of the stimulus. The tuning based on functional connectivity was narrower and more robust than predicted by the independent firing rate tuning curves. To determine how disparity estimates might improve over time (i.e., coarse-to-fine), we examined the temporal evolution of disparity tuning. We found that the firing rate-based disparity tuning was initially very broad. The functional connectivity-based disparity tuning emerged shortly after and was much narrower. Functional connectivity continued to strengthen as the firing rate tuning became sharper. Our results suggest that a coarse-to-fine mechanism likely interacts with, and may even arise from, cooperative processing that allows the brain to converge to a correspondence solution.

Acknowledgment: Supported by NIMH IBSC MH64445 and NSF CISE IIS-0413211 grants

5:30 *938* **An Early Gain-Control Mechanism in Binocular Combination**

George Sperling[1] (sperling@uci.edu), Jian Ding[1]; [1]Department of Cognitive Sciences, University of California, Irvine CA 92697-5100 USA

To measure each eye's individual contribution to a binocularly perceived

(cyclopean) image, we present a horizontal sinewave grating in a different phase to each eye. The perceived phase of the cyclopean grating defines the relative contributions. These perceived phase data are encapsulated by a gain-contol model in which each eye exerts gain control on the other eye, and additionally gain control on the other eye's gain control (Ding and Sperling, Proc. Natl. Acad. Sciences, in press). Here we define the gain control by masking experiments. Temporal masking. Adding a moving sinewave to one eye's image, increased the masked eye's contribution to the cyclopean image equally for frequencies less than about 15 Hz, then less with increasing frequency. When bandpass-filtered noise was added to the one eye's grating, the more noise, the greater the relative contribution of the noisy eye. The most efficient masking noise was 4x higher in spatial frequency than the sinewave being judged. Similar results were obtained with perpendicular masking gratings as a function of spatial frequency. Barely visible masked gratings completely dominate clearly visible gratings of equal contrast. The masking stimulus perturbs the masked eye's contents but exerts gain control on the other eye. Masking as a function of the orientation angle of masking gratings was tested with 8x higher-spatial-frequency gratings. Effectiveness was somewhat greater for both vertical and horizontal gratings than for diagonal orientations. This orientation selectivity of masking indicates that at least some of the interocular gain control is of cortical (versus LGN) origin.

Acknowledgment: Air Force Office of Scientific Research, Life Sciences, Grant FA9550-04-1-0225

5:45 *939* Binocular energy responses to natural images

Paul B Hibbard[1] (pbh2@st-andrews.ac.uk), Samira Bouzit[1]; [1]School of Psychology, University of St Andrews, UK

The responses of many binocular cells in the primary visual cortex are well described by the binocular energy model (Fleet et al., 1996). If we are to understand how these cells encode and interpret the binocular information in natural images, it is important to consider how they respond to such images. We therefore analysed the responses of the binocular energy model to a collection of natural, binocular images, that were taken with a pair of digital cameras with an inter-camera distance of 6.5 cm. Images were either indoor "still-lifes" or outdoor scenes. The responses of model binocular energy units to these stimuli were computed. Responses were calculated over a range of spatial frequencies and orientations, for units that encoded binocular disparity via positional shifts in their receptive fields. The results show (i) a strong peak in responses for disparities around zero for locations close to fixation; (ii) a rapid broadening of the response distribution with increasing eccentricity; (iii) responses that are much more tightly tuned around zero for vertical than for horizontal disparity and (iv) marked differences in responses to indoor and outdoor scenes. These results are consistent with physiological and psychophysical studies of disparity encoding (Prince et al, 2002; Cumming, 2002; Ogle, 1950). They also show that a coarse estimate of distance may be obtained from the responses of a population of binocular neurons, without needing to scale disparities, or even to solve the correspondence problem.

Acknowledgment: funded by EPSRC grant GR/S22585/01 to PBH

Poster Session I

Tuesday, May 9, 2006

Contextual, Associative, Statistical Learning Effects (941-951), Binocular Rivalry (952-964), Action Effects on Perception (965-972), Eye Movement Effects on Perception and Action (973-979), Face Perception: Adaptation and Aftereffects (980-991), Neural Coding, Cortical Receptive Fields (992-1005), Spatial Vision: Adaptation and Illusions, (1006-1012), Gaze/Reference Frames (1013-1024, 102)

Poster Session: 8:00 - 11:00 am ***Municipal Auditorium***
Author presents: 9:45 - 10:45 am

Contextual, Associative, Statistical Learning Effects

940 Abstract withdrawn.

I1 *941* Learning predictive cues to optimize visual search

Jason A Droll[1] (droll@psych.ucsb.edu), Binh T Pham[1], Craig K Abbey[1], Miguel P Eckstein[1]; [1]Dept. of Psychology, University of California Santa Barbara

Observers performing visual search tasks that require both detection and localization of a target often show improved performance as the experiment progresses, especially when the target is accompanied by a predictive cue. Is this increase in performance due to a general improvement in signal encoding, or a re-weighting of visual information with respect to each cue? Twelve subjects performed 300 trials in which they searched for a bright target among dimmer distractors with contrast noise (mean 110 and 60, stdev. 20), displayed for 2s. Each of the six stimuli was surrounded by a colored circle. Subjects were told that some colors were more likely to contain the target, although the distribution of this likelihood was not specified. Subjects reported the presence and location of the target. Performance in the perceptual task improved by the final quarter of trials and accompanied a change in gaze strategy. By the final quarter of trials, first saccades most frequently targeted predictive cues (24% vs. 13%), and had longer fixation duration (348ms vs 243ms), even on trials when no target was in fact present. False alarm trials for perceptual decisions and first saccades also suggested that localization was most affected by the noise in valid cues. However, this learning was suboptimal when compared to an ideal Bayesian learner model exposed to similar cue statistics. We conclude that visual-saccadic and perceptual decisions during search may be influenced by learned statistics of cue validity, allowing observers to more optimally weight sensory evidence when seeking relevant information.

Acknowledgment: Supported by NIHEY grant 015925

I2 *942* Decomposing the effect of contextual priors in visual search: Where does thetime go?

Barbara Hidalgo-Sotelo[1] (bhs@mit.edu), Aude Oliva[1]; [1]Department of Brain and Cognitive Sciences, MIT

Among the many visual searches we perform daily, often the same environment issearched for the same item multiple times. Contextual cueing research has shownthat repeated configurations facilitate attentional guidance toward the target(Chun & Jiang 1998). We investigated the influence of contextual priors inguiding visual search by monitoring eye movements as participants searchfamiliar real-world scenes. The level of search difficulty was either easy(target visible within a glance) or difficult (target requiring foveation).Additionally, we manipulated the expectation of target presence in a givenscene. One group of subjects established strong contextual priors: the targetwould always be present or always absent. A second group established weakerpriors: a given scene was presented with the target present only 50% of thetime. After twenty epochs of search, reaction times in the strong contextualprior group improved by 280 ms, while the weak prior group improved by only 190ms. A decomposition of reaction times shows this improvement is found in twostages. First, the scan time to fixate the target is decreased, implying afaster exploration stage. Second, the time spent fixating the target beforeresponse (gaze duration) also decreases. Interestingly, the magnitude of scantime improvement was the same for both groups. The remaining RT improvement inthe strong prior group is entirely manifested in decreased gaze duration. Theseresults demonstrate experience-dependent influences at different stages ofvisual search and have implications for models of context-dependent sceneprocessing.

Acknowledgment: This work is supported by a NSF graduate fellowship to B.H.S

I3 *943* Gaze Patterns in Search Reflect Learnt Environmental Probabilities and Rewards

Krista M Gigone[1] (kgigone@bcs.rochester.edu), Jason A Droll[1,2], Mary M Hayhoe[1]; [1]University of Rochester, [2]University of California, Santa Barbara

Given attentional limitations and the dynamic nature of many scenes, strategic gaze direction may often be necessary to acquire needed information. Neural recordings have indicated that saccadic eye movement circuitry is sensitive to both stimulus probability and reward magnitude. We investigated the influences of these variables on strategic gaze allocation in visual search. Subjects searched an array of abstract objects for a change in orientation across successive frames while statistics of object changes and reward magnitude were manipulated. In one condition, we manipulated the probability that each object would change across all trials while keeping reward magnitude constant across all objects. As the experiment progressed, fixations became distributed among the objects in proportion to their relative probabilities of change. Total fixation durations to the highest-posterior objects (1063ms) were longer than those to the lowest-posterior objects (607ms), even on trials when these objects were not changing. The utility of this strategy is reflected in the faster reaction times on trials in which objects with higher change probabilities were identified as changing (642ms vs. 817ms). In a second condition, the probability of each object changing was held constant and the reward magnitude for detecting changes to each object was varied. As the experiment progressed, subjects learned to select objects that gave them greater rewards more often than objects with the same probability of changing but lower point values. Such sophisticated exploitation of environmental probabilities and rewards suggests that gaze allocation is governed by learnt models of the probabilistic structure of the environment.

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I4 *944* Implicit learning of base rate information in change detection occurs for location but not identity

Melissa R Beck[1] (mbeck1@gmu.edu), Bonnie L Angelone[2], Daniel T Levin[3], Matthew S Peterson[4], D. Alexander Varakin[3]; [1]Naval Research Laboratory, [2]Rowan University, [3]Vanderbilt University, [4]George Mason University, [5]Vanderbilt University

Previous research using visual search tasks and target localization tasks demonstrates that the visual system can implicitly learn base rate information and then use this information to guide visual attention. Recent findings showing that changes with a high base rate are detected more readily than low base rate changes suggests that this ability may apply to change detection tasks as well. We examined the possibility that change probabilities can be implicitly learned while completing a change detection task and then used to improve change detection performance. Participants completed 120 training trials during which one of six shapes changed color. In the shape condition, the shape that changed color was the same identity on every trial. In the location condition, the shape that changed color was always in the same location. Ability to learn and use this change regularity information was examined with 24 test trials in which changes occurred in the trained location or shape on 12 trials and the untrained locations or shapes for the remaining 12 trials. In the shape condition, change detection performance for the trained shape was not different from performance on the untrained shapes. In the location condition, change detection performance was better for the trained location than the untrained locations. Post-experiment questionnaires revealed that participants did not have explicit knowledge of the trained change probability for the shape or the location conditions. These results indicate that implicit acquisition of change probability information occurs for location but not identity.

I5 *945* When the unconscious shows the way:the neural basis of contextual cueing revealed in MEG

Maximilien Chaumon[1] (chaumon@chups.jussieu.fr), Valérie Drouet[1], Catherine Tallon-Baudry[1]; [1]Laboratoire de neurosciences cognitives et imagerie cérébrale, CNRS UPR 640, Paris, France

In visual search tasks, a target is detected faster when repeatedly presented within a particular context of distractors. Contextual cueing (Chun & Jiang 1998) shows that our brain keeps trace of previously encountered visual scenes with a high-capacity memory. Formed in a few trials, this memory can be used to guide attention and does not lead to any conscious knowledge. These findings challenge our understanding of the neural mechanisms of memory, attention and consciousness: how can a long-lasting neural memory be acquired in a few stimulus presentations? What are the neural mechanisms of this unconscious guidance of attention?To investigate these issues, we recorded magneto-encephalographic (MEG) data in normal subjects performing a modified version of the contextual cueing paradigm. In our predictive condition each context is repeatedly associated with a single position of the target. In the non predictive condition, each context is associated on successive presentations with each possible position of the target. Therefore controlling for repetition effects, all contexts were repeated an equal number of times in our experiment. Reaction times were shorter in the predictive condition and this facilitation was implicit. We analyzed the acquisition of contextual associations during the first presentations and how these associations guide attention during the last presentations. Analysis of evoked fields shows that unconscious knowledge about the spatial regularities in vision can influence our perception within 110 ms after stimulus presentation. Further analysis of evoked and induced responses and their localization should help understand the brain mechanisms involved in unconscious influences on visual perception.

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I6 *946* What is learned in ignored visual context?

Kamin Kim[1] (k.kamin@gmail.com), Min-Shik Kim[1]; [1]Department of Psychology, Yonsei University, Korea

Jiang and Leung (2005) showed that implicit learning of visual contexts occurred even for unattended contexts. They asked participants to search for a target from distractors of two colors, either matching (target-matching) or not matching the target color (target-mismatching). The target-mismatching context was ignored, but its repetition facilitated target search when it was attended later. Precisely, what kind of information is gained from the ignored context, and used during the later visual search process? We adapted the experimental design of Jiang and Leung with one modification that the stimulus display contained two target stimuli, one belonging to the attended set and the other to the ignored. In both sets, a target location was either repeated with or without a specific distractor configuration. We were interested in whether an ignored target location would be guided by a repeated distractor configuration. After a learning phase of 12 epochs, a transfer phase epoch followed, where two sets switched their color in half of the trials (switch/stay conditions); in the switch condition, previously attended set became ignored and vice versa. In the switch condition, response time level for the target within the context that had been ignored was not different from that for a target in a novel context. Learning of ignored context did not guide attention to the target location within that context. This suggests that what is learned in the ignored context is the spatial relationship between the distractor configuration and the attended, rather than the ignored target.

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I7 *947* The time course of contextual modulation in visual search

Hirokazu Ogawa[1,2] (hirokazu-ogawa@aist.go.jp), Katsumi Watanabe[1,3]; [1]National Institute of Advanced Industrial Science and Technology, [2]Japan Society for the Promotion of Science, [3]Japan Science and Technology Agency

Observers conduct visual search more efficiently when the same spatial context is repeated (contextual cueing effect). The present experiment examined the time course of contextual guidance of attention by using a masking procedure. In the training phase, participants searched for a rotated-T target among rotated-L distractors and indicated the orientation of the target as quickly and accurately as possible. Thirty-two layouts were repeatedly presented 20 times. In the following test phase, the repeated and newly generated layouts were presented for 10 ms and then masked. The stimulus onset asynchrony between display and mask was varied. Participants made a two alternative forced choice to indicate the orientation of the target. The contextual cueing effect was evaluated as accuracy of performance in the test phase. The contextual cueing effect learned in the training phase was successfully transferred to the test phase. The contextual effect was evident with stimulus onset asynchrony as short as 150 ms. These results suggest that contextual guidance of attention emerges at early stages of visual processing, possibly involving a feed-forward, rather than iterative, processes.

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I8 *948* Incidental Memory for Relevant Locations in Real World Scenes

Ian P. Rasmussen[1] (ipr@lclark.edu), Mark W. Becker[1], Alec Scharff[1], Alex Hickok[1]; [1]Department of Psychology, Lewis & Clark College, Portland, OR.

In previous studies, we reported that subjects use scene-specific memory to guide attention in a repeated change detection task. In those experiments, different sources of information seemed to be hierarchical in that attention seemed to be allocated to previously relevant locations in a scene before previously relevant objects. However, in those experiments subjects

indicated the presence of a change by clicking on the spatial location of the change. In experiment 1, we now show that even when object identity is made salient by requiring a response based on object identity rather than location, the allocation of attention based on location information continues to occur prior to allocation based on object information. In experiment 2, we show that location-based information is still effective at cuing relevant locations in a scene even when the scene's viewpoint is altered between two viewings. This lack of viewpoint dependence suggests that the scene-specific memory that is utilized when allocating attention in real world photographs is not identical to the implicit memory system underlying contextual cuing, which previous research has shown to be viewpoint dependent (Chua & Chun, 2003).

I9 *949* Target location probability effects in visual search are an effect of sequential dependencies.

Carol E Walthew[1] (Carol.Walthew@bristol.ac.uk), Iain D Gilchrist[1]; [1]Department of Experimental Psychology, University of Bristol

We investigate the effect of manipulating the probability of the target being in a particular location in a search task and what processes underpin these effects. Participants searched for a target (Landolt C with gap at top) amongst 7 distractors (Landolt Cs with gap at base). For each trial, the latency and landing position of the first saccade was analyzed. In Experiment 1 the target was twice as likely to appear on one side of the display as the other. The first saccade was directed to the target more often when it occurred in the more frequent locations. This benefit could be a result of sequential dependencies or implicit learning of the spatial probabilities. Experiment 2 demonstrated that there were sequential dependencies in this task. When the target appeared with equal probability at each location, performance on the current trial improved when the target had appeared at the same location on either of the two preceding trials. In Experiment 3 the target was twice as likely to appear on one side of the display as the other (cf. Experiment 1), but with the additional constraint that the target location could not repeat within a sequence of 4 trials. The results showed that when short term target location repetitions were eliminated there was no longer an advantage for more frequent locations. These results suggest that the benefits for more frequently occurring locations result from short-term target location repetitions rather than implicit learning of the spatial probabilities.

I10 *950* Learning of arbitrary visual associations by trial-and-error

Catherine Matthews[1] (cmatthew@fas.harvard.edu), Hing Eng[1], Timothy Vickery[1], Won Mok Shim[1], Yuhong Jiang[1]; [1]Harvard University Department of Psychology

Aim: A hallmark of human intelligence is our ability to map any stimulus onto a response on the basis of an arbitrary rule. Extensive cognitive neuroscience research has focused on humans' ability to follow a pre-specified rule. But how do we learn arbitrary visual associations when the rule is not explicitly given, but must be discovered by trial-and-error? In this study we investigated whether arbitrary associative learning can be characterized as a single abstract ability or whether it is better described as a heterogeneous function. Methods: Human subjects learned, by trial-and-error, the one-to-one mapping of N visual images and N horizontally arrayed locations, a paradigm modified from WA Suzuki's studies. We varied the set size from 2 to 8, tested various types of visual images (natural scene, scrambled scenes, visual objects, abstract art, and words), and strategically employed articulatory suppression. Results: When verbal working memory was not suppressed, humans were best at mapping words onto locations, but long-term memory for the associations was poor. Articulatory suppression impaired word-location association, but did not impair learning of non-verbal images. Of the non-verbal images, learning was better for highly familiar scenes than for unfamiliar scenes, better for scenes from different categories than for scenes within a category, but equivalent for scenes, objects, and abstract art. Conclusion: Arbitrary associative learning can rely on at least two routes: verbal and visual, with verbal learning leading to fast mapping but quick forgetting, and visual learning leading to slower mapping but more robust long-term memory.

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I11 *951* Selective attention and general attentional resources in the learning of spatial context

Timothy J. Vickery[1] (vickery@wjh.harvard.edu), Rachel S. Sussman[1], Yuhong Jiang[1]; [1]Harvard University

Aim: When viewing a complex scene, our visual attention is guided not only by salient features, but also by past experience. Predictive visual context often facilitates target detection, showing spatial context learning. We explored whether spatial context learning is dependent on selective attention or general attentional resources. **Method:** Experiment 1 manipulated selective attention to backgrounds by combining low-pass filtered backgrounds and high-pass filtered search arrays, such that items could be attended independently of backgrounds. Throughout, backgrounds were consistently or inconsistently paired with target position. Experiments 2 and 3 manipulated general attention by adding a visual working memory load for colors or spatial locations to half of the trials in every training block, while target locations were consistently paired with distractor configurations. **Results:** Experiment 1 showed that no benefit occurs with low-pass filtered backgrounds and high-pass filtered search arrays. In experiments 2 and 3, learning was observed for the trained over untrained displays whether or not a secondary task was required. **Discussion and conclusions:** Prior research has shown that unattended background scenes cue target locations, but the scenes had features that could be selected incidentally during target search. When the targets can be selected independent of the correlated information, no learning is observed, demonstrating that selective attention is a prerequisite for statistical learning of spatial configuration. Further, this learning does not seem to depend on general attention, as equivalent learning was observed with or without VWM load.

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Binocular Rivalry

I12 *952* Transition phases show the importance of noise in binocular rivalry

Jan W Brascamp[1] (j.w.brascamp@bio.uu.nl), Andre J Noest[1], Raymond Van Ee[2], Albert V Van den Berg[1]; [1]Functional Neurobiology, Utrecht University, Utrecht, The Netherlands, [2]Physics of Man, Utrecht University, Utrecht, The Netherlands

Introduction. During binocular rivalry, transition phases often take up about half of the observation time. We have characterised transition durations in terms of their dependence on stimulus strength and their distributions, providing constraints on models complementary to those posed by dominance durations (VSS 2005). Trying to reconcile existing models with data on transition phases, we find that realistic behaviour requires an interaction between deterministic factors (adaptation, mutual inhibition) and noise, leading to our present question: What is the relative importance of deterministic and stochastic forces underlying the change from one percept to the other?Results. We present a model of transitions in binocular rivalry, which relates distributions of transition durations to the relative strength of deterministic and stochastic components. It starts from the accepted idea that binocular rivalry can be described as a non-linear system with two stable states (attractors), in which transitions are initiated when adaptation reduces the stability of one attractor. The model treats transitions as a random walk (the stochastic component) in a flow field (the deterministic component), from the destabilised attractor to the other one. Transition durations for various contrast conditions differed from traditional Gamma distributions and were better described by our model's

two-parameter distribution. We found consistent effects of stimulus contrast on fit parameters, indicating a stronger relative influence of noise at lower contrast. Further work includes testing the effect of specifically manipulating the noise content of the stimulus during transitions.

I13 *953* Hysteresis effects in stereopsis and binocular rivalry

Athena Buckthought[1] (athenab@magma.ca), Jeounghoon Kim[2], Hugh R. Wilson[1]; [1]Centre for Vision Research, York University, Toronto, Canada, [2]Korea Advanced Institute of Science & Technology, Taejon, Korea

Neural hysteresis plays a fundamental role in stereopsis and reveals the existence of positive feedback at the cortical level (Wilson & Cowan, 1972). Using a model of cortical dynamics, we predicted that it should be possible to measure hysteresis as a function of orientation disparity in tilted gratings in which a transition is perceived between stereopsis and binocular rivalry. Methods. The patterns were 2 cpd or 4 cpd sinewave gratings with orientation disparities (0-40 deg) resulting in various degrees of tilt. A sequence of 40 pattern pairs was used, with the orientation disparity increased by a fixed increment in successive pairs. During each experimental trial a movie of the 40 pairs was shown at a rate of 0.5, 1 or 2 pairs per second. In separate trials the same movie was shown in reverse order. Two transition points were measured: the point at which the single tilted grating broke into two rivalrous gratings (T1), and the point at which the two rivalrous gratings merged into a single tilted grating (T2). Results. Transitions occurred at different orientation disparities (T1=24.7 deg, T2=17.8 deg at 2 cpd; T1=27.1 deg, T2=18.0 deg at 4 cpd) corresponding to a timing difference of 3.5-4.6 sec. This was consistent with hysteresis and far exceeded the effects which could be attributed to reaction time or adaptation. The results are consistent with a cortical model with positive feedback arising from recurrent inhibition between binocular units coding different disparities and orientations. Stereopsis and rivalry are two possible states of the network.

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I14 *954* Race to gain dominance in binocular rivalry: faster for familiar and recognizable stimuli

Yi Jiang[1] (jiang067@umn.edu), Patricia Costello[2], Sheng He[1]; [1]Department of Psychology, University of Minnesota, [2]Department of Psychology, Gustavus Adolphus College

Previous studies have demonstrated that familiar and recognizable stimuli enjoy an advantage of predominance during binocular rivalry. However, the observed advantage of familiar objects is usually attributed to enhanced processing when they are in the dominant phase. In the current study, we investigated the processing of a visual stimulus while it is suppressed. Specifically, do familiar and recognizable stimuli have an advantage in breaking suppression and gaining dominance? A standard high contrast dynamic noise pattern was presented to one eye at the beginning of each trial, and then a test image was introduced to the other eye. We measured the time it took for the test image to overcome the suppression noise and become dominant. The critical manipulation was the familiarity of the test image. In the first experiment, we found a face inversion effect: an upright face took less time to gain dominance compared to an upside-down face against the identical suppression noise. In the second experiment, two types of test stimuli (Chinese characters and Hebrew words), initially suppressed, were presented to three groups of observers (Chinese, Hebrew, and English speakers). Results showed a significant observer group X stimulus type interaction: Chinese characters were faster to gain dominance compared to Hebrew words for Chinese speakers, and the reverse was true for Hebrew speakers. These results suggest that familiar and recognizable information, even when suppressed and invisible, is processed differently from unfamiliar information and has an advantage in attaining the dominant conscious state.

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I15 *955* Learning affects binocular rivalry

Chris L.E. Paffen[1] (c.paffen@fss.uu.nl), Frans A.J. Verstraten[1], Zoltan Vidnyánszky[2]; [1]Helmholtz Institute, Psychonomics division, Utrecht University, Heidelberglaan 2, 3584 CS, Utrecht, The Netherlands., [2]Neurobiology Research Group, Hungarian Academy of Sciences - Semmelweis University, Tuzolto u. 58, Budapest, H-1094, Hungary.

IntroductionThe competitive mechanisms giving rise to binocular rivalry might overlap with selection mechanisms underlying object-based attention (Leopold and Logothetis, 1999). Here we tested whether binocular rivalry between moving stimuli is affected by attention-based long-term modulation of sensitivity for specific motion directions.MethodOn pre- and post training days, observers reported their dominant perception of pairs of rival motion stimuli with different motion directions (right vs. down, left-up vs. down, left-up vs. right). During 5 training days, observers performed a speed discrimination task on rightward (attended) motion, presented simultaneously with downward (neglected) motion (in a bivectorial transparent dot motion display). ResultsDominance durations of the attended motion direction increased, and those of the neglected motion direction decreased as a result of training. Surprisingly, presenting a control motion direction (the left-up direction which was not present during training) with either the attended or neglected motion direction lead to a training-induced decrease in the dominance durations of the neglected motion that was much larger than the training-induced increase in the dominance durations of the attended motion. Conclusion-Attention-based long-term modulation of the sensitivity for visual features affects binocular rivalry primarily via decreasing the dominance of the visual information that was task-irrelevant during learning.

I16 *956* Brain stimulation can make you change your mind

Joel Pearson[1,2] (Joelp@psych.usyd.edu.au), Duje Tadin[2], Randolph Blake[2]; [1]School of Psychology, The University of Sydney, NSW Australia 2006., [2]Vanderbilt Vision Research Center, Nashville, TN 37203, USA.

During binocular rivalry, perception is bistable in that observers perceive only one of two monocular stimuli, with perception inevitably switching to the other stimulus after some variable duration. A related form of bistability occurs when dissimilar stimuli (still presented one to each eye) are swapped rapidly between the eyes— a phenomenon commonly termed stimulus rivalry.Here, we report that transcranial magnetic stimulation (TMS) of early visual areas perturbs the dynamics of binocular rivalry while having no measurable effect on stimulus rivalry. The location of the TMS coil was adjusted until observers reported a phosphene overlapping the subsequent stimulus area. A single TMS pulse was delivered every 3.2 s while observers tracked perceptual alternations during rivalry. TMS increased the probability of experiencing binocular rivalry alternations ~ 0.75 s after the TMS pulse. When we applied TMS at a location eliciting peripheral phosphenes, we found only a weak effect, indicating retinotopic specificity of the interaction between TMS and binocular rivalry. Stimulus rivalry, however, was unaffected by TMS stimulation, indicating that these two seemingly related dynamical processes differ in their neural bases. In addition, the effect of TMS on the duration of a binocular rivalry state was proportional to the length of time an observer had been in that state.Hence, rather than merely inducing a temporary lesion, the effect of TMS was retinotopically specific and proportional to the time course of binocular rivalry or the brain state at any given instant. Supported by NIH EY13358 (RB).

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I17 957 The occurrence of binocular rivalry and dichoptic masking depends on temporal aspects of stimulation

Jeroen J.A. van Boxtel[1] (j.j.a.vanboxtel@phys.uu.nl), Allard P. Kamphuisen[1], Raymond van Ee[1], Casper J. Erkelens[1]; [1]Helmholtz Institute, Utrecht University, Department Physics of Man

Binocular rivalry (BR) and dichoptic masking (DM) are often-used tools in the study of conscious perception. In BR two incompatible stimuli in the two eyes compete perceptually; in DM a stimulus to one eye becomes invisible when preceded by a stimulus in the other eye, the optimal delay being about 100ms. Spatial aspects of BR, like differences of luminance, contrast, orientation etc. have been extensively studied. Temporal aspects much less so. It is known that BR may occur when images to the two eyes are presented asynchronously without temporal overlap (O'Shea, Crassini, Percept Psychophys; 1984). O'Shea and Crassini found monocular stimulus presentations (T_on) of 10ms, separated by binocular blanks (T_off) up to about 140ms resulted in BR. T_on and T_off were not systematically varied. We chose to systematically investigate how the occurrence of BR depends on T_on and T_off, and found that BR occurred when the sum of T_on and T_off was less than about 150ms, independent of their exact values. In our study, DM was not observed when BR took place, even when one of the two stimuli followed the other at 100ms. When BR broke down (at periods of 2*(T_on+T_off) > about 300ms), DM took effect, and was observed at temporal delays from about 10 to 150ms. BR and DM may rely on a single mechanism with a temporal integration window of about 300ms (i.e. a flicker fusion frequency around 3Hz). During flicker fusion, BR is observed, otherwise DM occurs.

I18 958 On the contribution of second-order boundary contour strength to binocular rivalry

Jingping Xu[1] (j0xu0007@louisville.edu), Zijiang, J He[1], Teng Leng Ooi[2]; [1]University of Louisville, USA, [2]Pennsylvania College of Optometry, USA

The alternation frequency of competing images in binocular rivalry is affected by their boundary contours. When one eye views a vertical grating disk(SF=5cpd, diameter=1.25deg, contrast=86%) surrounded by a horizontal grating background(7.5x7.5deg) and the fellow eye views only the horizontal grating background, the observer perceives the vertical grating disk almost continuously despite the corresponding retinal area receiving a horizontal grating. This is because only the vertical grating owns the boundary contour that defines the disk (Ooi & He, 2005). We modified the abovementioned rivalry display by inserting a relative spatial phase shift(0-180deg) in a circular/disk area within the horizontal grating in the fellow eye that corresponded with the vertical grating disk. This allowed us to investigate how rivalry is affected by second-order boundary contours. We found: (i) Increasing the relative spatial phase to strengthen the second-order boundary contour of the horizontal grating disk decreased the predominance and dominance duration of perceiving the vertical grating disk. (ii) The competing images had about the same predominance when the relative spatial phase was about 108deg or larger. Together, these suggest that second-order contours behave qualitatively similar to first-order contours. (iii) When the boundary contour of the horizontal disk was weak, the dominance duration of the vertical grating disk was longest at rivalry onset and decreased at longer rivalry observation interval. This reveals a novel adaptation effect, which was masked when the boundary contour strengths of competing images were about equal. A similar adaptation occurred with prior exposure to a monocular display.

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I19 959 Hierarchical processes of motion perception in binocular rivalry

Takashi Shinozaki[1] (tshino@brain.k.u-tokyo.ac.jp), Yoichi Miyawaki[2], Tsunehiro Takeda[1]; [1]University of Tokyo, Japan, [2]RIKEN Brain Science Institute, Japan

Drifting grating patterns with different motion directions independently presented to the two eyes induce two perceptual interpretations (Andrews & Blakemore, 2002). One is "pattern motion" that forms a superimposed pattern moving with a single direction, equivalent to the vector sum of the two motion directions. The other is "component motion" that forms two independent motion directions followed by monocular dominance in which one eye's motion is perceived alone. Although this perceptual process involves not only interocular rivalry (right or left eye's image) but also motion-type rivalry (pattern or component motion), most of the previous studies discussed only one of those rivalries independently. Here we studied this double rivalry process during binocular rivalry of motion direction in terms of the temporal order of each rivalry. We measured reaction times (RTs) using a visual stimulus for which the probability of each perceptual interpretation was approximately equal. RTs to perceive a consistent motion direction in pattern and component motion conditions were 400 ms and 750 ms slower, respectively, than that in the condition when identical motion stimuli were presented to the two eyes. We further measured magnetoencephalography (MEG) signal evoked by the corresponding visual stimulus condition, indicating significant difference in the RMS amplitude between the two perceptual interpretations (pattern or component motion) in the latency range consistent to the RT measurement. These results suggested that motion-type rivalry was resolved before interocular rivalry and these rivalries in motion perception were processed hierarchically.

I20 960 The critical role of boundary contours in the early temporal processing of binocular rivalry

Yong Su[1] (y0su0002@louisville.edu), Zijiang J He[1], Teng Leng Ooi[2]; [1]University of Louisville, USA, [2]Pennsylvania College of Optometry, USA

When one eye views a vertical grating disk (SF=4cpd, contrast=95%) surrounded by a horizontal grating background and the fellow eye views only the horizontal grating background, the observer perceives the vertical grating disk almost continuously despite the corresponding retinal area receiving a horizontal grating. This is because the monocular boundary contour (MBC) that defines the disk is a critical factor in perceptual dominance (Ooi et al, 2005). Is the preeminence of boundary contours evident at the early temporal stage of binocular rivalry processing? We investigated this question using three types of rivalry displays: (i) The abovementioned MBC-display; (ii) A binocular boundary contour (BBC)-display, in which a circular/disk area of the horizontal grating background that corresponded to the vertical disk in the MBC-display was phase shifted by 180deg to create a horizontal grating disk; (iii) A typical rivalry display (horizontal vs. vertical grating disks). We varied the stimulus presentation duration (30, 50, 100, 150 msec) and disk size (1.0, 1.3, 1.6, 1.9 deg). Observers responded with four possible percepts: global grating disk, piecemeal, checkerboard, indeterminate. We found that the stimulus duration for perceiving the global grating disk above 50% frequency was 30 msec for the smaller MBC-displays (<1.6deg), and 50 msec for the larger (1.9deg) MBC-display. In contrast, for the BBC and typical rivalry displays, observers seldom saw the global grating disk percept (<5%) for all the durations and sizes tested. These findings reveal the primacy of boundary contours, and that rivalry begins earlier (temporal) than previously thought.

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I21 961 Motion aftereffects under complete binocular rivalry suppression

Hiroki Watanabe[1] (hiroki@bs.t.u-tokyo.ac.jp), Kazushi Maruya[2,3], Masataka Watanabe[1]; [1]Department of Quantum Engineering and Systems Science, The University of Tokyo, [2]The Jikei University, [3]Intelligent modeling laboratory, Univeristy of Tokyo

Previous studies have suggested the existence of several distinct motion-detectors in the visual system; such as the first-order detector, the second-order detector, and the feature-tracker. However, it is not clear how these motion detectors are involved in visual-awareness. One way to verify the problem is to measure the magnitude of motion aftereffects(MAE) under binocular rivalry suppression (BRS)(Blake & Fox, 1974). In previous stud-

ies however, adaptation stimulus were not completely suppressed and the relation of visual awareness and motion detectors remains controversial. Here, we developed a powerful variant of continuous flash suppression (Tsuchiya & Koch, 2005) where motion stimulus can be erased from conscious awareness for several tens of seconds. We measured the magnitude of both static and flicker MAE under normal viewing and BRS conditions. Two types of motion were used for adaptation; 2f+3f-motion and 1f-motion. In 2f+3f-motion, direction of first-order motion is opposite to that of higher-order motion which observers perceived dominantly. Psychophysical results indicate that for 2f+3f-motion adaptation, flicker MAE completely vanishes under BR suppression, while it decreases but does not dissappears for 1f-motion adaptation. On the other hand, static MAE occurred in both 2f+3f-motion and 1f-motion adaptation even when observers did not perceive the adaptation presented stimulus at all. Taking into consideration that flicker MAE reflects adaptation of all three motion detectors(Nishida & Ashida, 2001) and that both 1st and 2nd order motion detectors are monocular, our results suggest that higher-order motion-tracker system is highly correlated with visual awareness.

I22 *962* Auditory modulation of binocular rivalry

Amanda. L. Parker[1] (amandap@psych.usyd.edu.au), David. M. Alais[1]; [1]The University of Sydney, Department of Psychology

AIM: To determine whether audition alters the temporal dynamics of binocular rivalry (BR) and flash suppression (FS). METHODS: Exp.1: Concentric gratings (2.7deg diameter, 2.4cpd) loomed or receded at 1Hz or 3Hz. Subjects monitored BR alternations in three 8min trials for three conditions: 1Hz looming/1Hz receding, 1Hz looming/3Hz receding, and 3Hz Looming/1Hz receding. These were paired with either: no sound, a looming tone matching the looming grating, or a receding tone matching the receding grating. Exp.2: The same concentric gratings were used in a FS paradigm (changing at 2Hz). SOA thresholds for complete suppression of lead stimulus by 'flash' stimulus were measured under auditory and no-sound conditions. Sounds included: constant tones, 'beep' warning tones, looming/receding and expanding/contracting tones. RESULTS: Exp.1: 1 and 3Hz looming gratings predominated over receding gratings. Adding auditory looming (1 or 3Hz) increased looming predominance, relative to no-sound. Receding sounds did not influence predominance. Exp.2: Expanding 'flash' stimuli required shorter SOA's to suppress contracting stimuli than the reverse configuration. Adding sounds further reduced SOA thresholds for both configurations (even for non-matched stimuli). CONCLUSIONS: In BR, visual looming predominates over receding. Adding auditory looming further enhances this looming predominance. This suggests auditory input can help resolve visual ambiguity. In FS, auditory input influenced SOA thresholds. Unlike in BR, this effect was not specific to matched audiovisual signals. FS appears more susceptible to auditory modulation generally- evidence that FS is distinct from BR and not just a `one-cycle' version of BR.

I23 *963* THE EFFECT OF CROWDING ON ORIENTATION-SPECIFIC ADAPTATION USING BINOCULAR RIVALRY

Sarah Hancock[1] (s.hancock@psych.york.ac.uk), David Whitney[2], Timothy J Andrews[1]; [1]Department of Psychology, University of York, York YO10 5DD, [2]Center for Mind and Brain, UC Davis, CA 95616

We determined the influence of awareness on orientation-specific adaptation using binocular rivalry. We found that, if both eyes briefly viewed an adapting grating in peripheral vision prior to the presentation of the same grating to one eye and an orthogonal grating to the other eye, subjects tended to report perceptual dominance of the non-adapted grating. Next, we measured the strength of this visual adaptation when the adapting grating was surrounded by gratings of different orientation such that subjects were not aware of the adaptor's orientation (crowding). We found that crowding dramatically reduced the effect of adaptation on subsequent binocular rivalry. That is, subjects were more likely to report perceptual dominance of the adapted grating during crowding compared to the non-crowded (single) condition. Finally, we tested adaptation when the adaptor was surrounded by gratings of the same orientation. In this situation, subjects were aware of the orientation of the adaptor and reported adaptation that was equivalent to the non-crowded condition. The implication is that the surrounding gratings only reduce the strength of the adaptation if they affect awareness of the adaptor. In conclusion, our results show that binocular rivalry depends on processing that occurs beyond the stage that is affected by crowding.

I24 *964* Predicting conscious perception under rivalry from activity in LGN and V1

John-Dylan Haynes[1,2,3] (haynes@cbs.mpg.de), Ralf Deichmann[2], Geraint Rees[2,3]; [1]Max Planck Institute for Cognitive and Brain Sciences, [2]Wellcome Department of Imaging Neuroscience, UCL, [3]Institute of Cognitive Neuroscience, UCL

When dissimilar images are presented to the two eyes, they compete for perceptual dominance so that each image is visible in turn for a few seconds while the other is suppressed. Psychophysically, such binocular rivalry is associated with relative suppression of local, eye-based representations that can also be modulated by high-level influences such as perceptual grouping. However, it is currently unclear how early in visual processing the suppression of eye-based signals can occur. Here we used high-resolution functional magnetic resonance imaging (fMRI) in conjunction with a new binocular rivalry stimulus to show that signals recorded from the human lateral geniculate nucleus (LGN) and primary visual cortex (V1) exhibit eye-specific modulation during rivalry. Regions of LGN and V1 that showed strong eye-preference independently showed strongly reduced activity during binocular rivalry when the stimulus presented in their preferred eye was perceptually suppressed. The human LGN is thus the earliest stage of visual processing that reflects eye-specific dominance and suppression under rivalry.

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Action Effects on Perception

I25 *965* Within striking distance: Task efficacy influences perceived size and distance

John M. Franchak[1] (franchak@psychology.rutgers.edu), Jeanine K. Stefanucci[2], Dennis R. Proffitt[2]; [1]Rutgers University-Newark, [2]University of Virginia

Past research has shown that a target was perceived to be smaller when the observer's effectiveness of dropping a dart on the target was reduced (Wesp et al., 2004). Additionally, perceived distance is overestimated when the physical effort required to traverse a distance is increased (Proffitt et al., 2003). In three experiments, we found that observers who performed a difficult throwing task perceived a target as smaller and the distance to the target as farther than observers that completed the same task under easier circumstances. Participants attempted to slide beanbags into targets at different distances and of different sizes under normal or difficult conditions. In the difficult condition, participants slid the beanbag with their non-dominant hand while their eyes were closed, and the easy condition allowed participants to slide the beanbags with their dominant hands and their eyes open. Afterwards, participants were blindfolded, and then tried to walk to the target or turned in the opposite direction of the target and tried to walk the distance to the target. Walking distances were significantly greater for participants who acted on the target under difficult conditions than those who acted on the target under normal circumstances. A visual matching task was performed to assess participants' perception of the target's width. Participants in the difficult condition gave smaller estimates for the target's width. These results suggest that the ease with which an observer acts on a target influences the perceived size, location, and distance of the target.

I26 966 Does energy expenditure affect the perception of egocentric distance? A failure to replicate Experiment 1 of Proffitt, Stefanucci, Banton, and Epstein (2003)

Jeffrey J Hutchison[1] (Jeffrey_Hutchison@brown.edu), Jack M Loomis[2]; [1]Brown University, Department of Cognitive Science, [2]Univeristy of California, Santa Barbara Department of Psychology

In a series of recent studies, Proffitt and his colleagues have reported that the perceived distance to a target is influenced by the energy expenditure associated with any action, such as walking or throwing, for spanning the distance to the target. In particular, Proffitt, Stefanucci, Banton, and Epstein (2003) reported that wearing a heavy backpack caused verbal reports of distance to increase. We conducted a study to determine whether three responses dependent on perceived distance (verbal report of distance, blind walking, and estimates of object size) are influenced by the backpack manipulation. In two experiments, one involving a between-participants design and the other involving a within-participants design, we found that none of the three responses were influenced by the wearing of a heavy backpack.

I27 967 MOTOR FORCE LEARNING INFLUENCES VISUAL PERCEPTION OF ACCELERATION

Liana E. Brown[1,3] (lbrown38@uwo.ca), Elizabeth T. Wilson[2], Melvyn A. Goodale[1,2,3], Paul L. Gribble[1,2,3]; [1]Department of Psychology, University of Western Ontario, [2]Department of Physiology and Pharmacology, University of Western Ontario, [3]CIHR Group on Action and Perception

Does force information learned by the motor system influence visual perception of moving targets? Ss trained in one of three force fields (FF) by making reaching movements while holding a robotic manipulandum. The robot applied a constant force to the hand throughout each movement, either in a leftward or rightward direction. For one group no forces were applied (null field). The trained force was also applied during interception, which followed immediately. The target accelerated from left to right and Ss tried to "punch" it. Ss who trained in the rightward FF hit significantly more accelerating targets than the null group and Ss who trained in the leftward FF hit significantly fewer accelerating targets than the null group. All groups initiated their missed responses too late, but timing estimates from the right group were significantly better than those of the left and null groups. In Exp. 2, Ss intercepted the target by pressing a button when the target arrived at the interception point. Again, timing estimates from the right group were better than those of the left and null groups. In Exp. 3, subjects performed the interception task without first training in the FF. We found no influence of concurrent force information on interception performance. These experiments show that force information learned by the motor system affects perception of acceleration, that FF training is needed before this effect is observed, and that access to force information is more effective when one interacts with the visual target than when one responds remotely.

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I28 968 Size-weight illusion dissociates from grip forces when objects lifted from other hand

Erik C. Chang[1] (audachang@gmail.com), Melvyn A. Goodale[1]; [1]University of Western Ontario, London ON N6A 5C2 Canada

When lifting two visible objects of the same weight but different volumes, the smaller object is judged to be the heavier. It has been suggested that the illusion arises from a mismatch between expectation and sensory feedback. To clarify the role of sensory feedback, we measured estimates of heaviness and precision-grip forces when participants lifted objects (1331 cm^3 and 147 cm^3; 0.33 kg each) that were resting either on a table or on the palm of their other hand. Testing order was counterbalanced across participants and object size was alternated randomly between trials. A robust size-weight illusion, as evidenced by the ratio of small-to-large heaviness estimates (average: 1.42), was observed in both the table and palm conditions, with the table condition showing a slightly stronger illusion (1.55 vs. 1.29). Participants who first lifted the objects from the table (without first lifting the object from the palm of their other hand) generated peak grip forces that were significantly greater for the larger of the two objects. After that initial lift, however, the grip forces applied to the two objects rapidly converged and remained so for the rest of the experiment. In contrast, participants who first lifted objects from the palm applied equivalent grip forces to both objects on the very first trial and continued to do so for the remainder of the experiment. These results suggest that even though the lifting hand can use information from the supporting hand to scale grip forces accurately, the size-weight illusion is only slightly diminished.

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I29 969 Size-manipulation of the Body-Schema Using the Rubber Hand Illusion

Edward A G Cooke[1] (edcooke@gmail.com), J.Kevin O'Regan[1]; [1]Université Renée Descartes, Paris V

In this study, we use the paradigm of the Rubber Hand Illusion (RHI) to investigate the representation of size in the body-schema. In RHI manipulations, a visually presented rubber hand is stroked in synchrony with the hidden hand of the participant to create a visuo-tactile 'conflict' that results, through the dominance of vision, in the illusion that the tactile sensations stem from the visually specified but inanimate rubber hand. In this experiment, we varied the size of the rubber hands in this procedure, employing a large or a small hand, according to the condition. After three minutes of synchronous or (control) asynchronous stroking to the real and rubber hands, we had participants estimate real hand size using a template-matching task or we had them make a reach-and-pincer movement to a pair of dots. From data due to 20 consecutively recruited healthy volunteers who each sat all conditions, we found that synchronous stimulation to both the small and large hands resulted in significantly different hand-size estimation to that after asynchronous stimulation: in the big-hand condition participants overestimated hand-size and in the small-hand condition participants underestimated hand-size. We found just in the big-hand condition that participants' pincering behaviour was modified: participants who had viewed a big hand being synchronously stimulated made significantly smaller pincer-movements than those in the equivalent control condition. We discuss the implications of these results for the representation of body-size and its relationship to the representation of peripersonal space.

I30 970 Writing facilitates the learning of abstract visual representations of letter-like symbols

Karin H James[1] (khjames@indiana.edu); [1]Indiana University

Most adults can quickly and accurately read text in many different formats, including cursive writing, font changes in typed text and even some orientation changes. For this to occur, the visual system first must become highly efficient at recognizing letters in their many permutations. In early childhood, visual exposure is typically limited to upright, single font letters usually presented in capitals. Later, when children learn to write, letters take many different visual forms. The current study addressed whether the interaction between writing and visual perception during learning affects the ability to generalize across letter formats. That is, does writing experience lead to abstract visual representations of letters? To examine the interaction between writing and visual perception we trained adult subjects to recognize novel, 2D symbols, or "false fonts" in one of four ways: visual study only, visual and auditory study, visual study and writing the symbols, or visual study and typing the symbols. Results of post-learning sequential matching and visual search tests indicated that visual recognition was facilitated (relative to pre-training measures) under learning conditions that included a motor component (i.e., writing or typ-

ing). However, recognition was more robust to changes in font and orientation after learning by writing the symbols than after other learning conditions. These results suggest that writing letters during learning facilitates the construction of abstract letter representations.

URL: http://mypage.iu.edu/~khjames/

I31 *971* Active Visualization Methods Enable Perception of Structure and Motion in Higher Dimensional Spaces: Comparing Active Vs. Passive Perception of the Rigidity of 3D and 4D Objects

Sidharth Thakur[1] (sithakur@cs.indiana.edu), Andrew J Hanson[1], Geoffrey P Bingham[1]; [1]Indiana University, Bloomington, IN

Active perception can be used to facilitate perception of the rigid motion of either 3D or 4D objects projected to a lower dimension. The perspective on 3D rotating objects can be actively adjusted to place the axis of rotation so that the 2D motion in a frontoparallel plane is rigid. Likewise, the perspective on 4D rotating objects can be actively adjusted to make the invariant plane frontoparallel, rendering the 2D display static and therefore rigid. Although such active perception is not required to judge the rigidity of 3D rotating objects, we asked can the rigidity of 4D objects be judged and if so, whether active perception is required. Naive observers were trained to use the above active methods to judge displays of rotating objects and then they were tested in judging whether motion was rigid or non-rigid and of 3D or 4D objects. Subsequently, observers were tested in the same manner, but allowing only passive viewing from multiple perspectives excluding those yielding 2D rigid motion. The expectation was that active perception would allow more rapid and accurate judgments of the rigidity of both 3D and 4D objects, but that passive viewing would only allow accurate judgment of 3D objects, even after extensive training and practice. The results indicate that active visualization methods are indeed required to allow perceptual access to the structure and motion of 4D objects.

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I32 *972* Effect of Load and Landmark Distance on Mental Self-rotation

Bruce Bridgeman[1] (bruceb@ucsc.edu), Steven Macramalla[1]; [1]University of California, Santa Cruz

Chronometric studies provide strong support that mental imagery recruits perceptual processes (Shepard & Metzler, 1970; Shepard & Cooper, 1971). Further, there is recent evidence that information on effort is important in perceptual coding (Proffitt, 2003). If imagery recruits perceptual processes and perception is influenced by anticipated effort, then imagery should be affected by anticipated effort. In two experiments, participants imagined self-rotation between two landmarks separated by 90 or 180 deg. In a near condition the landmarks were 2m away, while in a far condition they were 90m away. Imagined rotation between distant objects required significantly more time (175msec more for 90 deg rotations), even though the imagined self-motion was identical in both conditions. While the instructions were for self-rotation only, the result indicates that participants took the path from one landmark to the other into account without being aware that they did so. In a second experiment participants wore an 8kg backpack under the same conditions, with no change in instructions. Rotation times were 126msec longer and the near/far difference was 165msec. Of the tests of individual differences in field-dependence, sex, and handedness, only sex produced a significant difference ($p<.02$). The results suggest that spatial metrics, attended path, and anticipated effort all play a role in coding of mental imagery, but further research is required to ascertain whether the effects on anticipated effort are due to sensorimotor processes or semantically based tacit knowledge.

URL: http://psych.ucsc.edu/faculty/bruceb/

Eye Movement Effects on Perception and Action

I33 *973* Asymmetrical modulation of the temporal impulse response during smooth pursuit

Jianliang Tong[1] (jtong@optometry.uh.edu), Saumil S. Patel[1,2,3], Harold E. Bedell[1,3]; [1]College of Optometry, University of Houston, [2]Department of Electrical & Computer Engineering, University of Houston, [3]Center for Neuro-Engineering & Cognitive Science, University of Houston

Purpose. Recent experiments indicate that the extent of perceived motion smear is attenuated asymmetrically during smooth pursuit eye movements (Tong, et al., Vision Res. 2005). In this study, we investigated whether the asymmetrical reduction of perceived smear during pursuit is associated with an asymmetrical speeding up of the temporal impulse response function (TIRF). **Methods.** The stimulus was a 10 deg patch of a vertical sinusoidal grating, presented on a 20″ monochrome monitor and viewed monocularly from 114 cm after reflection from a galvanometer mirror. On each trial, a 1 cpd stimulus was presented for 400 ms, with Gaussian temporal windowing to limit the spread of the temporal frequency spectrum. Contrast sensitivity was determined for leftward and rightward image motion at temporal frequencies between 6 and 30 Hz, during fixation and rightward pursuit at 8 deg/s. Horizontal eye position was measured on pursuit trials using IR limbal tracking. TIRFs were determined by iterative Fourier analysis to fit the temporal contrast sensitivity functions measured for each direction of target motion during fixation and pursuit. **Results.** As we reported previously (VSS, 2003), the natural frequency of the TIRF is higher during smooth pursuit than fixation. Moreover, the TIRF is 10 - 15% faster for gratings that move AGAINST compared to WITH the direction of pursuit. **Conclusion.** The results are consistent with the hypothesis that extra-retinal signals reduce perceived smear during pursuit, partly by increasing the speed of visual processing preferentially for one direction of image motion.

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I34 *974* Perisaccadic localization of TMS-induced phosphene

Junghyun Park[1] (jpark@caltech.edu), Daw-An Wu[1], Shinsuke Shimojo[1, 2]; [1]California Institute of Technology, USA, [2]JST.ERATO Shimojo "Implicit Brain Functions" Project, Japan

Accurate spatial localization of a visual stimulus requires the integration of its retinal position with the direction of gaze at the time of stimulus presentation. But studies have shown that brief visual targets presented near the time of saccades tend to be mislocalized. Mislocalization starts growing long before a saccade (~100ms) and reaches a maximum at saccade onset. This presaccadic mislocalization has often been attributed to the temporal mismatch between the visual and eye position signals due to the long visual afferent delay (>50ms). To directly test if the visual afferent delay is necessary for presaccadic mislocalization, we investigated how observers localize phosphenes induced by transcranial magnetic stimulation (TMS) of the visual cortex (thus bypassing the afferent delay) around the time of saccades.Observers who consistently perceived single phosphene with a sharp vertical edge were screened and tested in two conditions. In one condition, a dual-pulse TMS was applied over the left visual cortex at various times while they were performing a delayed (rightward) saccade task. Observers reported the perceived position of the leftmost edge of the phosphene with a mouse cursor presented after a saccade. In the other condition, instead of applying TMS, a dim vertical bar was presented (13ms) on the monitor screen.Most observers mislocalized TMS-induced phosphene near the time of saccades as they did for the flashed bar. The time course and magnitude of the error for both types of stimuli were practically identical. Thus presaccadic mislocalization should be explained with some other factors than afferent delay.

I35 975 The perceived location of one flash or two successive flashes at the time of a saccade involves an extraretinal signal that begins changing at the onset of or following the saccade

Jordan Pola[1] (jpola@sunyopt.edu); [1]State University of New York College of Optometry, USA

When subjects make a saccade in the dark, they tend to mislocalize both a single target flash (Matin, 1972; Honda, 1990; Schlag & Schlag-Rey, 1995; Bockisch & Miller, 1999) and two successive target flashes (Matin, 1976; Sogo & Osaka, 2002). The "current view" is that this mislocalization comes from an extraretinal (exR) signal that begins changing prior to the onset of a saccade and continues to change during and following the saccade. However, a target flash produces retinal (R) signal persistence that can last for 300 msec. Pola (2004) has developed a model showing that this persistence interacting with an exR signal could have a significant influence on the features of flash mislocalization. In the present study, this model was used to explore what happens when R signal persistence interacts with three different types of exR signals: a slow, a moderately fast, and a fast exR signal. There are three main findings: (1) All three exR signals fail to yield single flash or successive flash mislocalization similar to experimental data when the exR signals begin to change in advance of a saccade. (2) The exR signals must begin at the time of, or following saccade onset, to give mislocalization similar to experimental findings. (3) As the speed of the exR signal increases, the delay of the exR signal from saccade onset must also increase to produce proper mislocalization. These results, as opposed to current psychophysics and neurophysiology, suggest that the exR signal does not begin before the saccade.

I36 976 Microsaccades counteract visual fading during fixation

Susana Martinez-Conde[1] (smart@neuralcorrelate.com), Stephen L Macknik[1], Xoana G Troncoso[1], Thomas A Dyar[1]; [1]Barrow Neurological Institute, Phoenix, AZ, USA

Our eyes move continually even while we fixate our gaze on an object. If fixational eye movements are counteracted, our perception of stationary objects fades completely, due to neural adaptation. Some studies have suggested that fixational microsaccades refresh retinal images, thereby preventing adaptation and fading. However, other studies disagree, and so the role of microsaccades remains unclear. Here we correlate, for the first time, visibility during fixation to the occurrence of microsaccades. We asked subjects to indicate when Troxler fading of a peripheral target occurs, while simultaneously recording their eye movements with high precision. We found that before a fading period, the probability, rate and magnitude of microsaccades decreased. Before transitions towards visibility, the probability, rate and magnitude of microsaccades increased. These results reveal a direct link between suppression of microsaccades and fading, and suggest a causal relationship between microsaccade production and target visibility during fixation.

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URL: http://www.neuralcorrelate.com/smc_lab

I37 977 Systematic distortion of perceived 3D path of a moving object during disconjugate eye movement

Hyung-Chul O. Li[1] (hyung@kw.ac.kr); [1]Department of Industrial Psychology, Kwnagwoon University, Seoul, Korea

Unlike conjugate eye movement, pursuing a moving object in a 3D space (i.e., disconugate eye movement) might produce eye movement-induced disparity for any dynamic object that is present around a pursuit object. Li (2004) showed that the perceived slant of the target surface defined by the sequential display of partial contour information is systematically distorted during disconjugate eye movement, suggesting that eye movement-induced disparity is not compensated for with eye position information. The target surface employed in the research of Li does not exist in real life, and this can explain why we usually do not experience perceptual distortion of 3D slant during disconjugate eye movement in a natural environment. To examine this possibility, we simulated a series of stereoscopic movies containing a luminance-defined object that is moving vertically in a frontoparallel plane or in a 3D space and asked subjects to estimate the 3D slant of the path of the moving object. It should be noted that we usually encounter this type of stimulus in a real life environment. When the eye movement of the observers was not disconjugate, their estimates of the 3D path of the moving target were nearly correct. On the contrary, when their eye movement was disconjugate, their perception of the 3D path was systematically distorted. This finding is in complete agreement with Li's finding and implies that eye movement-induced disparity is not compensated for with eye position information.

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I38 978 Moving eyes and moving thought: The spatial compatibility between eye movements and cognition

Laura E. Thomas[1] (lethomas@s.psych.uiuc.edu), Alejandro Lleras[1]; [1]University of Illinois at Urbana-Champaign

In a recent study, Grant and Spivey (2003) proposed that eye movement trajectories can implicitly impact cognition. In an "insight" problem-solving task, participants whose gaze moved in trajectories reflecting the spatial constraints of the problem's solution were more likely to solve the problem. The authors proposed that perceptual manipulations to the problem diagram that influence eye movement trajectories during inspection would indirectly impact the likelihood of successful problem solving by way of this implicit eye-movement-to-cognition link. However, when testing this claim, Grant and Spivey failed to record eye movements and simply assumed that their perceptual manipulations successfully produced eye movement trajectories compatible with the problem's solution. Our goal was to directly test their claim by asking participants to perform an insight problem-solving task under free-viewing conditions while occasionally guiding their eye movements (via an unrelated tracking task) in either a pattern suggesting the problem's solution (related group) or in patterns that were unrelated to the solution (unrelated group). Eye movements were recorded throughout the experiment. Although participants reported that they were not aware of any relationship between the tracking task and the insight problem, the rate of successful problem solving was higher in the related than in the unrelated group, in spite of there being no scanning differences between groups during the free-viewing intervals. This experiment provides strong support for Grant and Spivey's claim that in spatial tasks, cognition can be "guided" by the patterns in which we move our eyes around the scene.

I39 979 Mobile Phone Use in a Driving Simulation Task: Differences in Eye Movements

Stacy A Balk[1] (sbalk@clemson.edu), Kristin S Moore[1], Jay E Steele[2], William J Spearman[2], Andrew T Duchowski[2]; [1]Department of Psychology, Clemson University, [2]Department of Computer Science, Clemson University

Every year there are nearly 43,000 traffic fatalities and it is estimated that 25% of crashes involve some degree of driver inattention (NHSTA, 2005,2000). A recent survey revealed 21% of crashes/near crashes reported by respondents involved at least one driver using a mobile phone (Seo&Torabi, 2004). The current study examined the effects of mobile phone use on drivers' attention and eye movements in a low-fidelity simulator. Sixteen Clemson University undergraduate students viewed 24 driving scenarios and responded to questions about vehicular events in the scenes. Eight participants simultaneously performed a language learning task (simulating a mobile phone conversation). The language learning group answered fewer questions about the driving scenes correctly (M=9.3) than the non-language group (M=16). Overall, participants' cor-

rectly responded to more scenarios with 4 cars (M=7.3/12) than with 7 cars (M=5.3/12). The total number of fixations on the vehicle(s) involved in the critical event in each scenario was greater for the non-language group (M=471.7) than for the language group (M=300.5). Additionally, participants in the language group who answered the event question correctly spent the same percentage of the total time looking at the vehicle of interest during the event (M=13.5%) as those people who answered incorrectly (M=12.4%). This finding provides support for the 'look but fail to see' phenomenon. The mean duration of total fixations was also greater for people in the non-language group (M=9574.5ms) than the language group (M=6523.4ms). This study supports previous findings that increasing mental workload (through mobile phone use, and/or increased traffic) decreases driving performance.

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Face Perception: Adaptation and Aftereffects

I40 *980* Improved facial identity recognition following adaptation

Tamara L Watson[1] (tamaraw@psych.usyd.edu.au), Gillian Rhodes[2], Colin WG Clifford[1]; [1]The University of Sydney, [2]The University of Western Australia

It has consistently been shown that prolonged exposure to a face can affect subsequent perception of other faces. For example, prolonged exposure to a Chinese face can result in a face being rated as Caucasian that was previously rated as neither Chinese nor Caucasian but somewhere in between. This and similar face after-effects have been taken as evidence that individual faces are encoded as a deviation from the norm of the population of faces to which the perceiver has previously been exposed. It is thought that this adaptability ensures that we are most sensitive to variations within the range of faces by which we are currently surrounded. If this is the case, adapting to an average Chinese face should allow for better discrimination between other Chinese faces. Participants learnt to discriminate between either four Chinese or four Caucasian individuals. They were then adapted to either an average Chinese or Caucasian face for 5mins. Following adaptation, participants completed a forced-choice task asking them to identify the individuals previously learnt from test faces with identity strength ranging between 5 and 50% of the individual identity morphed with the corresponding racial average. Discrimination thresholds within a group of faces were lower after adapting to an average face from the same ethnicity than after adapting to an average face from the other ethnicity. A functional benefit can be gained by encoding faces in an adaptive norm-based manner whereby an observer's current diet of faces will be the ones to which they are most sensitive.

I41 *981* An Objective Measure of the Effect of Adaptation on Recognition of Famous Faces

Nathan Witthoft[1,2] (witthoft@mit.edu), Jonathan Winawer[1,2]; [1]MIT, [2]Stanford University

Adaptation to faces has been shown to influence judgments of normality, emotion, gender, race, and identity of subsequently viewed faces (Webster et al 1999, 2004; Leopold et al 2001). The general method used is to adapt subjects to a face at one extreme of a continuum and measure people's subjective reports of the aftereffect on neutral or average faces. Here we use an objective recognition paradigm to show that adaptation can help or hinder subjects in identifying famous faces. 2 unknown faces were each morphed with 4 different famous faces (8 morphs total). Stimuli were grey-scale photographs of faces circumscribed by ovals which masked the ears and hairline. Subjects either adapted to one of the unknown faces or did not adapt to a face (baseline condition). Test faces from the morphs were presented in blocks with the amount of famous face present in the test faces increasing as the experiment progressed. At no time before or during the experiment were subjects told the identity of the famous faces used in the morphs. Results showed that if adaptation was to the unknown face used to make a morph, subjects needed less of a famous face to be present in the morph in order to identify it, relative to no adaptation. However, adaptation to a face not present in a morph made recognition worse than baseline. A replication using new stimuli and subjects produced similar results. Implications of the findings for models of face spaces and recognition are discussed.

I42 *982* Face adaptation depends on gaze (overt attention) to the face.

Farshad Moradi[1] (farshadm@caltech.edu), Shinsuke Shimojo[1,2]; [1]Computation and Neural Systems, California Institute of Technology, Pasadena, CA, [2] JST.ERATO Shimojo "Implicit Brain Functions" Project, Japan

We studies gaze dependence of adaptation to faces and scenes using fMRI. Previous studies indicate face adaptation is non-retinotopic, but its gaze dependency has not been systematically examined. In Experiment 1 we demonstrated robust adaptation to foveal faces and scenes in FFA and PPA, respectively, using a psychophysical paradigm known to induce identity aftereffect: after 4 sec adaptation to a face(scene) followed by 0.8 sec blank, either a different, or an identical image of the same category (probe) was presented for 0.8 sec. Observers reported if adaptor and test are the same. A different probe evoked significantly larger BOLD response in FFA(PPA) than the same image. In Experiment 2, adaptor and probe were displayed in periphery (7.2 deg, same hemifield), and we measured BOLD activity in the contralateral area. Adaptation to faces, but not scenes, was considerably weaker than in Experiment 1. Experiment 3 examined whether gaze affects the adaptation phase, or the subsequent testing (probe). A foveal adaptor resulted in significant aftereffect in periphery. Almost no adaptation occurred when adaptor was peripheral and probe was foveal. No such dependency was found for scenes. The BOLD activities evoked by peripheral and foveal faces/scenes were about the same. Thus, different activation is ruled out as a confound. We conclude that adaptation to faces but not scenes depends on overt attention during adaptation. These results are unlikely to be due to the reduced resolution in the periphery as scenes contained more high-spatial frequency information than faces.

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I43 *983* Effects of Synthetic Face Adaptation: An fMRI study

Grigori Yourganov[1] (grigori@yorku.ca), Nicole D. Anderson[1], Hugh R. Wilson[1]; [1]Centre for Vision Research, York University

Previous psychophysical evidence suggests that face processing mechanisms can be adapted in an identity-specific manner. Moreover, the effect of adaptation critically depends on the identity strength of the test face, with faces closer to the mean being more affected than faces further from the mean (Anderson & Wilson, 2005). Here, we have studied the underlying neural processes of this identity-specific adaptation effect using an event-related fMRI adaptation paradigm. BOLD responses in the fusiform face area (FFA) were measured for synthetic faces with the same identity but at different distances from the mean using a 3T MRI system. Signals were assessed either without adaptation or after adapting to a strong (12%) anti-face (on the opposite side of the mean). As a control, responses were also measured for an irrelevant task (i.e. contrast judgements for a Gabor patch) using the same adaptation protocol as for the face-processing task. This allowed us to tease apart identity-specific adaptation effects on the BOLD signal from non-specific effects of the adaptation protocol. With no adaptation, the BOLD signal from the FFA showed no marked difference between the faces with different identity strengths. After adaptation, the BOLD responses to faces with identities closer to the mean face were lower than responses to faces with stronger identities. This pattern of responses is qualitatively similar to the pattern of results observed with different identity strengths using psychophysical methods, and may reflect the operation of a gain control mechanism subserving face perception.

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I44 *984* Gender Adaptation Effects Across Age-based Categories of Faces

Susan E. Barrett[1] (seb6@lehigh.edu), Alice J. O'Toole[2], Fang Jiang[2], Laura B. Chomiak[1], Alison L. Gray[1], David S. Highhill[1]; [1]Lehigh University, [2]University of Texas at Dallas

The generalization of adaptation effects across age-based categories of faces was examined using a gender classification task. On each trial, participants adapted to an adult male or female face for 5 s and then viewed a 300 ms presentation of a morphed face created from a different pair of male and female faces. The morphed faces were created from three different pairs of adult faces or from three different pairs of faces of 7 to 10 year old boys and girls. For each face, an ovular view of the internal regions of the face was presented so gender stereotypic cues, such as hairstyle, were not visible. Although gender markers are subtle in these faces, especially in the child faces, adults could accurately determine the gender of both the adult and child faces. Decisions about the intermediate morphed faces varied as a function of the adapting stimulus. After viewing an adult male, participants were more likely to perceive the intermediate morphed face as female. Conversely, after viewing an adult female, participants were more likely to perceive the intermediate morphed faces as male. This was true for both the adult and child faces. The present findings demonstrate that adaptation aftereffects generalize to new faces that are drawn from a different natural category than the set of adapting faces. These results suggest exposure to adult male and female faces may be important for defining the gender boundary in a different age-based category of faces.

I45 *985* The role of familiarity in view transferability of face identity adaptation

Fang Jiang[1] (fxj018100@utdallas.edu), Volker Blanz[2], Alice J. O'Toole[1]; [1]The University of Texas at Dallas, [2]Max-Planck-Institut für Informatik

The aftereffects induced by complex shapes like faces have provided insights into the nature of high-level visual representations. Previous studies have shown that face adaptation survives two-dimensional affine transformations. More recent studies report varying degrees of three-dimensional view-transferability for high-level aftereffects, with divergent interpretations (Jiang et al., in press; Jeffery et al., in press). The viewpoint transferability of face adaptation, however, may depend on the familiarity of the face—with more familiar faces having more robust representations (Roark et al., in press). In the present study, we tested the role of familiarization in the view transferability of face identity adaptation. During learning, we varied participants' experience with the original faces and their .35-level anti-caricatures. The familiarity manipulation consisted of three pure repetition conditions (2, 4, or 8 exposures) and one multiple-view presentation condition (4 exposures to the frontal view and 4 exposures to the 30-degree view). In all conditions, we measured the effect of "anti-face" adaptation on identifying anti-caricatures of faces (Leopold et al., 2001). We tested identification of faces from the .10-level anti-caricatures, both within and across-viewpoint. High levels of familiarity, developed from 8-exposure repetition and the multiple-view presentation conditions significantly improved the view-transferability of face identity adaptation. This indicates that a more robust representation of faces can be developed from familiarization, which in turn benefits recognition across viewpoints.

I46 *986* An inversion effect in face adaptation?

Maiko Yasuda[1] (maiko@unr.nevada.edu), Yoko Mizokami[1], Tamara L. Watson[2], Michael A. Webster[1]; [1]University of Nevada, Reno, [2]University of Sydney

Adaptation to a distorted face (e.g. expanded) induces a negative aftereffect (e.g. contracted) in the original face. Previous studies have shown that these aftereffects are comparable for upright and inverted images, but have not controlled whether the distortion itself shows an inversion effect. We directly tested whether differences in adaptation are tied to differences in recognition, by using a contingent aftereffect in which observers are simultaneously adapted to opposite distortions in two different faces (e.g. expanded face A vs. contracted face B). For distinct upright faces this leads to opposite aftereffects depending on face identity. We examined whether this contingency is reduced for two faces that become less distinguishable when inverted. Face pairs consisted of an original frontal-view image and a Thatcherized version with mouth and eyes rotated, changes which are very salient in upright faces while difficult to discern in inverted faces. Subjects adapted to a contracted version of one alternated with an expanded version of the other at a rate of 1 sec/image. A 2AFC staircase was then used to null the perceived distortions in either face. Upright faces showed a contingent aftereffect between the original and Thatcherized face. This effect was weaker for the inverted face pair, though not for all subjects, a difference which could reflect differences in which aspects of the images were used to judge the distortions. Such effects are consistent with the possibility that face adaptation can show an inversion effect when inversion reduces sensitivity to the stimulus dimensions controlling the adaptation.

I47 *987* Partial transfer of face viewpoint aftereffect across different individuals

Fang Fang[1] (fang0057@umn.edu), Kumiko Ijichi[1], Sheng He[1]; [1]Department of Psychology, University of Minnesota

After visual adaptation to an object viewed 30 degrees from one side, when the same object was subsequently presented near the frontal view, the perceived viewing directions were biased in a direction opposite to that of the adapted viewpoint. This aftereffect was termed the viewpoint aftereffect, and supports the existence of viewer-centered object representation in the human visual system (Fang and He, 2005). The current psychophysical experiment examined whether the face viewpoint aftereffect is sensitive to the identity of the adapting and test faces. Test faces were generated through morphing an original face towards the average face and through this dimension to its anti-face. Results show that there was a partial transfer of face viewpoint aftereffect across different individuals. The strength of face viewpoint aftereffect depended on the similarity of adapting and test faces. However, even when they were extremely dissimilar (e.g. adapt to a face, and test with its anti-face), there was still a substantial viewpoint aftereffect. In an fMRI face viewpoint adaptation experiment, we found both right fusiform face area (rFFA) and right superior temporal sulcus (rSTS) showed a viewpoint-tuned fMRI adaptation effect. Therefore, rSTS and rFFA could be the cortical areas in the human visual system which are responsible for the partial transfer of face viewpoint aftereffect across different individuals.

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I48 *988* Does familiarity play a role in producing viewpoint aftereffects with faces?

Jae-Jin Ryu[1] (jryu4@po-box.mcgill.ca), Avi Chaudhuri[1]; [1]Department of Psychology, McGill University, Montreal, Canada

Viewpoint aftereffects refer to the finding that after a prolonged exposure to the image of an object oriented to either the left or the right side (adaptor image), the perception of the image presented near the frontal view is biased in a direction opposite to the adaptor image (Fang & He, 2005). The aftereffects suggest that representations of visual stimuli are organized in a viewpoint-specific manner. The present study investigated whether qualitative or quantitative differences between representations of familiar and unfamiliar faces suggested in the literature on face processing can be reflected in differences in the viewpoint aftereffects. Familiarization of faces was achieved by presenting semantic information about each face, along with multiple images of faces presented at different viewpoints. Magnitude of the viewpoint aftereffects elicited by familiar faces was significantly greater than that induced by unfamiliar faces. In addition, when

the adaptor image was orientated to the left side, greater aftereffects were obtained, regardless of the degree of familiarity associated with the faces. The results indicate that familiarity exert influences on perceptual processes mediating the viewpoint aftereffects.

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URL: http://www.cvl.mcgill.ca

I49 *989* Is the "Face Aftereffect" Retinotopic or Spatiotopic?

Seyed-Reza Afraz[1] (afraz@fas.harvard.edu), Patrick Cavanagh[1]; [1]Department of Psychology, Harvard University

Selective adaptation to one face leads to systematic distortion in the appearance of subsequently presented faces, a phenomenon which has been called the "face aftereffect". Here we compared the strength of the face aftereffect when, following an eye movement, two adjacent test faces are presented, one at the same retinal position as the adapting face and the other at the same spatial position as the adapting face. The adjacent tests provide a direct measure of the relative strength of retinotopic versus spatiotopic effects and the results show that the retinotopic aftereffect is stronger than the spatiotopic aftereffect.

I50 *990* Face aftereffects and unattended faces

Janice E Murray[1] (jmur@psy.otago.ac.nz), Chen Yan[1]; [1]University of Otago

After adaptation to faces with contracted (or expanded) internal features, faces previously perceived as normal appear distorted in the opposite direction. These face aftereffects suggest that face-coding mechanisms adapt rapidly to changes in the spatial relations of face features and/or the global structure of the face. Previous work by Lavie et al. (2003) has shown that task-irrelevant faces are processed for identity regardless of the perceptual load in a task-relevant search task. This suggests that face processing is automatic and not dependent on general capacity limits. To what degree does face adaptation require attention? To answer this question, adaptation to ignored faces was tested under two conditions of perceptual load, low (two search items) and high (six search items). Before and after an adaptation phase, participants rated the normality of morphed distorted faces ranging from maximally contracted through normal to maximally expanded. In the adaptation phase, participants were presented with a vertical array of two or six letter strings flanked to the left or right by a face with maximally contracted features. Participants either attended to the adaptation faces, or ignored them and decided whether a target word in the array was a fruit or a vegetable. A reduced but significant face aftereffect was observed when adaptation faces were ignored, regardless of perceptual load. These results suggest that face adaptation, as a possible mechanism for rapid updating of what looks normal, occurs automatically and independent of general capacity limits.

I51 *991* Figural aftereffects transfer, but are also contingent on, race categories.

Emma Jaquet[1] (jaquee01@student.uwa.edu.au), Gillian Rhodes[1], William G. Hayward[2]; [1]The University of Western Australia, [2]The University of Hong Kong

Race is perceived categorically in faces. Clear boundaries separate faces perceived as belonging to one race category, e.g., Caucasian, and those perceived as belonging to another, e.g., African American (Levin & Angelone, 2002). We investigated the functional independence of these race categories by attempting to alter perception of faces from one race independently of another race. Participants were adapted to configurally distorted Chinese (or Caucasian) faces and tested for transfer of aftereffects to Caucasian (or Chinese) faces (Experiment 1). In the Experiment 2 participants were adapted simultaneously to Caucasian faces distorted one way, and Chinese faces distorted in the opposite way to determined if race-contingent aftereffects could be induced. Some transfer of aftereffects between race categories was found in Experiment 1. Perception of normality was systematically biased in the direction of the adapting distortion in most cases, regardless of which race was viewed during adaptation. In Experiment 2, perceptions of normality were biased in opposite directions for the two races. These results suggest that the perceptual system can update our face norms in a way that is insensitive to race categories. However, where a race distinction is made relevant, the perceptual system can selectively update the norms of each face category. These results present evidence that coding of race categories may rely on both shared and distinct neural populations.

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Neural Coding, Cortical Receptive Fields

I52 *992* From Spikes to Objects:How Multiple Levels of Thalamic and Cortical Interactions Control Visual Learning. Attention, and Recognition

Massimiliano Versace[1] (versace@cns.bu.edu), Stephen Grossberg[1]; [1]Department of Cognitive and Neural Systems, Boston University

How are multiple levels of brain organization coordinated to control visual learning, attention, and recognition? A realistic model of cortico-cortical and thalamo-cortical visual learning and information processing investigates how higher-order specific thalamic nuclei as well as nonspecific thalamic nuclei, such as the midline and intralaminar nuclei, interact with multiple cortical areas for this purpose. The model embodies detailed predictions about how the various layers of cortical and thalamic regions interact. It hereby proposes how synchronization of neuronal spiking occurs within and across multiple brain regions and thalamic nuclei and simulates the functional link between synchronization and spike-timing-dependent synaptic plasticity. The model is described in terms of spiking neurons that obey Hodgkin-Huxley type dynamics. Its operations explicate across multiple levels of description (biophysical, neurophysiological, field potentials, anatomical, and perceptual) operations from Adaptive Resonance Theory, in particular how bottom-up/top-down matches can lead either to attention, resonance, and learning, and how mismatches can cause reset and hypothesis testing. The model links data about cortical and thalamic neurophysiology and anatomy and single cell biophysics by explaining their role in realizing functional properties such as resonance/learning, reset/search, top-down attention, and synchrony. In particular, the model quantitatively simulates data on single cell biophysics, both cortical and subcortical, aggregate cell recordings (current-source densities and local field potentials), and single cell and large-scale oscillations in the gamma and beta frequency bands, while clarifying the functional meaning of different oscillation frequencies during visual learning, attention, and information processing. Supported in part by AFOSR, NSF and ONR

I53 *993* Brain without Bayes: Temporal dynamics of decision-making during form and motion perception by the laminar circuits of visual cortex

Praveen K Pilly[1] (advait@cns.bu.edu), Stephen Grossberg[1]; [1]Cognitive and Neural Systems, Boston University

Neurophysiological and fMRI experiments have probed how the brain makes decisions. Speed and accuracy of perceptual decisions covary with the certainty in the input image, and are related to the rate of evidence accumulation in parietal and frontal cortical "decision neurons" (Shadlen and Newsome, 2001; Roitman and Shadlen, 2002; Heekeren et al., 2004). Some modelers claim perception to be a form of Bayesian inference, which estimates an optimal interpretation of image data given priors and likelihoods. The Bayesian approach, however, uses classical statistical methods that do not explain the neocortical mechanisms that make the decisions. An emerging laminar model of visual cortex quantitatively simulates

dynamic properties of decision-making during form and motion perception. This LAMINART model embodies a new type of computation that goes beyond Bayesian methods. Model simulations illustrate how visual cortex may exhibit fast feedforward processing when visual data are unambiguous, and slower feedback processing to reduce uncertainty when several perceptual interpretations are possible. A tradeoff is shown between certainty and processing speed, leading to a new approach to speed/accuracy tradeoff data. These model cortical circuits embody a self-organizing system that does not need to compute the stationary probability distributions of Bayesian models while making real-time decisions. Instead, inhibitory shunting interactions within prescribed cortical layers exhibit self-normalizing properties which, together with long-range cooperative interactions, enable the cortex to carry out real-time probabilistic decision-making in which the amplitude and spatiotemporal distribution of cell activities covary with the certainty of the network's decision.

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I54 *994* A discrete-time feedback model can account for spike timing data in LGN

Janneke FM Jehee[1,2] (jehee@cs.rochester.edu), Dana H Ballard[1,2]; [1]Center for Visual Science, University of Rochester, [2]Department of Computer Science, University of Rochester

Evidence for the importance of spike timing is widespread. Synchronous activity has been revealed in single-cell recordings and EEG, and correlates with behavioral measures. Synchronous spikes are more effective in evoking a postsynaptic response, and synaptic plasticity critically depends on the precise timing of pre- and postsynaptic spikes. Yet, the standard view of neural coding holds that information is coded by spike rate, ignoring correlated patterns of neuronal activity. This rate code strategy is corroborated by a huge number of studies that reveal the correlation of increased firing rate with behavioral measures. How can these data be reconciled? We suggest that the cortex has adopted a signaling strategy that makes extensive use of spike timing for fast communication, but does it in a way that is consistent with the rate-code indications. Here, we show in simulations how this can be done. Specifically, we show that synchronous spike codes on both feed forward and feedback connections between cortical areas can be used to form oriented receptive fields given natural images as input. Moreover, we show that the decaying visual response of LGN neurons [1] is captured by our model, and that it critically depends on the model's feedback connections.The novel feature of our spike model is that it combines synchronous updating of an over-complete number of cells together with a probabilistic spike-routing strategy. These features allow the reproduction of synchronicity measurements as well as classical rate-code features. [1] Alonso, J-M., Usrey, W.M. & Reid, R.C. (1996). Nature, 383, 815-819.

I55 *995* Visual segmentation in a biomorphic neural network

Stefan Roth[1] (sro@ini.phys.ethz.ch), Daniel Kiper[1], Paul F. M. J Verschure[1]; [1]Institute of Neuroinformatics, University and ETH, Zurich

Based on our earlier work on the encoding of complex stimuli by cortical-networks (Wyss et al., 2003) we designed a neural network to classify visualstimuli. The transmission delays of the connections among the excitatoryneurons, which are proportional to length, result in a complex spatial andtemporal activity pattern when a visual stimulus is presented to the network.The pooled neuronal activity, or temporal population code - TPC, represents astimulus-specific fingerprint that is invariant to translations, rotations, andsmall distortions. The TPC thus allows a highly accurate and robust stimulusclassification in situations where a single target is presented to the network.However, classification fails when the scene also includes a closely positioneddistractor. We show here that by introducing dendritic attenuation in themodel, we are able to increase classification performance in the presence of adistractor, i.e. segmentation. Moreover, by combining codes of severalattenuation levels, we obtain a segmentation model that is robust and scalableboth with and without distractor.Hence, our results suggest that both dense lateral connectivity and dendriticstructure provide a complementary computational substrate for the encoding ofcomplex stimuli.This project is supported by the Swiss Federal Institute of Technology (ETH)Zurich.

I56 *996* Ruling out and ruling in neural codes

Sheila Nirenberg[1] (shn2010@med.cornell.edu), Adam Jacobs[1], Gene Fridman[1], Peter Latham[2], Robert Douglas[3], Nazia Alam[4], Glen Prusky[4]; [1]Department of Neurobiology, UCLA, Los Angeles, CA 90095, [2]Gatsby Computational Neuroscience Unit, University College London, London WC1N 3AR, UK, [3]Department of Ophthalmology and Visual Sciences, University of British Columbia, BC, Canada V5Z 3N9, [4]Canadian Centre for Behavioural Neuroscience, University of Lethbridge, Alberta, Canada T1K 3M4

One of the most pressing problems in systems neuroscience is determining what the neural code is. It has been known for many years that neural signals come in the form of spike trains, but it is not yet known what the unit of information is. E.g., do neurons use simple coarse codes, where the unit of information is just the number of spikes produced during some behaviorally relevant time interval, or do they use more complex, fine codes, where the unit of information is the single spike or some pattern of spikes? In the last several years, many codes have been proposed – coarse codes, fine codes, temporal correlation codes, cross correlation codes, etc. The array of candidates has grown as more and more studies have reported that different features of the spike train can potentially carry information. None of these studies, though, rule any of these codes out. Our aim here was to set up a strategy for doing this. We used as our model system the output cells of the retina. We recorded from all the output cells an animal uses to solve a task, evaluated the cells' spike trains for as long as the animal evaluates them, and used optimal (i.e., Bayesian) decoding. This approach makes it possible to get an upper bound on the performance of each code and eliminate those that are not viable. Our results show that coarse coding strategies are, in fact, not viable (even with pooling); finer, more information-rich codes are essential.

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I57 *997* The representation of visual features in the extrastriate cortex of the nocturnal New World monkey *Aotus*

Peter M. Kaskan[1] (peter.m.kaskan@vanderbilt.edu), Haidong Lu[1], Anna W. Roe[1], Jon H. Kaas[1]; [1]Vanderbilt University Dept. of Psychology

How are features of the visual world represented within the cortices of primates that have evolved under different ecological constraints? The second visual area (V2) of the nocturnal New World primate, *Aotus*, contains thin, pale, and thick cytochrome oxidase (CO) domains. Although the CO-domains of owl monkeys appear to be similar to those of macaque monkeys, the functions associated with these domains are uncertain. We used optical imaging to obtain functional maps of owl monkey V2, aligned CO-processed sections of the flattened neocortex to these maps, and placed injections of neuroanatomical tracers within V2. Maps of orientation preference in V2 reveal regions of high and low orientation selectivity. Orientation responsive domains are found in thick and pale CO-stripes. Regions of low orientation selectivity are centered upon thin CO-stripes. Regions of luminance modulation in V2 tend to lie between domains selective for orientation. Disparity may likewise have a modular organization involving thick stripes. The pattern of anatomical connections between stripes within V2 is non-specific, and implies the mixing of feature attributes within V2. In comparison, in macaque monkeys, surface features such as color and brightness are processed within thin stripes, adjacent to orientation selective thick and pale stripes. Our data indicate that there may be a similar functional organization for processing contours and surface features in owl monkeys. Though Old and New World primates have not shared a common ancestor in over 40 my, the organization of V2 in owl monkeys

and macaque monkeys is quite similar.

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I58 *998* Spatiotemporal dynamics of surround suppression in cat V1: stimulus-size and orientation-contrast

Satoshi Shimegi[1] (shimegi@vision.hss.osaka-u.ac.jp), Hiroyuki Kida[1], Ayako Ishikawa[2], Hiromichi Sato[1]; [1]Grad. Sch. Med., Osaka Univ., [2]Grad. Sch. Front. Biosci., Osaka Univ.

In the primary visual cortex (V1), a neuronal response to stimulation of the classical receptive field (CRF) is suppressively modulated by the stimulus presented at the receptive field surround (SRF). In this study, we examined stimulus-size tuning of neuronal responses (Exp.1), and tuning property of SRF effect on the orientation-contrast (OC) between CRF and SRF stimuli (Exp.2) in V1 neurons of anesthetized cats. Stationary flashes of sinusoidal grating were used as stimuli. In Exp.1, neurons were stimulated for 500 ms by varying diameters of circular grating patch with optimal orientation and spatial frequency for CRF response. The stimulus slightly larger than CRF size evoked strong suppression in early (40-80 ms) response, but not in late (> 80 ms) response. As stimulus size was enlarged further, the suppression of late response became strong while that of early response became moderate. In Exp.2, CRF was stimulated with a flash (500 ms) of the grating patch with optimal parameters and SRF was stimulated with a flash (50 ms) of the grating annulus with either iso- or cross-oriented to the CRF stimulus orientation. The late response was suppressed specifically by iso-oriented SRF while the early response was suppressed regardless of OC. Thus, size-dependency and orientation-specificity of the surround suppression changed dynamically in time, suggesting that a multiple mechanisms with different spatiotemporal characteristics are involved in the surround suppression.

I59 *999* Spatiotemporal dynamics of surround suppression in cat V1: spatial-frequency dependency

Ayako Ishikawa[1] (ishikawa@vision.hss.osaka-u.ac.jp), Satoshi Shimegi[2], Hiroyuki Kida[3], Hiromichi Sato[2]; [1]Grad. Sch. Front. Biosci., Osaka Univ., [2]Grad. Sch. Med., Osaka Univ., [3]Grad. Sch. Eng. Sci., Osaka Univ.

In the primary visual cortex (V1), a response to a stimulus in the classical receptive field (CRF) is suppressively modulated by a stimulus presented in the CRF surround (SRF). We examined the temporal dynamics of the response to CRF stimulation and the surround suppression in terms of spatial-frequency (SF) tuning of cat V1 neurons using stationary flashes of a circular sinusoidal grating patch (duration, 500ms) and an annulus (50ms) as CRF and SRF stimuli. In Experiment 1 (N=39), we stimulated CRF with grating patch of optimal orientation and varying SFs. The preferred SF shifted from low to high along time course of response. In Experiment 2 (N=48), CRF was stimulated with grating of optimal orientation and SF, while SRF was stimulated with grating of optimal orientation and varying SFs and stimulus-onset-asynchrony (SOA). SF tuning of surround suppression changed along time course of response, and effective SF of surround suppression shifted from the SF lower than that of CRF stimulus (CRF-SF) to that near CRF-SF. By changing SOA, we examined surround suppression on different temporal phases of CRF response. SRF stimulus only with low SF (<0.2c/deg) suppressed the initial phase of CRF response. These results suggest that multiple mechanisms with different SF- and temporal characteristics are involved in the surround suppression.

I60 *1000* Does map adjacency contribute to neuronal response construction in V2?

Benjamin M Ramsden[1] (bramsden@hsc.wvu.edu), Clinton G Cooper[2]; [1]Department of Neurobiology & Anatomy, and Sensory Neuroscience Research Center, West Virginia University School of Medicine, Morgantown, WV 26506, [2]Neuroscience Graduate Program, West Virginia University School of Medicine, Morgantown, WV 26506

What happens when two populations of visual cortex neurons, each with a particular (but different) stimulus preference, lie in close proximity? Does this adjacency simply lead to a local mixture of intervening neurons with different preferences? Or does it permit the construction of new integrated neuronal response, one that samples and then combines the characteristics of the two populations? To investigate the role that map adjacency may play in response construction, we have examined functional organization and single-unit response in selected locations of the second area of visual cortex (V2) of the macaque.Histological and functional evidence already suggest that a neuron's location within V2 may play some role in determining its stimulus preference and response characteristics. Histology has revealed thick, pale and thin stripe-like compartments that repeat across V2. Further mapping and electrophysiological studies have reported varying degrees of stimulus preference and functional organization associated with these different compartments. We applied intrinsic signal imaging and single-unit electrophysiology across multiple procedures. Guided by intrinsic signal maps, we targeted V2 locations for repeated electrophysiological sampling at borders of orientation domain-prevalent and domain-sparse zones. Our data support previous reports of clustered functional organization for orientation and color preference at these locations. Our high-density sampling reveal that neuronal clusters with disparate color or orientation preference can occur in relative proximity, sufficient to support inter-neuronal interaction and possible preference integration. We propose a cluster-based model for the investigation of parameters that may support integration via adjacency: connection density, preference strength and inter-cluster distance.

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I61 *1001* Comparison of color and luminance contrast response in V2 thin stripes

Haidong D. Lu[1] (haidong.lu@vanderbilt.edu), Gang Chen[1], Peter Kaskan[1], Anna W. Roe[1]; [1]Department of Psychology, Vanderbilt University

Both electrophysiology and functional imaging results suggest that V2 thin stripes are preferentially involved in processing of surface information, such as color and luminance. Optical imaging results have shown that there are different domains preferentially responsive to different hues and different directions of luminance changes. Electrophysiological recordings also show a mixture of cells selective for color, luminance or both. Consistent with these findings, we have shown that thin stripes exhibit higher luminance contrast gain than thick and pale stripes. It is unclear, however, what the organization of color and luminance signals within the thin stripe is, and whether they exhibit different contrast response.In this study, intrinsic signal optical imaging of area V2 in anesthetized macaque monkeys was used to reveal V2 thin stripe domains. Contrast responses of imaged domains within the thin stripes were quantitatively compared. Visual stimuli consisted of drifting horizontal and vertical sinusoidal gratings (isoluminant red-green or luminance), presented at different spatial frequencies and contrasts. We found that 1) Thin stripes can be preferentially activated (in contrast to thick/pale stripes) by low spatial frequency color stimuli at 10% contrast or lower. 2) Thin stripes are also preferentially activated by luminance gratings, but only at higher contrast levels. 3) Differential response to color and luminance (color-minus-luminance mapping signal) also increases with contrast.These findings support the hypothesis that thin stripes are preferentially involved in processing of color information and further support the differentiation of color and brightness signals within thin stripes.

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I62 *1002* Spatial frequency integration for stereo processing in macaque visual area V4

Hironori Kumano[1] (hkumano@bpe.es.osaka-u.ac.jp), Seiji Tanabe[2], Ichiro Fujita[2]; [1]Graduate School of Engineering Science, Osaka University, Japan, [2]Graduate School of Frontier Biosciences, Osaka University, Japan

Early in the stereo processing system, neurons compute the disparity energy of stereo images filtered by their receptive fields. While filtering is important for the initial encoding of binocular disparity, it is not sufficient to account for many aspects of stereopsis. This discrepancy is reduced if disparity energy signals are integrated across filters of multiple spatial scales. Here, we studied the convergence of spatial frequency channels in cortical area V4 of two awake, fixating monkeys. We first measured the spatial frequency tuning of neuronal responses to sinusoidal gratings or two-dimensional filtered noise images. We then examined the disparity tuning with both correlated and anti-correlated dynamic random-dot stereograms (RDSs) for each neuron. Neurons with broader spatial frequency tuning had more attenuated disparity tuning for anti-correlated RDSs. In a subset of V4 neurons, we analyzed responses to various combinations of binocular disparity and spatial frequency by using two-dimensional filtered noise stereograms. The preferred disparity of most V4 neurons was consistent across a wide range of spatial frequencies. The independence of preferred disparity to the spatial frequency of the stimulus critically differs from the prediction by the standard disparity energy model that have a phase disparity between their receptive fields in the left and right eyes. We propose that V4 neurons pool disparity energy signals across spatial frequency channels, and this spatial frequency convergence contributes to an unambiguous representation of stereoscopic depth.

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I63 *1003* MOTION COHERENCE HAS LITTLE EFFECT ON SURROUND SUPPRESSION IN AREA MT OF THE ALERT MONKEY.

J. Nicholas Hunter[1] (john_hunter@student.hms.harvard.edu), Richard T. Born[1]; [1]Department of Neurobiology, Harvard Medical School, Boston MA, USA

Many neurons in the middle temporal visual area (MT) of the macaque have suppressive surrounds that render wide field motion stimuli ineffective. In previous work we found that stimulus contrast had a profound effect on this receptive field property. Most MT cells that had strong suppressive surrounds at high contrast, had extremely weak or absent surrounds at low contrast (Pack et al., 2005). These results are consistent with perceptual observations (Tadin et al., 2005), as well as with information-theoretic models, which posit that the visual system uses inhibitory surrounds to reduce redundancy at high contrast, but spatially pool signals to maintain sensitivity at low contrast. We were interested to know whether such behavior would generalize to other conditions where high sensitivity would be beneficial, such as those produced by low motion coherence. We thus made similar size tuning measurements using stochastic motion stimuli (Britten et al. 1992) that allowed us to vary motion signal strength while keeping the contrast of individual dots high. In two alert macaques we found that low motion coherence stimuli activate as much surround suppression as high motion coherence stimuli. It appears that a small random dot stimulus, even one of low coherence, which is capable of eliciting spikes in center regions will also activate surround suppression mechanisms when increased in size and that suppressive influences are not always modulated when increased sensitivity is needed.

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I64 *1004* Impact of interhemispheric connections on orientation preference maps of the ferret

Kerstin E Schmidt[1] (schmidt@mpih-frankfurt.mpg.de), Stephen Lomber[2], Giorgio M Innocenti[3]; [1]Max-Planck-Institute for Brain Research, Frankfurt, [2]UT Dallas, Richardson, Texas, [3]Karolinska Institutet, Stockholm

Visual callosal connections extend between topographically corresponding regions in both hemispheres mainly representing the midline of the visual field (vertical meridian, VM). They are thought to extend preferentially between neurons of similar response properties and to integrate information from the two hemifields close to the VM. In ferrets as in other carnivores, the callosal zone expands extensively from the 17/18 border and covers a larger field than only the VM representation. In order to investigate the functional impact of callosal connections on neuronal responses in areas 17 and 18 of ferrets we reversibly deactivated visual areas 17, 18 and 19 in one hemisphere by the cryoloop technique. We chose loop temperatures (2°) known to deactivate all cortical layers because callosal connections in the ferret emerge from both, infra-granular and supra-granular layers. Before, during and after deactivation orientation preference maps in contra-lateral areas 17 and 18 were obtained by optical imaging of intrinsic signals while stimulating binocularly with moving iso-oriented whole-field gratings centered on the midline and extending up to 20° in both hemifields. Both the absolute level of activity as well as the specificity of responses were decreased in the absence of inter-hemispheric input by 13% (n=8). Our results suggest that callosal connections contribute to the strength and specificity of orientation responses in large parts of areas 17 and 18 representing the central visual field. These findings are compatible with callosal connections contributing to reconstruct complex visual stimuli which cross the boundaries of the visual hemifields.

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I65 *1005* Interhemispheric suppression: The case of the missing vertical meridian

Keith A. Schneider[1] (ks@rcbi.rochester.edu); [1]Rochester Center for Brain Imaging, University of Rochester, Rochester, NY, USA

IntroductionThe vertical meridian is apparently underrepresented in retinotopic maps of the human lateral geniculate nucleus (LGN), superior colliculus (SC) and cortex that are obtained using periodic stimuli and functional magnetic resonance imaging (fMRI). I hypothesize that this is a result of competition between hemispheres when representing bilateral stimuli.**Methods**Subjects' brains were scanned with a 3 T Siemens Trio scanner, using an 8-channel head coil (18 interleaved coronal slices covering the posterior thalamus and midbrain, TR = 2.5 s, TE = 42 ms, resolution 1.5×1.5×1.9 mm^3). During each scanning run, subjects viewed stimuli consisting of two complementary high-contrast flickering checkerboard patterns that alternated every 17.5 s. One pattern covered two quadrants of the visual field, sparing the vertical and horizontal meridians; the complementary pattern covered the opposite two quadrants. In Experiment 1, the two upper quadrants alternated with the two lower quadrants. In Experiment 2, pairs of diagonal quadrants alternated.**Results**When a checkerboard pattern was presented simultaneously with a corresponding pattern mirrored across the vertical meridian in Experiment 1, its fMRI response was suppressed 5-10% compared to that in Experiment 2, when no stimulus opposed it. The suppression was stronger in SC than in LGN. A simulation was performed to demonstrate that suppression of this magnitude is sufficient to account for the observed biases in retinotopic maps. **Conclusions**Responses to stimuli in human LGN and SC were suppressed during the presence of identical stimuli in the opposite visual hemifield. The observed hemispheric suppression can account for the apparent underrepresentation of the vertical meridian in retinotopic maps.

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Spatial Vision: Adaptation and Illusions

I66 *1006* Orientation Tuning of Visual Afterimages

Daniel R. VanHorn[1] (dvanhorn@purdue.edu), Gregory Francis[1]; [1]Purdue University

We conducted two experiments that explored the orientation tuning of a particular kind of afterimage induced by viewing two sequentially presented stimuli. Francis and Rothmayer (2003) and Francis and Schoonveld (2005) explained these types of afterimages using versions of Grossberg's

FACADE model (Grossberg, 1994). These versions of the FACADE model predict that if the second stimulus' orientation is not orthogonal to the orientation of the first stimulus no afterimage should be perceived. In our first experiment the first stimulus either consisted of a vertical bar grating or a horizontal bar grating. The second stimulus was a bar grating that flickered back and forth with its color complement and was orientated at various angles relative to the first stimulus. Subjects reported afterimages most often when the second stimulus was rotated 90 degrees relative to the first stimulus and rarely when the second stimulus was parallel to the first stimulus. Subjects also reported seeing afterimages for a range of intermediate orientations. In the second experiment, the first stimulus was a grid of horizontal and vertical bars and the second stimulus was a flickering bar grating that had been rotated at various angles, 0 to 90 degrees, from horizontal. Subjects reported vertically oriented afterimages when the second image was horizontal and horizontally oriented afterimages when the second image was vertical. When the second image was rotated 45 degrees from horizontal subjects reported seeing a grid afterimage. We discuss how variations of the model can account for the experimental findings.

I67 *1007* Time-course of recovery for the tilt after-effect

Michael J. Pianta[1] (mjp@unimelb.edu.au), Josephine Battista[1], Colin W.G. Clifford[2]; [1]Department of Optometry and Vision Sciences, The University of Melbourne, Victoria, 3010, [2]Department of Psychology, The University of Sydney, NSW, 2006

Aim: A recent model for the tilt after-effect (TAE) is based on two cortical adaptation mechanisms: centring, which can be thought of as adaptation to the centroid of the distribution of orientations; and scaling, which can be thought of as adaptation to variation along the orientation dimension (Clifford et al., 2000, *Proc R Soc Lond B Biol Sci*, 267:1705). We aimed to determine the time-course of recovery for these mechanisms after adaptation.**Methods:** For five subjects we measured the recovery of perceived orientation after adaptation to orientations between 0 and 90º (in 15º steps) relative to subjective vertical. Adapting stimuli were large 1 cycle/deg gabor patches, counter-phased at 1 Hz, and presented at 80% contrast for 30 s. Test stimuli were small 1 cycle/deg gabor patches presented at 50% contrast for 50 ms. Test stimuli were presented every 2 s over a period of one minute, starting 1 s after cessation of adaptation. Thirty runs of adaptation and recovery were performed, with an adaptive staircase procedure (psi) tracking subjective vertical at each time point.**Results:** Recovery data were well fitted using a model that assumed that the centring and scaling adaptation mechanisms recovered exponentially. The time constant for recovery was generally faster for the centring mechanism (6-20 s) than for the scaling mechanism (13-30 s).**Conclusion:** The different time constants for the centring and scaling mechanisms suggest that they are independent. These mechanisms may underlie the direct and indirect tilt aftereffects.

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I68 *1008* Grating adaptation influences the perceived length of an object.

Aurelio Bruno[1] (a.bruno@ucl.ac.uk), Alan Johnston[1]; [1]Department of Psychology, University College London, 26 Bedford Way, London WC1E 6BT, UK

The perceived spatial frequency of a sine grating is altered after adaptation to a higher or lower spatial frequency (Blakemore and Sutton, 1969, Science, 166 (902), 245-7). We investigated whether grating adaptation can also affect the apparent size of an object. We displayed a luminance-modulated sinusoidal grating for 30 seconds and then asked subjects to judge the relative length of two simultaneously presented lines, on either side of a central fixation point. One of the lines was displayed in the same spatial position as the adapting grating and its length was fixed across trials. The other line (whose length changed across trials) was displayed on the opposite side. The spatial frequency of the adapting grating was 2, 8, 16 or 32 cycles/deg and its orientation could be parallel or orthogonal to that of the lines. The length of the standard line was 25%, 50% or 75% of the spatial extent of the adapting grating. We observed that, when the orientation of the grating was parallel to that of the lines, the length of the standard line was constantly perceived as shorter than its actual length. The strength of this shortening effect was inversely related to the standard line length and it increased with adapting spatial frequency. Orthogonal gratings caused a similar shrinkage, but the effect was limited to mid to high spatial frequencies. We find that grating adaptation can affect subsequent length judgments even though there is little overlap in the spatial frequency content of the adaptation and test stimuli.

I69 *1009* A new twist to grid illusions

Michael W Levine[1] (mikel@uic.edu), J. Jason McAnany[1]; [1]University of Illinois at Chicago, Dept. of Psychology & Laboratory of Integrative Neuroscience

Several illusions depend upon a grid of rectangles separated by lighter alleys. In the Hermann grid, dark "smudges" appear in intersections; in the scintillating grid, black spots appear upon white disks in intersections. We described a phenomenon in which a white disk in an intersection vanishes completely. Lateral antagonism is hypothesized to play a major part in generating these illusions. However, if the alleys are curved these effects are abolished, requiring an alternative explanation. We verify the effect upon scintillation, and explore the effect of curvature on the vanishing disk. Since scintillation requires detectable disks, we needed to measure the threshold luminance of disks that scintillate such that subjects could not simply report detection. We devised a simultaneous staircase method in which subjects locate the strongest scintillation (or report none was present); each response adjusted the luminances of all four disks. This method was also used to determine visibility thresholds for disks. We confirmed the validity of the method by testing visibility with four interlaced traditional staircases.Curving the alleys not only raised the threshold for scintillation, but raised the detection thresholds of the disks themselves. Surprisingly, curvature also increased threshold for dark disks, which do not normally vanish. From these and related observations, we conclude that curved alleys render details (i.e.: disks) less visible. Lowered visibility would also apply to the smudges in the Hermann grid, and would preclude scintillation. Thus, the effects of curvature do not disqualify lateral antagonism as a contributing mechanism for the grid illusions.

URL: http://tigger.uic.edu/~mikel/

I70 *1010* Age-related changes in the blur aftereffect

Sarah L. Elliott[1] (slelliott@ucdavis.edu), Karin Schindler[1], Joseph L. Hardy[2], Michael A. Webster[3], John S. Werner[1]; [1]University of California, Davis, [2]Posit Science, [3]University of Nevada, Reno

Age-related changes in dark and light adaptation are well documented. However, less is known about how aging affects adaptation in higher-level visual mechanisms, such as form perception. Changes in adaptability with aging could result in either stronger aftereffects (e.g. greater fatigue) or weaker (e.g. reduced plasticity) depending on the mechanism of adaptation. To test for changes, we compared perceptual aftereffects following adaptation to blurred or sharpened images between younger adults (18 to 35 years) and older individuals (>65 years of age). Stimuli were 4-deg images of natural scenes filtered by multiplying the original amplitude spectrum by $f^{á}$, where f is spatial frequency and á was varied from –1 (strongly blurred) to +1(strongly sharpened). Subjects adapted to a sequence of blurred or sharpened images for 120 s, followed by a randomly chosen test image for 0.5 sec. A 2AFC task was used to vary the filter exponent of the test to define the subjective point of best focus. There was not a significant correlation between age and the level perceived as best focused in the null adaptation condition, or between age and the magnitude of the blur aftereffect. However, older subjects showed a smaller aftereffect for sharpened images. This difference may be due to lower sensitivity to the high spatial frequency information inherent in sharpened images. Our results suggest that the magnitude of spatial adaptation may remain stable with aging. In further tests we explore whether the temporal dynamics of the sensitivity changes also remain stable.

I71 *1011* **Chromatic Hermann Grid illusions occur with isoluminant stimuli**

James Comerford[1] (comerfordj@neco.edu), Frank Thorn[1], Elizabeth Garland[1]; [1]New England College of Optometry

Hermann grids with colored backgrounds have been found to induce illusory colored spots but not when the background and grid are isoluminant. However, Oehler and Spillmann found illusory spots for an isoluminant grid when the vertical and the horizontal bars differed in hue. We wished to quantify the strength of this illusion.8.3 deg grids with .4 deg wide bars were viewed from 57 cm. Four background hues were used. The vertical grid lines were continuous grey stripes while the horizontal lines were line segments with the color of the background (but different chroma), the complementary color (2 levels of chroma) or grey. An achromatic series of grids varying in luminance contrast was also presented. 10 subjects rated the strength of the illusion with reference to a five point scale.We found the illusion to occur with isoluminant grids with colored backgrounds and colored horizontal bars. When the background and the complementary colored lines of the isoluminant grid had equal chroma levels, the mean illusion strength was comparable to that for an achromatic grid with a contrast of .29. The illusion for the yellow background with blue and grey bars was significantly stronger (P = 0.0234) than for other color combinations. Reduced chroma reduced the strength of the illusion, but this was significant only for red/green stimuli. With grey bars the Hermann Grid illusion was virtually lost.We will discuss how the chromatic grid illusion might arise from a different mechanism than the achromatic illusion.

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I72 *1012* **Dichoptic transfer of a two-stimulus afterimage**

Justin Ericson[1] (justin.ericson@vanderbilt.edu), Greg Francis[2]; [1]Vanderbilt University, [2]Purdue University

We explored dichoptic transfer of an afterimage that requires presentation of a sequence of two inducing stimuli. Viewing a horizontal grating and then a vertical grating produces an afterimage of a horizontal grating, but replacing the vertical grating by a horizontal grating or a blank greatly reduces reports of afterimages. We investigated whether the afterimage transfers across eyes. Observers were shown a horizontal grating to the left eye. A subsequent vertical grating was then shown to either the left or right eye. The observer was then asked to judge the appearance of any afterimage using the left, right, or both eyes. Afterimage reports were most frequent (around 90% of trials) when the judgment was made with an eye that saw the first inducing stimulus. Reports of an afterimage were still common (74%) when the left eye saw only the first stimulus alone, which suggests dichoptic transfer. On the other hand, when the first and second stimuli were viewed with the left eye, but the judgment was made with the right eye, reports of afterimages dropped substantially (15%). Our results are generally in agreement with recent studies that emphasize a cortical component to afterimages, but are not easily explained by existing models. We interpret the data in terms of a model of neural visual processing that involves two types of after-responses: one is orientation based and combines information from the two eyes, the other is color based and includes both monocular and binocular information.

Gaze/Reference Frames

I73 *1013* **Post-perceptual locus for visual context effects: ERP evidence from the Rod and Frame Illusion.**

Jennifer E. Corbett[1] (jecorbet@psych.ubc.ca), Todd C. Handy[1], James T. Enns[1]; [1]The University of British Columbia

Visual context influences perceived orientation. To investigate where in the afferent stream of visual processing context has its modulatory effect, we asked participants to discriminate the orientation of a rod within the context of a frame. The frame was either tilted congruently with the rod (making the rod appear closer to upright, impairing orientation discrimination), or tilted incongruently (making the rod appear even more tilted than it actually was, facilitating orientation discrimination). Incongruently tilted rods increased both manual RT and P300 amplitude in most participants. For those who did not show an effect of tilt in RT, no similar modulation of the ERP waveform was observed. Our data suggest that visual context affects post-perceptual visual processing. The P300 has been implicated in stimulus evaluation to the extent that it triggers context-based updating (Donchin & Coles, 1988). From this perspective, the rod and frame illusion occurs during the contextual updating portion of processing, when the observer must reference the frame to help maintain the perception of scene stability in a dynamic world.

I74 *1014* **Bigger is better: Large visual displays improve spatial knowledge of a virtual environment**

Jonathan Z Bakdash[1] (jzb3e@virginia.edu), Jason S Augustyn[2], Dennis R Proffitt[1]; [1]University of Virginia, [2]U.S. Army Natick Soldier Systems Center

This study examined the effect of physical display size on spatial knowledge of a virtual environment (VE). Previous research by Tan (2004) found that performance for a path integration task in a VE was superior on a large display compared to a small one, even with visual angle held constant. This may be because large displays evoke a more egocentric frame of reference than small displays. To test whether the advantages of large displays extended to a navigation transfer task, the present studies examined the effect of display size on transferring knowledge about the spatial layout of a desktop VE to virtual reality (VR). Participants used a joystick to control their movement through a virtual city environment, finding and learning the locations of five targets separated by buildings. After 20 minutes of learning, participants' spatial knowledge was tested in a fully immersive environment by using virtual reality. Participants stood at each target location and pointed to each of the other, unseen targets. In the first study participants learned the VE on either an 18" LCD display or a 112" projected display. Visual angle was not equated. In the second study participants learned the VE on either a 24" or 72" projected display and visual angle was held constant. In both studies we found the average angular pointing error was significantly lower on the large display. Our results suggest that the advantage of a large desktop display for a virtual environment transfers to VR and is not dependent on visual angle.

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I75 *1015* **Coordinating saccades and smooth pursuit eye movements during visual tracking and perception of objects moving with variable speeds**

Krishna Srihasam[1] (sk@cns.bu.edu), Daniel Bullock[1], Steven Grossberg[1]; [1]Cognitive & Neural Systems, Boston University

How does the brain use eye movements to track objects that can move with variable speeds? Saccadic eye movements (SAC) foveate rapidly on peripheral visual or auditory targets and smooth pursuit eye movements (SPEM) keep an attended moving target near the fovea. During natural eye movements, SAC and SPEM are effectively coordinated. Analyses of tracking data in monkeys and humans (e.g., Rashbass, 1961; Van Gelder et al., 1995, 1997; Krauzlis & Miles, 1996, 1997; Tanaka et al., 1998; DeBrouwer et al., 2002; Gardner and Lisberger, 2002; Missal et al., 2002) reveal systematic deviations from predictions of the simplest model of SAC-SPEM interactions, which would use no interactions other than common target selection and recruitment of shared motoneurons. How are these two systems coordinated to promote effective visual localization and identification of moving targets? How do the systems interact so that the saccade is correctly calibrated to re-foveate a target while it is moving with variable speeds? A neural model of the interaction between the SAC and SPEM systems proposes answers to these questions. The model includes interactions of the following brain regions: motion processing areas MT, MST, FPA, DLPN;

saccade planning and execution areas LIP, FEF, SC; the saccadic generator in the brain stem; and the cerebellum. Model simulations illustrate its ability to quantitatively simulate behavioral deviations from predictions of the simplest parallel model, as well as its ability to functionally explain the anatomical, neurophysiological and behavioral data cited above

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I76 *1016* Initial hand position and movement direction affect reaching in a unilateral optic ataxia patient

Aarlenne Z Khan[1,2] (akhan@yorku.ca), Laure Pisella[2], Yves Rossetti[2], J Douglas Crawford[1]; [1]York Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Espace et Action, INSERM U534, 69676, Bron, France

We reported previously that optic ataxia (OA) resulting from posterior parietal cortex (PPC) damage results in deficits in the visuomotor transformation associated with a gaze-centered coding of reach targets (Khan et al., Nat Neurosci, 2005; Cer Cortex, 2005). Neurophysiological studies have shown that the PPC encodes both the movement goal and initial arm position in gaze-centered coordinates. This information could be used to calculate a desired movement vector (target position – hand position). To test this, we analyzed the effects of initial hand position and movement vector direction by measuring reaching accuracy of a right unilateral OA patient and neurologically intact controls while varying gaze (36° left to 36° right in 12° intervals), reach target (12° left, 0° and 12° right) and initial hand position (24° left, 0° and 24° right) while the head was fixed. Consistent with previous results, the OA patient's systematic errors varied as a function of reach target in gaze coordinates – greater errors when the reach target was in the affected compared to the unaffected visual field. In addition, reaching errors were also affected by the initial position of the hand relative to gaze. Finally, errors varied for different movement vectors when initial hand position and final reach target were both in the same visual field. We believe that these results are consistent with the notion that the PPC integrates the target and effector (e.g. the arm) position in a gaze-centered representation of space to compute the movement vector at this early stage in the visuomotor transformation.

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I77 *1017* Infants emerging ability to perceive gaze direction: Investigations with eye-tracking technology

Gustaf Gredebäck[1] (gustaf.gredeback@psyk.uu.se), Carolin Theuring[2], Petra Hauf[3]; [1]Department of Psychology, Uppsala University, Uppsala, Sweden, [2]Max Planck Institute for Human Cognitive and Brain Sciences, Munich, Germany, [3]Institute of Psychology, J. W. Goethe University, Frankfurt, Germany

The current study used a novel eye-tracking paradigm to investigate 5 to 12 month old infants' abilities to follow adults gaze direction. For that reason, infants were presented with movies in which a female model moved her eyes and head from a central location to fixate one of two toys presented on each side of her. The model always attended to the same toy but its location shifted between the left and right sides over successive trials. Infants gaze was simultaneously recorded with a Tobii 1750 eye tracker. The results show that infants' first gaze shift from the models face to either toy (after the model started moving gaze toward the toy) was directed to the attended toy in 3/4 of all trials at both 9 and 12 months of age. Six month old infants moved to the attended toy in 2/3 of all trials and 5 month olds performed at random without distinguishing the attended from the unattended toy. No long-term effects of the models gaze direction could be found. Infants looked equally long at the two toys following the first fixation. These results indicate that infants during the second half of the first year are sensitive to, and can follow, changes in the gaze direction of others. These young infants are, however, unable to make use of this information at a later time, even if the model is still attending to the same object.

I78 *1018* Evoked Brain Activity Distinguishes Looming From Other Optic Flow Patterns

Rick O. Gilmore[1] (rogilmore@psu.edu), Chuan Hou[2], Anthony M. Norcia[2], Mark Pettet[2]; [1]Department of Psychology, Penn State University, [2]Smith-Kettlewell Eye Research Institute

Humans discriminate approaching (looming) objects from receding ones shortly after birth (e.g., Ball 71), and looming motion may activate distinctive brain networks (Beer 02; Ptito 01, Wunderlich 02). We sought evidence for evoked brain activity that distinguished looming from other optic flow patterns. Adults viewed 20x20 deg patterns of optic flow produced by the motion of 1,025 7.2' white (105 cd/m2) dots on a black (5 cd/m2) background simulating a 1.5x1x1 m volume. The left/right pattern depicted lateral translation of the viewpoint at a simulated speed of .14 m/s. The rotational pattern depicted a +/- 17 deg rotation around the gaze axis. The loom/zoom display depicted forward/backward motion at 1 m/s. A full cycle of motion repeated at 1 Hz (F1), while the long lifetime (3 s) dots were updated at 30 Hz (F2). VEPs were recorded from five electrode sites (PO7, O1, Oz, O2, PO8) referenced to Cz, and Fourier spectra at integer harmonics of the two driving frequencies (F1 & F2) were extracted from the coherently averaged signals. The loom/zoom display evoked a larger first harmonic (1F1), especially over right hemisphere channels O2 and PO8, while the left/right display evoked both a larger second harmonic (2F1), and a larger dot update response (1F2). The larger 1F1 amplitude to the loom/zoom display suggests that cortical motion processing areas accord special status to optic flow specifying forward motion of the observer and distinguish it from backward, lateral, and rotational motion.

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I79 *1019* Microstimulation of the Frontal Eye Filed Evokes Kinematically Normal Gaze Shifts

J.A. Monteon[1,3] (jachin@yorku.ca), Hongying Wang[1,3], J.C. Martinez-Trujillo[4], J.D. Crawford[1,2,3]; [1]Centre for Vision Research, [2]Department of Psychology, [3]Department of Biology, York University, Toronto, Canada, [4]Department of Physiology, McGill University, Montreal, Canada

Electrical stimulation of the frontal eye field (FEF) in macaques that have their heads unrestrained (head-free) evokes gaze shifts composed of both, eye and head movements (Tu & Keating, 2000). This finding raises the following questions: 1) does the FEF encode gaze; 2) how do the eye and head contribute to these gaze shifts; 3) are the kinematics of the evoked movements similar to those occurring during natural behavior? Here, we addressed these issues by stimulating the right FEF of one head-free macaque and calculating the contribution of the head and the eyes to the elicited movements. Microstimulation trains (80 ìA, 300Hz, 200ms) were delivered during periods of fixation, the elicited gaze and head movements were recorded from 41 sites. Our results showed that: 1) the elicited gaze shifts ranged in amplitude (5° to 70°); 2) these gaze shifts were a combination of eye-in-head and head-in-space movements; 3) the directions of the evoked movements depended on the microstimulation site - directions of the evoked movements from medial sites were oriented downward and left, whereas more lateral sites showed upward-left directions; 4) in both, natural and evoked movements the head contribution to gaze increased as a function of gaze amplitude; 5) in both, natural and evoked movements the eye contribution to gaze increased linearly and reached a plateau at approximately 25° . In summary, these findings suggest that the FEF encodes gaze commands composed of eye and head movements that are kinematically indistinguishable from natural gaze movements.

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I80 *1020* Single-Pulse TMS Over Dorsal Posterior Parietal Cortex Disrupts Memory-Guided Pointing in Humans

Michael Vesia[1,3] (mvesia@yorku.ca), Jachin A. Monteon[1], Lauren E. Sergio[1,2,3], J.D. Crawford[1,2,3]; [1]Centre for Vision Research, [2]Department of Psychology, [3]Department of Kinesiology and Health Science, York University, Toronto, Canada

Previous studies suggest that the posterior parietal cortex (PPC) encodes reach-related activity in gaze-centered coordinates (Batista et al., Science, 1999; Medendorp et al., J. Neurosci., 2003). Does this gaze-centered signal encode the visual goal or the direction of the movement? A recent functional magnetic resonance imaging (fMRI) study suggests that following reversing prism adaptation; PPC activity remains tied to the reversed visual input rather than the direction of motor output (Fernandez-Ruiz et al. Soc. Neurosci. Abst., 2004). To further examine the output of PPC, we applied single-pulse transcranial magnetic stimulation (TMS) over the right dorsal PPC during a memory delay period while six subjects pointed to a remembered peripheral target. The TMS pulse produced a significant leftward (contralateral to stimulation) shift for pointing targets in both visual hemifields. Subjects then underwent a training session while wearing left-right Dove reversing prisms. After learning to correctly point to the optically reversed peripheral targets during the prisms training condition, subjects were retested on the pointing task while looking through the reversing prisms. Following prism adaptation, the pointing direction for a given remembered target reversed, but the direction of TMS shift did not change. These results suggest that a brief TMS pulse modifies the output of the right PPC in motor coordinates, rather than altering the visual coordinates of the memory representation upstream from the adapted visual-motor reversal. It also is plausible that this transformation occurs within a region in the PPC that encodes both visual and motor coordinates.

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I81 *1021* Frames of reference for gaze shifts in lateral intraparietal cortex (LIP)

A.G. Constantin[1,3] (alinagc@yorku.ca), Hongying Wang[3], Julio Martinez-Trujillo[4], J.D. Crawford[2,3]; [1]York University, Biology Dept,, [2]York University, Biology, Psychology, Kinesiology and Health Sciences, [3]Center for Vision Research, [4]McGill University, Psychology Dept.

Stimulation of LIP in head-restrained monkeys evokes saccadic eye movements (Thier & Anderson, 1996). These studies suggest that LIP encodes saccades in a head-fixed frame of reference. In contrast, single-unit studies suggest that LIP uses an eye-fixed frame. One goal of our study was to determine the reference frame for gaze shifts evoked from LIP in monkeys with head unrestrained. We microstimulated right LIP (using pulse trains of 300Hz, 150 ìA and 200 ms duration) and recorded 3D eye and head movements. Gaze shifts were consistently evoked at 205 sites, mainly in the up-left direction. Average gaze shifts (eye plus head) amplitude was 20 degrees, with the eye movement component predominant and the head movement component very small (< 1°). For the reference-frame analysis, we rotated gaze traces evoked from different initial eye and head positions into three coordinate systems (eye, head, and body), and computed gaze convergence in each of these frames, using two methods: ellipse fitting and convergence indexes computation (Trujillo et al. 2004). In all sites the distribution of gaze end-points was smallest (i.e. most convergent to a common point) when plotted in eye coordinates. This suggests that motor commands from LIP encode gaze in retinal (eye-fixed) coordinates, similar to the coding used by the visual inputs to this structure and its motor outputs to the superior colliculus (Klier et al. 2001).

I82 *1022* Visuospatial Contextual Processing in the Intraparietal Sulcus

Elizabeth Walter[1,2] (ewalter1@uoregon.edu), Paul Dassonville[1,2]; [1]University of Oregon, Department of Psychology, [2]University of Oregon, Institute of Neuroscience

When asked to judge the egocentric location of a target presented in the context of a large frame offset from the objective midline, the observer's report is typically biased in the direction opposite the frame's offset (that is, a target will be reported to lie to the right in the context of a left-shifted frame; the induced Roelofs effect, Bridgeman et al. 1997). Work in this lab has demonstrated that this illusion is caused by a distortion of the observer's egocentric reference frame, with the apparent midline pulled in the direction of the offset frame (Dassonville and Bala, 2004). The current study used fMRI to determine the brain areas responsible for processing the misleading contextual information. Subjects were asked to determine whether a small target was positioned left or right of midline in the presence of an offset rectangle designed to induce a Roelofs effect. We found localized, bilateral activations in the intraparietal sulcus (IPS) that were present only when subjects judged the target location in the presence of this shifted context; significantly less activation was present when the location judgment was made without a Roelofs-inducing frame, or when a color judgment was made with identical stimuli. We propose that this portion of IPS is selectively involved in processing visuospatial contextual information. Ongoing analyses will determine whether these regions of IPS are involved in actively processing the visual contextual information, or are instead more involved in suppressing this information (as would be required to accurately complete the location judgment task).

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I83 *1023* The radial orientation effect in human and non-human primates

Yuka Sasaki[1,5] (yuka@nmr.mgh.harvard.edu), Reza Rajimehr[1], Byoung Woo Kim[1], Tamara Knutsen[2], Leeland Ekstrom[1,4], Anders Dale[3], Wim Vanduffel[1,5], Roger Tootell[1,5]; [1]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, [2]Cal Tech, [3]UC San Diego, [4]HST, MIT, [5]Harvard Med School

Since stimulus orientation selectivity was first discovered in visual cortex, it has become well accepted that all orientations are represented in the cortical map, for each part of the visual field. However there have also been competing reports of a global variation in orientation sensitivity, specifically a bias for radial orientations (i.e. those that are collinear with a line intersecting the center of gaze). To test if there is a radial orientation bias in visual cortex, we systematically used human psychophysics, human fMRI, and monkey fMRI.Sensitivity to radial versus tangential orientations was measured psychophysically at 8 visual locations (upper-left, upper-vertical, upper-right, right-horizontal, lower-right, lower-vertical, lower-left, left-horizontal). Sensitivity was significantly higher to radial orientations than to tangential orientations in all subjects and locations. FMRI in both visual cortex of awake monkeys and humans showed results consistent with the psychophysics. FMRI activity was higher in the retinotopic representations of polar angle, which corresponded to the radial stimulus orientations. In a global demonstration of this, we activated complementary retinotopic quadrants of visual cortex by simply changing stimulus orientation, without changing its location in the visual field. The effect remained despite controls for attention. This evidence demonstrates a strong radial orientation bias in both human and monkey visual cortex, confirming a novel link between orientation sensitivity and the cortical retinotopy, which have previously been considered independent. This may indicate that orientation sensitivity is scaled according to a magnification factor, like that for other cortical receptive field properties.

I84 *1024* Gaze position effects and position-dependent motor tuning from primate superior colliculus (SC) neurons during head-unrestrained visually guided movements

Joseph F.X. DeSouza[1] (desouza@yorku.ca), Xiaogang Yan[1], Gunnar Blohm[1], Gerald P. Keith[1], HongYing Wang[1], J. Douglas Crawford[1]; [1]Centre for Vision Research, York University, Toronto, ON, Canada

Neural activity in the SC is highly correlated with gaze shifts composed of both eye and head movements (Freedman and Sparks, 1996; Munoz et al. 1991). Further, SC stimulation evokes eye and head gaze shifts that converge as a function of gaze amplitude and initial gaze position, consistent with an eye-fixed motor code for gaze (Klier et al. 2001). We hypothesize that SC neural activity correlates best with gaze target location in retinal coordinates. This predicts that the optimal directional tuning of SC neurons will change as a specific function of amplitude tuning and initial gaze

position (Smith and Crawford 2005). Electrical stimulation and/or visual receptive field examination are being used to estimate the optimal gaze amplitude and direction for each recording location. Monkeys randomly fixate one of three different initial gaze directions each separated by 20 degrees for 500 ms and then make their gaze shift to one of five visual targets placed along a semi-circle of iso-amplitude targets (centered around the position of the receptive field maximum for straight-ahead gaze). To date, we have recorded from thirty-two SC neurons that have been fully tested in the head-unrestrained paradigm. Initial analysis of these neurons show that SC neurons do indeed show strong initial gaze position dependent firing changes during head-unrestrained gaze shifts. Furthermore, a large majority of our SC neurons show a position-dependent modulation of their firing rates as a function of the initial gaze position as predicted by the Smith and Crawford (2005) model.

I85 *102* **Following the feeling: proprioceptive smooth pursuit revisited**

Marian E. Berryhill[1] (marianb@dartmouth.edu), Tanya Chiu[1], Howard C. Hughes[1]; [1]Dartmouth College, Dept of Psychological & Brain Sciences

Several previous studies have reported smooth pursuit to non-visual stimuli. We reexamined these claims using visual, auditory, proprioceptive, and touch stimuli. Subjects' eye movements were recorded using scleral search coils as they watched, heard, felt or moved a pendulum. Visual stimuli were pursued with high gain values and few small amplitude catch-up saccades. Auditory stimuli produced very low gains and rare instances of smooth pursuit. The proprioceptive condition, in which the subject held the pendulum and tracked its motion in the dark, produced short periods of smooth pursuit in some people. A tactile condition, in which the pendulum rolled along the subjects' arm, also produced limited segments of smooth pursuit. These two conditions were frequently interrupted by a significantly greater number of larger amplitude catch up saccades and reflected significantly lower gain values. These results force us to conclude that even under optimal circumstances it is not possible for proprioceptive or somatosensory stimuli to produce extended periods of smooth pursuit although isolated instances of smooth pursuit are observed. Not surprisingly, visual stimuli are unequivocally the best producers of smooth pursuit while auditory stimuli rarely elicit smooth pursuit.

Poster Session J

Tuesday, May 9, 2006

Goal-Directed Hand Movements (1025-1047), Attention: Other (1048-1059), Knowledge, Affect, Preference (1060-1074), Spatial Vision: Context and Space (1075-1087), Visual Representations in Memory (1088-1098), Reading (1099-1110)

Poster Session: 12:00 - 3:00 pm ***Municipal Auditorium***
Author presents: 1:00 - 2:00 pm

Goal-Directed Hand Movements

J1 *1025* Task-specific constraints shape the visual feedback control law used to control hand movements

Manu Chhabra[1] (mchhabra@cs.rochester.edu), David C Knill[2]; [1]Department of Computer Science, University of Rochester, [2]Center for Visual Science, University of Rochester

Purpose: We tested whether humans can shape the online feedback control law to take into account task-specific changes in the costs of different errors. Methods: Subjects pointed to a virtual button on a tabletop whose shape varied randomly from trial to trial between a square (1 cm x 1 cm) and a rectangle (1 cm x 6 cm) oriented either parallel or perpendicular to the direction between the start position and the button. Subjects viewed the button and a virtual rendering of their moving fingers through a horizontal mirror. On 25% of trials, the position of the virtual finger was perturbed by 1 cm in a direction parallel or perpendicular to the direction between the start position and the button when it went behind a virtual occluder. Results: Subjects corrected less for perturbations in the direction of the long axis of rectangular buttons than for perturbations in the direction of the short axis (50% to 80%). The differences in corrections showed up early in the movements – at most 200 msec. after the perturbations occurred. We derived optimal control laws for a model two-joint arm based on cost functions appropriate for the different button shapes. The behavior of the model qualitatively replicated subjects' behavior. Conclusions: Subjects are able to optimally shape the feedback control law used to correct errors online based on task demands. The changes are triggered on a short-time frame by the visual properties of the target and appear throughout a movement, not just in the end-phase.

J2 *1026* Visually based movement corrections: Evidence for a lower visual field specialization

Matthew Heath[1] (heathm@indiana.edu), Olav Krigolson[2]; [1]Department of Kinesiology and Program in Neuroscience, Indiana University, [2]Department of Psychology, University of Victoria

An anatomical disparity in the superior-inferior retinal axis (Curcio and Allen 1990) and an over-representation of the lower visual field (LVF) within constituent regions of the dorsal visual pathway is thought to underpin a functional bias in the processing of visual cues for goal-directed movements (Danckert and Goodale 2001; but see Binsted and Heath 2005). In the present investigation, we sought to determine whether this purported visual field asymmetry is linked to advantaged processing of visual cues for online error detection and correction mechanisms. Participant (N = 25) performed discrete reaching movements in the LVF and upper visual field (UVF) under a condition wherein target location remained stationary throughout the reaching trajectory and a separate condition wherein target location was unexpectedly perturbed at movement onset. We reasoned that the inclusion of an unexpected target perturbation might provide a novel means to assess whether reaches in the LVF implement more efficient and effective online movement corrections than their UVF counterparts. In terms of the impact of the target perturbation, participants readily modified their reaching trajectories commensurate with final target properties, that is, visual feedback was used for online error corrections. Interestingly, the manipulation of visual field did not influence the time-scale of unfolding reaching trajectories (i.e., equivalent movement times); however, endpoints for reaches in the LVF were less variable than their UVF counterparts. These finding highlight the importance of online and visually based movement corrections in the expression of a LVF advantage for visuomotor control.

J3 *1027* Feedback can be used to alter eye-hand coordination for rapid pointing

Anna Ma-Wyatt[1] (anna@ski.org), Martin Stritzke[2], Julia Trommershäuser[2]; [1]The Smith-Kettlewell Eye Research Institute, San Francisco, USA, [2]Department of Psychology, Giessen University, Giessen, Germany

In a natural environment, eye movements and hand movements are usually yoked. Humans are known to point more accurately if they have first saccaded to a visual target, even when it is no longer visible. Here we asked if observers can control the relative position of their eyes and hand to perform a rapid pointing task under risk. Observers pointed rapidly to a target region while avoiding a penalty region. Both regions were Gaussian blobs with sigma=0.5° and contrasts of 9% (target) and 17% (penalty), presented within a region 2-4° or 8-10° eccentric to initial fixation. If the touch landed within the target region, observers earned a reward (100 points), if it landed within the penalty region, points were deducted (0 to -500). Eye and hand movements were compared for two experimental conditions. In condition 1, observers received no feedback about their saccades. The average distance between the first saccade and the touch point was 1.5°. In condition 2 of the experiment, observers received feedback about the landing position of the first saccade. Observers received a penalty of -150 points if the distance between the saccade endpoint and the touch point was <1.5°. Observers were able to alter their performance in order to maximize their gain. In an accompanying paper, we present a model that defines optimal performance for eye-hand coordination under these conditions (Stritzke, Ma-Wyatt and Trommershäuser, submitted to VSS 2006).

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J4 *1028* Online action control and the influence of scene-based visual cues

Kristina Neely[1] (kaneely@indiana.edu), Matthew Heath[1]; [1]Department of Kinesiology and Program in Neuroscience, Indiana University.

We recently demonstrated that the Müller-Lyer (ML) figures reliably influ-

ence the online reorganization of goal-directed reaching movements (Heath and Neely 2005). Stemming from that previous work, the present investigation was designed to determine whether biased ocular-motor interactions impact visuomotor susceptibility to the ML figures. Participants were instructed to maintain visual fixation on the right vertex of neutral, fins-in, and fins-out ML figures while completing reaching movements to that vertex position. In one condition (i.e., experimental trials), the neutral ML figure was presented in advance of reaching movements and, on a percentage of trials, was changed to an illusory ML configuration at movement onset. In a second condition (i.e., the control trials), neutral, fins-in and fins-out ML figures were presented in advance and during reaching movements. Notably, and unlike previous work involving ocular-motor interactions and the ML figures (e.g., Binsted and Elliott 1999), the present work manipulated stimulus configuration at movement onset - thus providing a context to examine the extent to which scene-based visual cues influence online action control. We found that the early and late kinematics of control and experimental trials were biased in a direction consistent with the perceptual effects of the ML figures: a finding irrespective of the presence of continuous visual input from the limb. These results counter the view that biased ocular- and manual-motor interactions drive visuomotor susceptibility to the ML figures. Rather, the current findings suggest biased motor output stems from the integration of scene-based visual cues for online action control.

J5 *1029* Optimality of eye-hand coordination for different types of feedback about saccadic accuracy

Martin Stritzke[1] (martin.stritzke@psychol.uni-giessen.de), Anna Ma-Wyatt[2], Julia Trommershäuser[1]; [1]University of Giessen, [2]Smith-Kettlewell Eye Research Institute, San Francisco

We present a model that defines optimality of eye-hand coordination in a task in which subjects receive feedback about the landing position of the hand and about the relative distance between the landing position of the first saccade and the hand. In condition 1, feedback was only provided for the finger landing position. Subjects were awarded if they hit inside a visually specified target region and lost points if they hit a nearby penalty region. In conditions 2 and 3, additional feedback was provided about the relative distance between eye and finger position. In condition 2, subjects received a penalty if their first saccades landed beyond a distance of 1.5 degrees from the finger end point. In condition 3, subjects received an additional penalty if their first saccades landed within a distance of 1.5 degrees relative to the finger end point.Optimality was computed based on subjects' motor and saccadic end point variability, similar to optimal performance as defined for rapid pointing under risk (see Trommershäuser, Maloney, Landy, JOSA, 20, 1419). In condition 2, our model suggests an identical end point for the 1st saccade and the hand in order to maximize expected gain. In condition 3, optimal eye-hand coordination implies avoiding the penalty with the finger and simultaneously shifting the first saccade away from the visual target. Our experiments indicate that subjects follow an optimal strategy in condition 2, but fail to do so for condition 3 (see Ma-Wyatt, Stritzke, Trommershäuser, submitted to VSS 06, for results and experimental details).

Acknowledgment: Acknowledgments: This work was supported by the Deutsche Forschungsgemeinschaft (Emmy-Noether-Programm, Grant TR 528/1-2)

J6 *1030* Sensori-motor choices based on a rapid judgment of expected gain

Julia Trommershäuser[1] (julia.trommershaeuser@psychol.uni-giessen.de), Michael S. Landy[2], Laurence T. Maloney[2]; [1]Department of Psychology, Justus-Liebig-University Giessen, Germany, [2]Department of Psychology, New York University, and Center for Neural Science, New York University

In motor tasks with explicit rewards and penalties, humans choose movement strategies that nearly maximize expected gain (Trommershäuser et al., 2003, *JOSA, 20,* 1419). Here, we explore the link between movement planning under risk and decision making. Subjects rapidly selected one of two goals differing in expected gain. Goal configurations consisted of a target and nearby penalty circle. Hits on the target led to a monetary bonus; penalty hits incurred a cost. Late responses were penalized. Target/penalty pay-offs and spatial arrangement were varied. Subjects ran a training session, followed by a session in which they pointed at a single goal configuration. This was followed by four sessions in which subjects selected one of two goal configurations, either by pointing at one configuration or by key press. Payoffs for key presses were scored based on the performance in the previous pointing sessions. Six subjects completed the experiment. Movements to select one of two goal configurations did not differ from movements directed at a single configuration. Subjects preferred configurations with higher expected gain whether selection involved a pointing movement or key press. Choice probabilities were best fit by a model that assumes a non-linear scaling of maximum expected gain corrupted by additive noise. We conclude that movements under risk rely on a rapid judgment about the expected gain and that subjects base this judgment on an internal estimate of expected gain that is a non-linear function of actual expected gain.

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J7 *1031* Do humans generate a representation of their pointing variability?

Marc O. Ernst[1] (marc.ernst@tuebingen.mpg.de), Julia Trommershaeuser[2]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, Germeny, [2]Giessen University, Giessen, Germany

Humans have been shown to perform close to optimal when executing speeded pointing movements under risk (Trommershaeuser et al., 2003). Therefore, they either need to know their own variability in the execution of pointing movements or they need to adapt a strategy, possibly making use of repeated feedback, that allows them to adjust their performance accordingly. The purpose here was to test whethersubjects generate an explicit representation of their pointing variability.Subjects rapidly pointed toward a target region; hitting this region was rewarded by points. A penalty zone was presented with a small offset relative to the target. Subjects lost points for hitting the penalty region. We used a mirror-setup to manipulate subjects' pointing variability by adding two-dimensional bivariate (elliptic) Gaussian noise to their pointing response with either a large variance in x-direction and small in y, or vice versa. During training, subjects repeatedly pointed at target/penalty configurations that only varied with respect to the offset in x-direction. To behave optimal during training only the pointing variance in x-direction is relevant. Following training, we performed a test by sporadically introducing target/penalty configurations with an offset in y-direction. Only if subjects learned also the pointing variance in y-direction during training they perform optimal during test. Subjects shifted their end points away from the penalty region if pointing variability increased. This behavior was observed in x-direction during training, but also in y-direction during test. This transfer from training to test indicates that subjects have an explicit representation of their pointing variability.?

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J8 *1032* Optimality of reach timing under risk

Todd E Hudson[1,2] (hudson@cns.nyu.edu), Michael S Landy[1,2], Laurence T Maloney[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Timing is a crucial component of movement planning and control. We examined human performance in timed reaching tasks where there were asymmetric penalties for arriving early or late. An ideal movement planner based on statistical decision theory takes into account rewards, penalties and its own temporal uncertainty in movement to maximize expected

gain. Such a planner responds to changes in rewards/penalties by shifting its mean arrival time by predictable amounts. We compare each subject's performance in a timed reaching task to that of an ideal movement planner with the same timing uncertainty. *Methods*: Subjects pointed at spatial targets (1 cm radius circles) on a screen. Target location was chosen from a set of positions ~43 cm from the starting point of the reach. On each trial, subjects were given a brief temporal target zone (center: 650 ms), indicated by a green region on a timer bar, and a temporal penalty zone preceding or following the target (red region on timer bar). Touching the spatial target within the temporal target zone earned a reward; touching within the temporal penalty zone incurred a loss. Each of three subjects completed 256 trials across four different reward/penalty conditions. Subjects were instructed to earn the greatest reward possible.*Results*: The standard deviation of reach duration increased linearly with mean arrival time. The regression line relating mean reach durations and predicted optimal durations had a slope of .98 and r^2 of .90. Human performance was not distinguishable from optimal performance maximizing expected gain.

Acknowledgment: NIH EY08266

J9 *1033* Suboptimal movements under risk due to experimentally imposed anisotropic variability

Hadley Tassinari[1] (HadleyTassinari@nyu.edu), Todd E. Hudson[1,2], Michael S. Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Current research shows that subjects are nearly optimal in movement planning under risk; they appropriately take into account task-relevant response variability. However, none of these studies has directly manipulated movement variability. Here, we investigate whether participants respond appropriately to increased movement variability and to non-isotropic variability.

Methods: Participants pointed rapidly at a small target circle next to a penalty circle. Hits on the target yielded rewards; hits on the penalty region incurred a loss. Points won and lost were converted to monetary gains/losses, possibly increasing the subject's payment. Twelve orientations of relative target and penalty location were tested (every 30°). In some sessions, movement variability was manipulated by inducing the tonic stretch reflex through mechanical vibration of the triceps surae.

Results: Variability of movement end points was fit with a bivariate Gaussian. Vibration increased endpoint variability and resulted in an eccentric covariance ellipse. Agreeing with previous findings and predictions of an optimal movement planner that maximizes expected gain (Trommershaeuser et al., J Opt Soc Am A 20:1419-1433, 2003), subjects shifted movement end points farther away from the penalty region as penalty magnitude increased. The ideal movement planner should also shift farther with increased variability and when the target-penalty axis aligns with the long axis of the covariance ellipse. While most subjects shifted farther from the penalty region with increased movement variability, they did not adjust aim points appropriately in response to anisotropy in endpoint variability.

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J10 *1034* Humans trade off speed and accuracy to maximize expected gain in planning movements to targets that rapidly decrease in reward across time

Shih-Wei Wu[1] (sww214@nyu.edu), Mark Dean[2], Laurence T Maloney[1,3]; [1]Department of Psychology, New York University, [2]Department of Economics, New York University, [3]Center for Neural Science, New York University

We investigated how humans plan the timing of movement in a pointing task where the reward structure of the environment changed rapidly over time. On each trial, a 9mm target disk was presented at a random location on a touch monitor. Subjects were rewarded for touching the disk, but its reward value decreased linearly over time. To maximize earnings, subjects had to plan movement to balance their increasing chance of hitting the target against the decreasing value of doing so.In order to calculate optimal strategy, we first estimated each subject's speed-accuracy tradeoff function in a preliminary experiment, measuring performance in hitting the target with each of four different time limits (400, 600, 800, 1000 msec). Subjects were rewarded for hitting the target within the time limit. Using this data (480 trials per subject), we could predict what subjects must do to maximize expected gain. In the main experimental session no time limit was imposed and subjects could choose how quickly to move. Immediately after a target was presented, its value started to decrease at one of two rates (blocked), indicated to the subject by the length of a bar on the screen. Four naïve subjects participated (320 trials per subject). All subjects shifted the timing of their movement in response to the rate at which target value decreased. Subjects' movement timing came close to maximizing expected gain, measured both in efficiency and in choice of timing. We conclude that humans compensate for their own speed-accuracy tradeoff in planning movements.

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J11 *1035* Movement planning under risk differs from decision making under risk in how subjects make use of probability information

Laurence T Maloney[1,2] (ltm1@nyu.edu), Shih-Wei Wu[1], Maria F Dal Martello[3]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of General Psychology, University of Padova

Trommershäuser, Maloney & Landy (JOSA, 2003) studied performance in tasks that were formally equivalent to decision making under risk. They found that subjects' planned movements nearly maximized expected gain, a result inconsistent with the decision making literature. Here we replicated a decision making experiment (Wu & Gonzalez, Management Science,1996) that tested whether subjects correctly use probability information in choosing between lotteries. We replicate the original experiment with the probabilities of outcomes *explicitly* given in the lotteries and we also replicated the experiment with each lottery translated into an equivalent motor task ("motor lottery") where the probability of each outcome is *implicit* in movement uncertainty. We will describe how we measured subjects' movement uncertainty and designed an equivalent motor lottery for any given lottery. Each subject ran the implicit and explicit conditions in counterbalanced order. **Task:** On each trial in both conditions subjects indicated which lottery/motor lottery they preferred (2AFC). They knew that, at the end of the experiment, they would be allowed to attempt only one of their preferred explicit lotteries and one of their preferred implicit motor lotteries chosen at random and receive the outcome. **Results:** All subjects failed to correctly use probability information or maximize expected gain in the explicit condition, consistent with Wu & Gonzalez. Five out of eight of these subjects made choices consistent with maximizing expected gain in the implicit (motor lottery) condition. The results indicate that planning rapid movements differs qualitatively from classical decision making in how subjects make use of probability information.

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J12 *1036* Humans store the relationship between their eye position and the visual reliability of familiar targets

Erik J Schlicht[1] (schl0360@umn.edu), Paul R Schrater[1]; [1]University of Minnesota

Humans can easily pick-up objects in the absence of any visual information when they are in a familiar and relatively invariant environment. In this case reach plans are based on a stored representation of the object, but the nature of this representation is unclear. One possibility is that the brain integrates relatively recent non-visual sensory information (e.g. touching the object). Alternatively, the brain could rely on previous visual experience in generating reach plans. To distinguish these possibilities, we used recent results from Schlicht & Schrater (VSS, 2005) that reach plans to

visual targets vary with eccentricity. Subjects repeatedly reached to a spatially fixed cylinder while fixating different points. Approximately one week following visual trials, we removed all the visual information about the target and hand but still required subjects to fixate different points (*Blind Condition*). Note that there is no sensory information about the target's location available until contact, requiring participants to use a stored target representation for reach planning. If subjects rely on previous visual experience to generate reach plans, it would predict a linear MGA (maximum grip aperture) profile with eccentricity (VSS, 2005). Conversely, if subjects rely on recent touch information, reach plans would not vary linearly. Surprisingly, subjects in the Blind Condition displayed a linear MGA trend, consonant with the former prediction. These results suggest that the brain may be using eye position information during reach planning to *predict* the target's visual reliability, and that this stored association is resistant to decay over time.

J13 *1037* The Kalman Filter as a model of visuo-motor adaptation behavior

Johannes Burge[1] (jburge@berkeley.edu), Marc O Ernst[2], Martin S Banks[1,3]; [1]Vision Science Program, University of California, Berkeley, CA, USA, [2]Max-Planck Institute for Biological Cybernetics, Tuebingen, Germany, [3]Helen Wills Neuroscience Institute, University of California, Berkeley, CA, USA

When the introduction of a prism makes visually guided reaching biased and inaccurate, adaptation occurs to restore accuracy. Baddeley et. al. (2003) suggested that bias in everyday life more often accumulates from a series of small changes, a process well simulated with a random walk. If bias were the only source of error, recalibration would be simple: correct the last error. But reaching behavior is also subject to random error. Does the visuo-motor system efficiently balance the need to filter random error with the need to adapt to time-varying bias? We investigated whether the Kalman filter, the optimal algorithm for this problem, is a good model of visuo-motor adaptation. The filter predicts that adaptation rate will be determined by the relative variances of current measurements and of changing bias: rate should decrease with increasing feedback variance and *increase* with increasing walk variance. We tested these predictions with a pointing task. Subjects pointed rapidly with an unseen hand to a brief visual target. Visual feedback indicated where the point ended. We blurred the visual feedback to increase its variance. The relationship between the actual point location and the location of the visual feedback was altered with a random walk. As the subject adapted, we measured trial-by-trial pointing to determine the adaptation rate. Adaptation rate decreased with increasing blur and increased with increasing variance of the random walk, in good agreement with the Kalman filter model. Additionally, ideal observer analysis showed subjects performed with a high level of efficiency.

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J14 *1038* Effect of visual adaptation on arm kinaesthesia

Teser Wong[1] (teser@yorku.ca), Denise Y.P. Henriques[1]; [1]School of Kinesiology & Health Science, Centre of Vision Research, York University, Toronto, Canada

How do multiple senses interact to guide motor learning? We know that vision can override other senses; e.g. when subjects reach along a straight path but their vision is distorted so they see their hand curving rightward, they come to move the hand along a leftward-curving path that looks straight. But does vision simply overrule the kinaesthetic sense of hand path, or does it recalibrate it so that curved paths also feel straight? We measured subjects' sense of hand path curvature using a task developed by Henriques & Soechting (2003). In one experiment we then distorted the subjects' visual feedback of their unseen hand, so they learned to move the hand along a curve in order to produce a straight-looking path, and then we tested for changes in kinaesthetic sensitivity. Half of the subjects showed a moderate change in their kinaesthetic sense of curvature in the same direction as the distorted vision, while the other half showed no significant change. In another experiment we tested subjects' kinaesthetic perception of circularity, then distorted their visual feedback so they learned to move their unseen hand along an elongated ellipse to move a cursor along a circle. When we retested their kinaesthetic sense of circularity, nearly all the subjects misjudged the circle in the direction of the visual distortion. These results suggest that the visual error signals that drive adaptation in a motor system also recalibrate other relevant senses, perhaps to keep them consistent so they can cooperate effectively.

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J15 *1039* Can subjects with visual impairment scale object size and distance accurately when reaching and grasping under different viewing conditions?

Carmen Gonzalez-Alvarez[1] (c.gonzalez@apu.ac.uk), Ahalya Subramanian[1], Shahina Pardhan[1]; [1]Anglia Rusking University

Purpose: It has been shown that reach-to-grasp movements are affected by reduced visual information. We investigated prehensile movements in subjects with visual impairment under different experimental conditions.Methodology: 15 visually impaired subjects (Mean VA= 1.23 LogMAR) participated. Prehensile movements were measured under binocular and monocular viewing using two object sizes and two object distances. The object to be grasped was white, black, or transparent placed on a black table against a white wall. Vicon-460 motion analysis system recorded and reconstructed the 3D hand and fingers movements. Kinematic indices were obtained for transport and grasp components. Results: Repeated measures analysis of variance showed that object size affected the grasp component, and object distance affected the transport component. As expected, maximum grip aperture was larger with increasing object size ($p<0.05$). Maximum velocity and overall movement duration increased with increasing object distance ($p<0.05$). We also found that visually impairment subjects opened their hand wider when objects were closer ($p<0.05$). No significant differences were found between binocular and monocular viewing ($p>0.05$). When comparing the effect of object colour-contrast it was found that the transport component was affected, but the maximum grip remained similar for the different object colours. Movement duration increased and subjects opened their hand earlier when they were required to grasp a transparent object compared to a white one ($p<0.05$).Conclusions: Results demonstrate that there is a break down in size constancy in subjects with visual impairment. Data are modelled with respect to visual acuity and contrast sensitivity in subjects with low vision.

J16 *1040* REFERENCE FRAME CONVERSIONS FOR VISUALLY-GUIDED ARM MOVEMENTS

Gianluca U Sorrento[1] (sorrento@yorku.ca), Denise Y.P. Henriques[1]; [1]School of Kinesiology and Health Science, Centre of Vision Research, York University, Toronto, Canada

Visual object locations are stored in an eye-fixed frame until they are chosen as targets for an action, such as pointing. But is the location converted to an arm-related representation which persists and is used for subsequent actions involving that object, or is the object reconverted from an eye to an arm frame afresh for each movement? Subjects began by looking at a peripheral, fixation spot, while pointing to a briefly-presented target. After they finished pointing, subjects looked at a second fixation spot (on the opposite side of the target) and pointed to the same remembered target. How did errors compare in first and second pointing movements? If subjects convert from the eye frame for each movement, they should make similar errors, with respect to the eye (reconversion hypothesis). But if subjects convert just once for both movements, they should make similar errors, with respect to the torso (motor-memory hypothesis). We found that subjects tended to err in the same direction relative to the torso on their second movement as on their first, consistent with the motor-memory hypothesis. But one subject erred in the same direction relative to the eye,

consistent with the reconversion hypothesis. We conclude that most people convert an object just once from the eye frame of visual memory to a frame more suited for motor control, and they use that converted representation for subsequent motor planning. But individuals may use different strategies, some referring back to the original eye-fixed frame and converting afresh before each action.

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J17 *1041* Depth information is integrated across multiple objects for reaching and grasping.

Peter Scarfe[1] (ps18@st-andrews.ac.uk), Simon J Watt[2], Paul B Hibbard[1]; [1]School of Psychology, University of St Andrews, Scotland, UK, [2]School of Psychology, University of Bangor, Wales, UK

The accuracy with which three-dimensional shape is perceived can in principle be improved by integrating information across extended regions of the visual scene. Psychophysical studies have shown that the 3-D shape of a static object is perceived more accurately when both motion and stereo information are available in a second object in the scene (Landy and Brenner, 2001), but only when the two objects are the same size, and presented at the same distance. There is therefore little evidence that stereo-motion combination provides a distance estimate to scale other aspects of the visual scene. We used a simple prehension task to investigate whether the presence of another object altered the apparent shape and distance of an object to be grasped. Participants grasped a static, binocularly-viewed elliptical cylinder, presented alone or in the presence of a second cylinder. This flanking object was either static or rotating, and was viewed either monocularly or binocularly. The presence of the flanking object had a significant effect on both grip apertures and wrist velocities of reaches to the target object. The direction of this effect differed across observers, but in each case the data were consistent with changes in apparent size and distance (slower reaches with smaller grasps; faster reaches with larger grasps). These results cannot be attributed to an increase in the precision of estimates of object properties with increasing visual information. Rather, the results show that information from the surrounding scene contributes to estimates of both an object's distance and 3-D shape.

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J18 *1042* Structured Perceptual Displays Produce Exceptions to Fitts's Law

Jay Pratt[1] (pratt@psych.utoronto.ca), Jos J Adam[2], Martin H Fischer[3]; [1]University of Toronto, [2]University of Maastricht, [3]University of Dundee

In 1954, Paul Fitts found that the movement time for limb movements increases as a logarithmic function of Index of Difficulty (ID; relationship between target size and movement amplitude). Fitts's equation for predicting MT from ID has become known as Fitts's Law and is perhaps the most robust law in cognitive psychology, being found across a wide range of target sizes, movement amplitdues, and types of responses. Using a simple perceptual manipulation, however, we show two major violations of Fitts's Law. In our first two experiments, which use targets that appear in structured perceptual displays with multiple placeholders indicating the possible target locations (unlike a typical Fitts task that uses isolated targets in an otherwise empty display), MTs to the most distant target (i.e., the highest ID) violate the logarithmic function that describes the less distant targets. Rather, the MTs to the most distant targets is equal or less than the MT to the second most distant targets. Our third experiment extends these findings by showing that the first target location in a perceptual array of placeholder boxes also produce fast MTs that violate Fitts's Law. These findings suggest that Fitts's Law may only hold in unstructured displays, and that it is susceptible to a relatively simple perceptual manipulation. This indicates that Fitts's law may be limited to egocentric visuomotor action, as the results from the present experiments indicate that the visual control of hand movements also make use of allocentric spatial information.

J19 *1043* Multi-resolution model of human motor control

Oh-Sang Kwon[1] (landarzt@psych.purdue.edu), Zygmunt Pizlo[1], Howard N Zelaznik[2], George Chiu[3]; [1]Department of Psychological Sciences Purdue University, [2]Department of Health and Kinesiology Purdue University, [3]School of Mechanical Engineering Purdue University

The multi-resolution (pyramid) architecture is a well-established model of the human visual system. According to this model, the visual system forms multiple representations of a stimulus, each representation characterized by the spatial size of the features represented and the spatial resolution with which they are represented. A pyramid algorithm has been used to account for the speed-accuracy trade-off in visual tasks (Pizlo et al., 1995). In this model, the time it takes to judge the line of length D with accuracy d is proportional to log(D/d). Interestingly, an analogous function, called Fitts' Law (1954), is used to characterize skilled motor performance. Thus it is possible that the , visual and motor systems share the same multi-resolution architecture. To examine this claim, we tested human subjects in a transfer of motor skill. In the experiment, a trained motor skill was transferred to the task (1) where the sizes of movements remained the same but more accurate movements were required or (2) where the sizes of movements were scaled by the same factor as the required accuracy. The degree of transfer in (2) was substantially higher than in (1), supporting the multi-resolution model. Examination of the micro-structure of movement duration within the sequence showed that relative timing was not maintained. This result conflicts with the popular generalized motor program model. Experiment 2, in which transfer involved equal distance stimuli, provided a more direct test of the relative timing model. Results of Experiment 2 were again inconsistent with the relative timing model.

J20 *1044* Forks vs. Fingers: A Comparison Hand and Mouth Kinematics During Feeding

Derek J Quinlan[1] (dquinlan@uwo.ca), Melvyn A Goodale[1,2], Jody C Culham[1,2]; [1]Neuroscience Program, University of Western Ontario, [2]Psychology, University of Western Ontario

We examined the effect of tool use on feeding kinematics of the hand, arm and mouth. Previously, we had subjects use their fingers to reach out to pick up cheese cubes and then reach inward to bring them to the mouth to bite. We found that the hand opened considerably wider than the cheese prior to contact (large "overgrasp"); whereas, the mouth opened only slightly larger than the cheese (small "overbite"). We hypothesized that the overbite was smaller than the overgrasp because mouth preshaping was guided by both visual and haptic (touch) cues to object size, whereas hand preshaping was guided by vision alone. In the present experiment, we had subjects perform reaching and feeding using a fork. We hypothesized that the removal of size-related haptic information in feeding with a fork would cause mouth-preshaping kinematics to become more similar to hand grasping movements because mouth-preshaping would now be solely guided by visual information. Surprisingly, fork use did not affect mouth kinematics, suggesting that the small overbite is not due to the availability of haptic cues to food size. However, fork use did change the kinematics of the arm. When reaching with the fork, velocity peaked much earlier than when reaching with the fingers, especially for outward reaches. We hypothesize that fork-reaches peak earlier in order to accommodate longer deceleration phases required to maintain accuracy, particularly during outward reaches when errors in trajectory cannot be corrected by small head movements.

J21 *1045* Left handedness does not extend to visually guided grasping

Robert L. Whitwell[1] (rwhitwell@hotmail.com), Brendan Morrissey[1], Claudia, L.R. Gonzalez[1], Tzvi Ganel[2], Melvynn A. Goodale[1]; [1]Department of Psychology, Univeristy of Western Ontario, [2]Department of Behavioral Sciences, Ben-Gurion University of the Negev

Handedness is one of the most salient traits of cerebral asymmetry. Ninety

percent of the human population would be classified as right handed in that they tend to favor this hand for a range of tasks, such as writing and using tools. In the case of more "basic" behaviors, such as reaching out and picking up an object, however, it would make sense (from an ecological and biomechanical perspective) to use the hand closer to the object rather than the preferred hand. Yet few studies have directly compared hand use in visually-guided grasping tasks in right- and left-handed subjects. In the present study, we measured spontaneous hand preference in a 'natural' grasping task. We asked right- and left-handed subjects to put a puzzle together or to create different LEGO© models, as quickly and as accurately as possible, without any instruction about which hand to use. Their hand movements were videotaped and preference for grasping in ipsilateral and contralateral space was measured. Right handers showed a marked preference for their dominant hand when picking up objects; left handers, however, did not show any preference. Furthermore, compared to right handers, left handers used their non-dominant hand significantly more often to pick up objects in ipsilateral as well as contralateral space. Our results show that handedness in left handers does not extend to precision grasp and suggest that right handedness for visuomotor control may reflect a universal left-hemisphere specialization for this class of behaviours.

J22 *1046* Reaching to grasp isoluminant and isochromatic objects.

Gord Binsted[1] (gord.binsted@usask.ca), Andrei Georgescu[1], Deb Saucier[1]; [1]University of Saskatchewan

Seminal works by Ungerlaider & Mishkin (1982) and Goodale & Milner (1992, 2004) provided evidence that two discrete visual pathways exist -- what/where or action/perception respectively. Livingstone and Hubel (1987) extended this dichotomy to include isolated color processing; chromatic information being the domain of perceptual (ventral) pathways via the parvocellular system and luminance processing occupying the dorsal (action) stream via the magnocellular system.The present study utilized three experiments to examine the utility of chromatic and luminance information for the selection, planning and execution of grasping actions. Experiment one required participants to grasp an object (red) presented in an isoluminant environment and varying in both location and size. Experiments 2 and 3 presented participants with two objects presented in either an isoluminant (40 cd/m^2; red/green objects, purple background) or an achromatic (black (4 cd/m^2)/white (136 cd/m^2) objects, grey (34 cd/m^2) background) fashion; participants were to grasp the white/red object respectively. During experiment two participants only received vision of the objects during movement planning (i.e. during reaction time) while experiment 3 required participants to grasp with vision only available during execution (i.e. during movement time). Based on the proposed associations between colour/what/perception and luminance/where/action participants were hypothesized to show marked deficits in movement production under isoluminant conditions, as compared to achromatic. Action based purely on color processing evolved more slowly and conservatively, nevertheless, grasping was successful. Thus, although preferential associations appear to exist, colour and lumance information is shared between processing streams.

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J23 *1047* What does the brain do when you fake it? An fMRI study of pantomimed and real grasping

Grzegorz Kroliczak[1] (gkrolic2@uwo.ca), Cristiana Cavina Pratesi[1], David Goodman[1], Jody C Culham[1]; [1]CIHR Group in Action & Perception, Department of Psychology, University of Western Ontario, London, Canada

Behavioral and neuropsychological studies indicate that faked actions may tap different systems than genuine actions. We tested this idea directly with the use of functional magnetic resonance imaging (fMRI). Namely, we were interested to know if an area implicated in visually-guided grasping – the anterior intraparietal (AIP) sulcus – would also be involved in pantomimed grasping, or whether other areas would be recruited. Methods. Brain activation was measured while 10 right-handed participants performed the following tasks: (1) grasping real three-dimensional objects, (2) reaching towards the objects and touching them with the knuckle, without hand preshaping, (3) pantomimed grasping in an adjacent location where no object was present, (4) pantomimed reaching, and (5) passive viewing of the objects. Participants were tested on average with 6 functional runs in a slow event-related design. Results. A contrast between real grasping and real reaching revealed greater activation in AIP bilaterally. Pantomimed grasping, as opposed to pantomimed reaching, produced greater activity near right AIP and in slightly posterior regions of right parietal cortex. In addition, a contrast between pantomimed actions vs. real actions revealed activation in the right medial temporal gyrus. Conclusions. Fake actions seem to recruit more right hemisphere regions, perhaps because visuomotor transformations in the right hemisphere are more perceptually driven. In fact, the right hemisphere might be typically invoked by unnatural, unpracticed actions as opposed to skilled, natural actions typically mediated by the left hemisphere.

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Attention: Other

J24 *1048* Ability to task-switch in action video game players

C.S. Green[1,2] (csgreen@bcs.rochester.edu), Daphne Bavelier[1,2]; [1]Center for Visual Science, University of Rochester, [2]Department of Brain and Cognitive Sciences, University of Rochester

The ability to switch between competing goals depending on task demands is a key determinant of cognitive skills. This work investigates whether action video game players (VGPs) show changes in this ability. We first compared two versions of the attentional blink task, one with a task-switch between T1 and T2 and one without. Previous work documents a larger blink in the task-switch than in the non-task-switch condition indicating an added cost of task-switching. Accordingly, the size of the blink was greater in the task-switch version than in the non-task-switch version in non-video game players (NVGPs). Conversely, in addition to displaying overall reductions in blink depth compared to NVGPs, VGP performance was equivalent with and without a task-switch, suggesting a lesser cost of task-switching in VGPs. To directly assess task-switching ability, a standard task-switching paradigm was employed in which subjects were presented with colored shapes and were asked to predictably switch between naming the color and the shape of the item. While both groups showed the typical task-switch cost (an increase in reaction time on the switch trials), this increase was significantly smaller in VGPs than in NVGPs, establishing enhanced task-switching abilities in VGPs. Furthermore, the VGP effect was similar whether the subjects used a manual or vocal method of response, suggesting that the results are likely not due to a greater ability of VGPs at performing arbitrary stimulus-response mappings.

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J25 *1049* The Effects of Video Game Playing on Perceptual and Cognitive Abilities

Walter R. Boot[1] (wboot@s.psych.uiuc.edu), Arthur F. Kramer[1], Monica Fabiani[1], Gabriele Gratton[1], Daniel J. Simons[1], Xiaoang Irene Wan[1], Michael S. Ambinder[1], Laura E. Thomas[1], Stan J. Colcombe[1], Jason Agran[1], Kathy Low[1], Yukie Lee[1]; [1]University of Illinois at Urbana-Champaign

Video game training can improve performance in a number of visual and attentional tasks (Green & Bavelier, 2003). Our study examines transfer from video game training using more participants, more training, a more

extensive battery of attention and cognitive tasks, and several neuroimaging measures. Participants were trained on either a puzzle game (Tetris), action game (Medal of Honor), or strategy game (Rise of Nations) for 20 hours. Cognitive and perceptual abilities were assessed before training, during training, and again after twenty hours of training. Assessment included tests of visual/attentional processing in addition to measures of processing speed, long-term and short-term memory, inhibition, and problem solving. We predicted improvements in different cognitive tasks depending on the extent to which those underlying cognitive capacities are used in each training game. MRI images obtained before and after training were used to determine whether video game training leads to structural changes in selective regions of the brain. ERPs also were recorded pre and post-training. The results of this ongoing project (with approximately 15 participants in each group currently) replicate but also qualify the findings of Green and Bavelier. For example, preliminary data suggest that with limited training on Medal of Honor participants show improvement in the functional field of view task (after 10 hours), but with more training, group differences virtually disappear; with 20 hours of training participants trained on Tetris improved as much as participants trained on an action video game. Time course of training effects and specificity of transfer will be discussed.

J26 *1050* Hemifield Independence is a Signature of Location-based Attentional Filtering

George A. Alvarez[1] (alvarez@mit.edu), Patrick Cavanagh[2]; [1]Massachusetts Institute of Technology, [2]Harvard University

Attentive tracking shows independent attentional limits for the left and right visual hemifields (Alvarez & Cavanagh, 2005), whereas visual search does not (Luck et al., 1989). We test whether location-based filtering is the critical process that operates independently in the two hemifields: it is present in tracking (attend to a subset of items, suppress the others) but not in standard visual search (all items are potential targets). **Method:** We devised a subset visual search where16 black placeholders were presented and 2 to 10 of them were then cued, with either bilateral (half in each hemifield) or unilateral cues (all in one hemifield). After one second, the placeholders became 16 letters (one T and 15 Ls). The T always appeared within the cued subset and observers were instructed to search only in the subset and report the orientation of the T. In the standard condition 2-10 letters (the target T among Ls) were presented either bilaterally or unilaterally. **Results:** Consistent with previous research, there was no difference in search slope between the bilateral and unilateral displays in the standard task ($t(13)=1.05$, $p=.31$). However, in the subset task, search slopes were 1.35 times steeper for unilateral displays relative to bilateral displays ($t(13)=2.83$, $p<.05$). **Conclusion:** There is some hemifield independence in a visual search task when the task requires observers to attend to a subset of the items while suppressing the others. These results suggest that hemifield independence is a property of location-based, attentional filtering.

J27 *1051* Rate threshold for phase discrimination of flickering dots is low and decreases with eccentricity despite cortical scaling

S. Mehdi Aghdaee[1] (aghdaee@fas.harvard.edu), Patrick Cavanagh[1]; [1]Harvard University, Vision Sciences Lab

The maximum rate at which a normal observer can distinguish between in-phase vs. out-of-phase flicker of widely spaced stimuli is around 8-10 Hz (Battelli et al, *Neuron*, 32, 985-995, 2001). In this study, we evaluated this threshold rate at different eccentricities and in different hemifields. Two circles were presented for 500 milliseconds, both flickering at the same frequency, and observers were required to report whether the two were in-phase or out-of-phase. The stimuli appeared randomly at different hemifields and eccentricities and the size of stimuli and the inter-stimulus distance were scaled to account for cortical magnification at the eccentricity. At low temporal rates, observers could easily distinguish between the in-phase and out-of-phase conditions, but performance approached chance level at higher rates. The alternation rate at which each observer could distinguish in-phase from out-of-phase flicker with 75% accuracy was taken as the discrimination threshold. Our data show that the threshold (average of 4 Ss) drops from 13 Hz at 4° eccentricity to 10.1 Hz at 14° eccentricity. In addition, at 14° eccentricity, the threshold was higher in the lower than in the upper visual hemifield. These thresholds are quite different from those for flicker fusion that stay relatively constant at 20 to 30 Hz across eccentricities when cortically scaled as our stimuli were, and which do not differ between upper and lower fields.

J28 *1052* The correlation between motion aftereffect and fMRI measures of visual and auditory attention

Vivian, M. Ciaramitaro[1,2] (vivian@salk.edu), Geoffrey, M. Boynton[1]; [1]The Salk Institute for Biological Sciences, La Jolla, California USA, [2]University of California San Diego, Department of Psychology, La Jolla, California USA

Purpose: Previously we found that the fMRI response to an unattended visual stimulus depended on the modality directing attention away. In MT+ the response to an unattended visual stimulus was stronger when attending another visual stimulus. However, in V1 and V2 the response was stronger when attending an auditory stimulus. Here we measure the strength of a visual motion aftereffect (MAE) to obtain a behavioral measure analogous to our fMRI results.

Methods: Subjects were presented with two drifting gratings, to the left and right of fixation, and an auditory stimulus (binaural or dichotic). All stimuli were presented simultaneously and subjects were cued to attend one stimulus and perform either a speed discrimination task on one of the visual stimuli or a frequency discrimination task on an auditory stimulus. At the end of each trial, the strength of the MAE was measured using a nulling procedure in which subjects judged the direction of motion of a grating presented unpredictably at the location of one of the previously presented gratings.

Results: The MAE was strongest when the visual stimulus was attended. When the visual stimulus was ignored, the MAE was weakest when attention was directed away to another visual stimulus compared to when attention was directed to an auditory stimulus. This suggests that visual perception is more strongly suppressed when attending within the same modality, rather than across modalities. Interestingly, the effect of attention on the MAE is most consistent with our fMRI results in V1 and V2, and not in MT+.

J29 *1053* The Role of Simulated Motion on Visual Attention

Miranda Deller[1] (mdeller1@lakeheadu.ca), Jim McAuliffe[1], Michel Johnson[1], Bruce Weaver[1], Tim Wilson[2]; [1]Lakehead University, [2]University of Western Ontario

Responses to covert orienting of attention tasks (COVAT) produce a biphasic pattern of results. When the stimulus onset asynchrony (SOA) is less than 300 ms, reaction times (RTs) to cued targets are faster than uncued targets, while when the SOA is greater than 300 ms RTs to uncued targets are faster than cued targets. This latter phenomenon is termed inhibition of return (IOR). IOR is believed to be a mechanism that promotes efficient search by biasing attention to new locations. To date, much of the research on IOR has been restricted to situations in which participants are seated while viewing stimuli presented on a monitor; however, many searches take place while in motion. One way to look at the effect of linear motion on the orienting of attention is to stimulate the otoliths of the vestibular system by having people lie prone with their neck in a flexed position (known as head down neck flexion or HDNF). We had participants complete a COVAT (with SOAs of 100 and 800 ms) while in three different positions: seated, lying prone, and in HDNF. When in HDNF there was a significant decrease in the magnitude of responses compared to the other two positions; both less facilitation and less inhibition were observed. The results are discussed in terms of the relationship between vestibular activation (i.e., HDNF) and the orienting of visual attention.

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J30 *1054* Attentional Deployment Prior to the Execution of Hand and Eye Movement Sequences

Daniel Baldauf[1] (baldauf@psy.uni-muenchen.de), Heiner Deubel[1]; [1]Experimental Psychology, Ludwig-Maximilians-University, Munich

In a first series of experiments we examined the allocation of attention during the preparation of sequences of manual pointing movements in a dual task paradigm. As a primary task, the subjects had to perform a sequence of one, two or three reaching movements to targets arranged on a clock face. The secondary task was a 2AFC discrimination task in which a discrimination target ('E' or mirrored 'E') was presented among distractors either at one of the movement goals or at any other position. The data show that discrimination performance is superior at the locations of all movement goals while it is close to chance at the positions that are not relevant for the movement. Interestingly, discrimination performance is at chance also at the intermediate location between two movement target positions. We conclude that during movement preparation - well before the actual execution of the hand movement - attention is allocated in parallel to all movement goals, and is spatially divided among the non-contiguous target locations.

In a second line of experiments we analysed attentional deployment before sequences of two and three saccades in a similar experimental approach. In line with the results for pointing, we find that also during the preparation of saccade sequences all movement goals are attended in parallel before the onset of the first saccade. This suggests that attentional selection is identical irrespective of the effector system used.

J31 *1055* Perceptual learning and exogenous attention

Anna Marie Giordano[1] (amg223@nyu.edu), Marisa Carrasco[2]; [1]New York University, Department of Psychology, [2]New York University, Department of Psychology & Center for Neural Science

Goal: Covert attention improves discriminability and accelerates the rate of visual information processing (Carrasco & McElree, 2001). With exogenous cues, the valid-cue benefits and the invalid-cue costs in both discriminability and processing speed are comparable across cue validity (Giordano, McElree & Carrasco, 2004). Here we examined perceptual learning using the speed-accuracy tradeoff procedure (enabling conjoint measures of discriminability and speed of information processing) and manipulating cue validity. Methods: Observers performed an orientation discrimination task in which a peripheral location cue preceded a target presented alone or with distracters. The target appeared in one of 8 iso–eccentric locations. Trials were blocked by cue validity; the cue was valid either a third, half, or all the time. A response tone prompted observers, who were informed of cue validity, to respond after various lags (40–2000 ms). Observers completed a session/day for 9 consecutive days for each cue validity. Data were binned into three groups, each consisting of three consecutive sessions per cue validity.Results & Conclusion: For each cue validity, discriminability shows no evidence of perceptual learning over time. Temporal dynamics suggest perceptual learning for the neutral cue condition; faster processing speed over sessions. Processing time was faster for the valid-cue condition than for the neutral condition, but remained constant throughout. There is no additional effect of perceptual learning at the attended location. Across cue validity the magnitude of the attentional effect on processing speed is at maximum level from the start. These results support the automaticity of exogenous attention.

J32 *1056* An investigation of relationships among visual-attention processes.

Marcia Grabowecky[1] (grabowecky@northwestern.edu), Lucica Iordanescu[1], KatieAnn Skogsberg[1], Sarah Novis[1], Michael Rock[1], Satoru Suzuki[1]; [1]Department of Psychology, Northwestern University

Behavioral attention research has primarily focused on identifying and characterizing distinct attention processes. To move toward a more integrative understanding of visual attention, we have begun to investigate relationships among attention mechanisms. We systematically tested each observer in a battery of voluntary-attention tasks that collectively evaluated a variety of attention processes (e.g., focusing in time, in space and to objects, distributing attention across space to grasp global structures, shifting, multi-item tracking, and maintaining vigilance). Correlation-based analyses (across a large number of observers) were used to elucidate how behaviorally defined attention processes are mediated by shared, separate, and/or antagonistic underlying mechanisms. The results suggest an antagonistic relationship between the ability to centrally focus attention and the ability to distribute attention (e.g., if one is superior at focusing, one tends to be inferior at distributing). The results also suggest that a global-attention mechanism subserves both global-object processing (including object-based attention) and global-motion processing. Interestingly, this mechanism appears to have its own attention-maintenance mechanism that is not involved in spatial attention processes (e.g., focusing, shifting and tracking). Other findings include that spatial shifting of attention involves separate contributions from the processes of attentive tracking and the rapid engagement of attention, and maintaining focused attention involves the ability to rapidly re-engage attention (suggesting that maintaining focal attention requires rapid and frequent refocusing of strayed attention). Thus, by examining performance correlations among a variety of attention tasks, we have provided insights into the structure of underlying mechanisms that mediate common attention tasks.

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J33 *1057* Do Patients with Alzheimer's Disease Compensate for Impaired Visual Attention When Driving?

Lindsay M Vaux[1] (lindsay-vaux@uiowa.edu), Maureen A Marron[1], Matthew Rizzo[1]; [1]Department of Neurology, College of Medicine, University of Iowa

Alzheimer's Disease (AD) impairs attentional processes that are critically important to safe driving. AD drivers with attentional impairments measured on the Useful Field of View task (UFOV; Ball, et al., 1993) are at increased risk for driving errors in instrumented vehicles (Uc, et al., 2004), crashes in driving simulators (Rizzo, et al., 1997), and crash frequency reported in state driving records (Owsley, et al., 1991). A key to mitigating driving safety error risk is self-awareness of acquired impairments. To determine if drivers with mild AD strategically change their behavior to compensate for their attentional impairments, we compared the self–reported driving habits (Driving Habits Questionnaire, Sloane et al., 1990) of AD patients (74.4 years; UFOV total = 1280.4) and age-matched elderly drivers without UFOV decline (72.8 years; UFOV total = 742.9). Compared to normal elderly drivers, AD drivers compensated by driving less frequently and for fewer miles, having someone else drive, and avoiding "high risk" situations such as merging, making left-hand turns, driving in rain, at night, in rush-hour traffic, and in high traffic (all ps <0.05), suggesting that some drivers with mild AD maintain an awareness of their cognitive limitations and appropriately adjust their driving behaviors. However, the percentage of AD drivers not engaging in compensatory behaviors was high, suggesting a need for educating AD drivers or their families about compensatory strategies or driving restrictions. Future research should examine whether self-awareness of attentional impairments and use of compensatory strategies results in fewer crashes or safety errors in these patients.

J34 *1058* Response Inhibition Has Negative Consequences for Subsequent Emotional Evaluation of Faces and Places

Nikki Westoby[1] (n.westoby@bangor.ac.uk), Jane E. Raymond[1]; [1]University of Wales, Bangor

Previous studies using pairs of stimuli or multi-item arrays showed that when one stimulus becomes the target of attention, other concurrent distracting stimuli engender emotional devaluation upon encounter a few seconds later (Raymond et al, 2003; Fenske et al., 2003). Here we asked whether this emotional consequence of ignoring could be produced with-

out concurrent stimulus competition and whether it could persist over a greater time span. We also asked if explicit memory for prior distractors played a role in distractor devaluation. We presented successively alternating face and place images in a simple go/no-go speeded response task cued by conjunctions of frame colour and gender (faces task) or scene type and name of a central letter overlay (scenes task). After each block of 48 trials, we obtained trustworthiness ratings of novel and previously seen go and no-go faces (or liking ratings of places) approximately three minutes after their initial presentation. We then tested recognition memory (using novel foils) for go and no-go scenes (or faces) from the preceding block of trials. We found large, robust devaluation of both faces and places from previous no-go trials in conditions where no-go stimuli also produced good explicit recognition. There was no effect on item evaluation in conditions producing near chance d' scores for recognition memory. These data support the view that response inhibition associated with an image is encoded in memory along with other stimulus features. When the image is encountered subsequently, this inhibition appears to modulate emotional response.

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J35 *1059* Position invariant motion contrast effects are mediated by attention

Xiaohua Zhuang[1,2] (xzhuang@eden.rutgers.edu), Thomas V. Papathomas[1,3], Zoltan Vidnyanszky[4]; [1]Lab of Vision Research, Rutgers University, Piscataway, NJ, USA, [2]Dept of Psychology, Rutgers University, Piscataway, NJ, USA, [3]Dept of Biomedical Engineering, Rutgers University, Piscataway, NJ, USA, [4]Neurobiology Research Group, Hungarian Academy of Sciences-Semmelweis University, 1094 Budapest, Hungary

Objectives: Motion threshold increases if the threshold-measuring test motion stimulus (the probe) is preceded by a strong motion signal (the prime) that shares the direction and the location of the probe; this effect is called the motion contrast effect (MCE, Raymond, 1994; Raymond and Isaak, 1998). Here we investigated the position specificity of the MCE by varying the separation between the retinal location of the prime and probe motion.

Methods: Random-dot-pattern (RDP) stimuli were shown to observers in the priming and test motion, using circular apertures. These two motions were presented sequentially either on the same side of the fixation mark (i.e., in the same aperture), or in different (left and right) sides, symmetric with respect to the fixation mark. The distances between the innermost points of the apertures and the fixation point were either 0 or 10 degrees. For the priming motion, observers were asked to perform a speed discrimination task; for the test motion, observers needed to report the direction of the coherent motion contained in the aperture.

Results: We found a smaller, but significant MCE in the conditions where the prime and probe stimuli were shown in different positions, as compared to when their positions were identical. Importantly, the magnitude of the position-invariant MCE was similar in the different prime motion separations that were tested.

Conclusions: Our findings suggest that the MCE consists of a position-specific and a position-invariant component, and that the latter is mediated by visual attention.

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Knowledge, Affect, Preference

J36 *1060* Measuring implicit emotional reactions: A picture's worth is found inwards.

Felicity Greenwell[1] (f.greenwell@bangor.ac.uk), James Intriligator[1]; [1]University of Wales, Bangor

Purpose. To measure the implicit emotional reactions evoked by visual stimuli. We do this by using a new measurement technique based on the Extrinsic Affective Simon Task (DeHouwer, 1998). **Stimuli.** One set of "base pictures" (half of which are clearly very positive, half very negative) and one set of "test pictures". For the current study we used pictures from the International Affective Picture System (IAPS). **Procedure.** On each trial, the observer sees a single picture (base or test) surrounded by a frame (white, blue, or green). If the frame is white, observers classify the picture's valence (e.g. 1 = positive, 2 = negative). If the frame is blue or green, observers classify the frame color (e.g. 1 = green, 2 = blue). They are asked to respond as quickly and accurately as possible. **Results.** We find that in the blue/green classification task, response speed and accuracy are strongly influenced by the picture valence – suggesting that some level of emotional processing has taken place. In the example above, responses are slower and less accurate when observers see implicitly negative pictures with green frames (negative primes a "2" response, yet green requires a "1" response). We compare our implicit measure to various explicit measures (in terms of speed, accuracy, and robustness). **Discussion.** This technique successfully measures implicit reactions along the emotional dimension of valence (positive / negative). We demonstrate how it can be extended to measure a broad range of other dimensions.

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J37 *1061* Can affective priming be object-based?

Carys K Ball[1] (c.ball@bangor.ac.uk), Jane E Raymond[1], Mark J Fenske[2]; [1]University of Wales, Bangor, [2]Harvard Medical School, USA

When an emotionally charged prime stimulus (e.g. a happy or angry face) is presented immediately prior to and at the same location as a target stimulus (e.g. a novel abstract image), affective evaluation of the target is typically biased in the direction of the prime's valence. Conventional theories of the affective priming (AP) effect posit that primes initiate a general affective state that 'spreads' to any other stimuli presented immediately thereafter (SOA up to approximately 300 ms). An alternative view, more in line with object-based theories of attention, is that AP results because affective information is bound to objects, not general states; if, in conventional AP experiments primes and targets are perceptually experienced as the same object, affective information should transfer from prime to target. This view predicts that AP should be found when prime objects become transformed into target objects and not when primes and targets appear as different objects. To test this idea, we presented two objects, with an emotionally valenced prime briefly appearing on one and a neutral stimulus appearing on the other. On half the trials the primed object transformed into the target (same-object condition) and on remaining trials the non-primed object became the target (different-object condition). Targets were then evaluated on an emotional scale. AP effects were evident for same-object conditions and absent for different-object conditions. Our findings support the view that object-based processing may underlie affective priming and that affective information may be bound to an object much like other object features.

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J38 *1062* The modulation of social-emotional judgments in a directed forgetting paradigm

Brian A. Goolsby[1] (b.goolsby@bangor.ac.uk), Jane E. Raymond[1], Kimron Shapiro[1]; [1]University of Wales, Bangor

Previous research demonstrated that emotional evaluations of stimuli that were previously ignored in a spatial attention task were more negative than evaluations of previously attended stimuli. Raymond and colleagues (Raymond et al., 2003; 2005; Fenske et al., 2004; 2005) proposed an inhibition account to explain this distractor devaluation (DD) effect. This states that inhibition applied to the distractor (to reduce response competition with the target) becomes associated and stored with the object representation and is re-instantiated (with negative consequences) when emotionally evaluating that object. The present study investigated whether DD effects are specific to inhibition arising from target-distractor competition. In a directed forgetting paradigm (Taylor, 2005), participants studied a series of neutral faces one at a time, followed by either a recognition memory test or an evaluation task. We cued participants either to remember or forget each face. The SOA between the face and the cue was varied. At test, participants saw "remember", "forget", or "novel" faces and either classified them as old or new or rated them for trustworthiness (1 to 5 scale). Encoding instruction affected recognition memory and ratings, but with different time courses. We conclude that (1) DD effects can be obtained with sequential presentation, (2) DD effects require time to form a representation of the face prior to the "forget" instruction and time to associate the face with the inhibitory signal, and (3) inhibition applied to the memory trace with directed forgetting has differential effects on recognition memory and evaluative judgments.

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J39 *1063* Affective Responses to Stimuli viewed from Egocentric vs. Allocentric Perspectives

Amy E Hayes[1] (a.hayes@bangor.ac.uk), Matthew A Paul[2], Boukje Beuger[2], Steven P Tipper[2]; [1]School of Sport, Health and Exercise Sciences, University of Wales, Bangor, [2]School of Psychology, University of Wales, Bangor

Past research has shown that affective responses to items can be influenced by cognitive processes such as perceptual fluency (e.g Reber, Winkielman & Schwarz, 1998) or inhibitory processes in visual attention (e.g. Raymond, Fenske & Tavassoli, 2003). Here we investigated whether the viewpoint from which an object is observed, i.e. from an egocentric vs. an allocentric perspective, influences affective response to the object. Subjects viewed digitised video clips of an actor picking up an object and moving it to a new location on a table. After viewing each video clip, the observers rated how much they liked the object that was the target of the action. Half the subjects viewed clips that were filmed from the actor's point of view (egocentric perspective), and half the subjects viewed clips that were filmed from the viewpoint of a person facing the actor from across the table (allocentric perspective). Visual angle of the target objects were held constant across the two perspectives. We found that observers who viewed the action from an egocentric perspective produced higher overall liking ratings than observers who viewed the action from an allocentric perspective. Results suggest that affective ratings are influenced not only by the identity of the object and the event in which it is embedded, but also by the perspective from which the event is viewed.

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J40 *1064* IOR for aversive stimuli is magnified when emotionally congruent responses are required

Helena J. V. Rutherford[1] (psp037@bangor.ac.uk), Jane E. Raymond[1]; [1]University of Wales, Bangor

Inhibition of return (IOR) refers to slower responding to a target appearing at a previously attended versus unattended visual location. It probably acts to aid visual search by inhibiting processing at previously searched locations. We asked whether IOR would be modulated by the congruency between a target's emotional valence (positive versus negative) and the required response (approach versus avoid) because slowed avoidance of negative stimuli, even if occurring at previously searched locations, seems maladaptive. In four conditions (n = 20 per condition), targets were either spiders or faces requiring speeded approach (key down) or avoid (key up) detection responses. Targets were preceded by a brief task-irrelevant cue (neutral circle, 85 ms) at the same or a different location. Cue-target intervals (SOAs) ranged from 100 to 3200 ms. Interestingly, modest cue benefits with short SOAs and robust IOR with longer SOAs were found for both avoid and approach responses regardless of target type (faces or spiders), indicating that IOR does not work by creating location-based avoidance. Moreover, for spiders, avoidance responses (emotionally congruent) produced significantly ($p<.001$) larger IOR (26 ms) than approach responses (11 ms) (emotionally incongruent). No such difference was found for face targets ($F < 1$). These results show that for negative stimuli, IOR is more potent when stimulus and response are emotionally congruent. Perhaps the fast automatic mechanisms that detect spiders and initiate avoidance are particularly susceptible to low-level attentional control mechanisms thought to mediate exogenously generated IOR.

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J41 *1065* Goal bias in non-linguistic Motion event representations: The role of intentionality

Laura Lakusta[1] (lakusta@fas.harvard.edu), Allison Wessel[1], Barbara Landau[1]; [1]Johns Hopkins University

In language there is a bias to represent Goals (end points) over Sources (starting points). The current studies explored the possibility that this bias originates in non-linguistic representations of events. We used a non-linguistic Change Detection method. Four-year-olds and adults were shown pairs of Motion events in which a human actor moved from a Source to a Goal. The second event in each pair changed Source, Goal, Figure, or Motion or had no change at all. After viewing the second event, participants judged whether the events were the same or different. In Experiment 1, Goal changes were correctly detected more often than Source changes, suggesting a non-linguistic Goal bias. Experiment 2 showed that a Goal bias became weaker when the human actor gazed at the Source rather than at the Goal. Specifically, compared to Experiment 1, encoding of the Source improved while encoding of the Motion and Figure suffered. Experiment 3 showed that a Goal bias also weakened when the events contained only inanimate objects. These results shed light on the nature of a Goal bias in cognition and as well as the encoding of event components more generally. First, the mechanism responsible for a Goal bias may be attention, and the conceptual factors driving this attentional mechanism may be the animacy and intentionality present in the event. Second, attentional resources used for encoding an event may be constrained such that when the encoding of one component improves (e.g., Source), the encoding of another component may suffer (e.g., Figure).

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J42 *1066* Is Contingency Sufficient For Detecting Intentionality?

Jonathan S. Beier[1] (jsbeier@wjh.harvard.edu), Susan Carey[1]; [1]Harvard University

Many have suggested that a novel object's contingent interaction with the environment leads to a perception of intentionality. We investigated whether contingency alone is sufficient for attributing intentionality, or whether other features typical of person-person social exchanges are also necessary.Following Johnson (under review), adult participants viewed one of seven 2-minute movies featuring a novel object interacting with a person by beeping. In some movies, contingency was present but the exchange lacked some feature of typical human communication (action-at-a-distance, verbal regard, turn-taking structure, presence of person). For instance, in one movie the actor did not speak but instead clapped his hands towards the object. In other movies, the actor displayed normal

communicative behavior, but the object did not respond contingently. Participants were assigned an agency-attribution score derived from their use of mental-state terms while describing the object in a subsequent survey.We found that, with no person present, a contingently acting object is construed as intentional somewhat more than a non-contingent one. When a person exhibits vocal regard towards the object, agent-attribution is high, independent of the object's responses and the contingency they may (or may not) establish. When a person is present but does not exhibit vocal regard, the object's contingent responses do not support construal of its intentionality. This work establishes that, for adults, social modeling is a stronger cue for detecting intentional beings than their contingent behavior.

J43 *1067* Arithmetic in symbolic and non-symbolic numerical domains

Camilla K. Gilmore[1] (cgilmore@wjh.harvard.edu), Elizabeth S. Spelke[1]; [1]Department of Psychology, Harvard University

Numerical understanding and processes can be guided either by exact symbolic representations or approximate non-symbolic representations of number. These systems may differ in the extent to which they support mathematical competencies. Previous work has demonstrated that non-symbolic numerical representations can support approximate arithmetic: Children are able to perform additions and subtractions of sets in the visual-spatial or auditory modality before they can succeed with equivalent symbolic problems (Barth et al, 2005). It is not known to what extent each of these two systems can support understanding of more complex aspects of the arithmetical framework, for example the inverse relationship between addition and subtraction. This was tested within the non-symbolic domain by showing children (aged 4 - 6 years) animations using visual-spatial representations of number (arrays of dots). Children compared two arrays of different numerosities after one of the arrays had either undergone an inverse transformation (subsequent addition and subtraction of same size sets), a non-inverse transformation (subsequent addition and subtraction of different size sets) or no transformation. Within the symbolic domain this was tested by giving children (aged 5 - 6 years) problems of the form a+b- b= (e.g. 11 + 5 - 5 =) and comparing this with performance on problems of the form a+a- b= (e.g. 9 + 9 - 5 =). Data will be presented to demonstrate the extent to which each of these numerical systems can support understanding of logical principles of arithmetic.

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J44 *1068* Action understanding in infants: New evidence by means of eye-tracking technology

Petra Hauf[1] (P.Hauf@psych.uni-frankfurt.de); [1]J. W. Goethe University Frankfurt, Germany

The present study analyzed the early development of action understanding. 9- and 11-month-old infants prefer to watch other persons acting on the same toy they have played with before, rather than to watch them acting on a novel toy. Besides infants selectively use the information of other persons' actions to control their own actions. By adopting eye tracking technology, this study investigated looking behavior in an action context. In Experiment 1, 9- and 11-month-old infants first played with a toy and afterward saw a video clip presented with the eye tracker monitor. This video showed two adults playing with either the same toy or a novel one. Infants of both age groups showed different looking pattern according to the toy presented in the video, indicating that own agentive experience influences subsequent looking behavior. In contrast Experiment 2 investigated infants who started watching a video. This video showed two adults selecting always the same of two toys and acting on this toy by turns. The second toy was always visible, but was completely ignored by the experimenters. The infants were required to play with both toys afterward and significantly selected the same toy as the two adults in the video. Furthermore eye tracking data indicated differences in looking behavior corresponding with infants own subsequent actions. Thus, eye tracking technology established successfully further evidence for the link between perceived and produced actions.

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J45 *1069* Previously Unknown Illusion Predicted by Evolved Navigation Theory.

Russell E Jackson[1] (russelljackson@mail.utexas.edu), Lawrence K Cormack[1]; [1]The University of Texas at Austin

Researchers often consider illusions as perceptual novelties that are largely insignificant in real-world perception, where veridical perception intuitively would appear to serve an organism's survival best. We instead predicted from Evolved Navigation Theory (ENT) that specific real-world settings should reliably result in perceptual illusions at a magnitude related to the fitness costs posed by the setting. Because navigating vertical (vs. horizontal) environmental distances reliably produces fitness costs via falling, ENT predicts overestimation specific to environmentally vertical stimulus distances. Additionally, because descending results in greatest frequency of falling, ENT predicts greater height overestimation when viewed from the top than bottom of a stimulus height.Participants estimated distance via distance matching in an ecologically valid outdoor setting. In Study 1, participants estimated retinally vertical lengths in either an environmentally vertical (looking ahead) or horizontal (looking down) condition. In Study 2, participants estimated a vertical height from both the top and bottom of the vertical surface. Data suggest that participants overperceived length on environmentally vertical, but not horizontal, surfaces. Furthermore, illusion magnitude increased with stimulus length (and thus falling cost likelihood). Finally, participants overestimated heights much more from the top (184% of actual) than bottom (143%) of a height. Using a causal theory (ENT) allowed us to predict a priori novel distance illusions based on navigational costs over evolution. It is possible that other illusions could be understood in terms of analyzing the consequences of the illusory percepts in the natural environment.

J46 *1070* Collaboration during visual search

Kelly A. Malcolmson[1] (ka2malco@watarts.uwaterloo.ca), Michael G. Reynolds[1], Daniel Smilek[1]; [1]University of Waterloo

In real world situations, such as driving in an unfamiliar city, searching for a street or a particular address is a collaborative process. Yet studies of visual attention in the laboratory often consider only a single individual searching in isolation. These studies have led to a considerable amount of knowledge about how single individuals search basic displays. However, at present very little is known about how attention is oriented when two or more individuals collaborate during search. The present study examines how collaboration affects visual search performance. Participants performed a standard conjunction search task both with a partner and on their own. They were instructed to press a button when the target was present and withhold a response when the target was absent. Accuracy in the condition where search was done in partners (*collaborative condition*) was compared to the pooled responses of pairs of individuals while completing the search alone (*nominal condition*). The results showed that collaborative pairs were more accurate at detecting the target than were the nominal groups (*collaborative facilitation*). In addition, nominal groups showed a clear response bias; the nominal groups were more likely to indicate that they had seen the target object (as indicated by significantly more hits and more false alarms) than in the collaborative condition. Signal detection analyses revealed that collaboration leads pairs to require a higher level of certainty before they are willing to claim they saw the target.

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J47 *1071* Visual Solution to the Traveling Salesman Problem

Zygmunt Pizlo[1] (pizlo@psych.purdue.edu), John Saalweachter[1], Emil Stefanov[1]; [1]Purdue University, West Lafayette, IN

Purpose. The Traveling Salesman Problem (TSP) refers to the task of finding the shortest tour of N cities. This task is considered computationally intractable, even if the cities reside on a Euclidean plane. TSP is similar to a number of tasks humans perform in everyday life, like visual navigation. We compared human performance to that of several AI algorithms. **Method.** Five subjects were tested on a Euclidean TSP with 6, 10, 20 and 50 cities. Each subject was tested with the same problems presented in a random order. The subjects were asked to produce as short tours as possible. **Results.** The time of solving a problem is proportional to the number of cities, suggesting that the computational complexity of the mental mechanisms is linear. At the same time, the tours produced by the subjects are, on average, only a few percent longer than the shortest tours. **Conclusions.** Human performance cannot be matched by any of the existing AI algorithms. In order to account for subjects' performance we used a multiresolution pyramid model, which produces tours in the process of a coarse-to-fine sequence of approximations. This model simulates the nonuniform distribution of acuity across the visual field and it solves the TSP problem by moving its fixation point from city to city. The complexity of the model is O(*NlogN*). This model can solve large problems (up to 1000 cities) fairly quickly, producing tours that are only 10% longer than the shortest tours.

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J48 *1072* What is the domain of causal perception? Investigating causal perception of motion and non-motion state change events in infancy

Paul Muentener[1] (pmuentener@wjh.harvard.edu), Susan Carey[1]; [1]Department of Psychology, Harvard University

When one object (A) collides with another object (B) and B goes into motion, adults perceive a causal interaction. Michotte argued that adults' causal perception is limited to motion events, providing evidence that adults fail to perceive non-motion events causally. The current study investigated the origins of this perceptual phenomenon. Previous research has found that infants represent an event as causal only if A contacts B. These studies, however, have not tested causal perception outside the domain of motion. If causal perception is a bottom-up, hard-wired perceptual process, as Michotte argued, infants' causal perceptions should not extend beyond motion events. Independent groups of infants were habituated to an ambiguous causal event involving three potential effects (motion: launching vs. non-motion: breaking or color/music change). During habituation A entered and an effect occurred on B. The actual interaction was occluded by a screen. During test the screen was removed, and infants were shown, in alternation, two events: 1) A contacted B and 2) A stopped short of B before the effect occurred. If infants represent the event as causal, then they should look longer at the gap test event because the causal relationship has changed. Infants looked longer at the gap test events only in the motion event condition. Thus, infants represented only the motion event as causal. These results provide support for Michotte's claim for domain-specificity in causal perception. The findings are also consistent with the claim that infants' knowledge of causal interactions between objects is limited to motion events.

J49 *1073* Reflexive social attention elicited by biological motion

Yoshiya Mori[1] (yoshiya@bpe.es.osaka-u.ac.jp), Mikio Inagaki[1], Lisa Wu[2], Taijiro Doi[3], Eishi Hirasaki[4], Hiroo Kumakura[4], Ichiro Fujita[1]; [1]Graduate School of Frontier Biosciences, Osaka University, [2]Massachusetts Institute of Technology, [3]Graduate School of Engineering Science, Osaka University, [4]Graduate School of Human Sciences, Osaka University

Guessing where another individual is attending and preparing for his/her upcoming action is crucial for members of a social group. Experiments have shown that both monkeys and humans automatically orient their attention to the direction of another's head or gaze. Here we report that the walking direction of another individual also elicits a reflexive shift of visuospatial attention in monkeys and humans. We examined how the reaction time to peripheral visual targets was affected by a prior, brief presentation of a walking biological motion (BM) stimulus. This stimulus comprises dynamic displays of light points placed on the major joints of a moving human or animal. During the task, human and monkey subjects responded to a target point after the disappearance of BM stimulus and the fixation point. Throughout the task, the walking direction of the BM stimulus was not predictive of the target direction, and was irrelevant for performing the task. We found that reaction times in congruent trials, where the walking direction of the BM stimulus and the direction of the target appearance were the same, were significantly shorter than those in incongruent trials. This effect is distinct from other stimulus-driven attention in that the sudden onset of the BM stimulus directs attention to other locations. The attention mechanisms driven by BM may be part of the intentionality inference system that is suggested to be a substructure of the neural mechanism of reading another's mental state, termed "theory of mind".

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J50 *1074* Relative rates of visual and cognitive decline in Alzheimer's Disease

Matthew Rizzo[1] (matthew-rizzo@uiowa.edu), Jeffrey D. Dawson[2], Ergun Y. Uc[1], Steven Anderson[1], Carissa L. Philippi[1], JonDavid Sparks[2]; [1]University of Iowa, Department of Neurology, [2]University of Iowa, Department of Biostatistics

Alzheimer's disease (AD) is known to affect visual pathways, but relative declines of vision versus cognition have not been well studied. Consequently, we tested 76 individuals with early AD (mean age 74) and 134 without dementia (mean age 70) on a baseline battery of tests of basic and higher-order visual perception and cognition; 70% returned for 1 or 2 annual follow-ups (mean of 2.2 visits per subject). AD subjects (mean age 74) had mean MMSE scores of 25.2 at baseline, with an average annual decrease of 1.2 points/year. Baseline results showed significant age-adjusted differences between groups on most tests, including near and far static visual acuity, contrast sensitivity, 3-D shape-from motion (SFM), visual attention, visuoconstructional ability, visual memory, verbal memory, speeded word finding, visuospatial perception, and attentional shifting, but not glare-disability. Longitudinal data methods (adjusting for age and person-level random effects) showed similar declines over time for both groups on tests of vision (contrast sensitivity, far visual acuity) and attention. Near visual acuity declined more in AD. SFM was stable in both groups. Of eight tests assessing higher order vision and/or cognitive ability, six declined more in the AD group (all but visuospatial perception and 1 of 2 measures of visuoconstructional ability). Differential changes in cognitive scores remained after adjusting for near visual acuity. The findings show that AD affects several aspects of vision, but the impairments in cognition occur faster than can be accounted for by basic visual decline.

Spatial Vision: Context and Space

J51 *1075* Aesthetics, Mondrians, and the Horizontal Effect

Andrew M. Haun[1] (amhaun01@louisville.edu), Bruce C. Hansen[2], Edward A. Essock[1,3]; [1]Department of Psychological and Brain Sciences, University of Louisville, [2]Vision Research Unit, Department of Ophthalmology, McGill University, [3]Department of Ophthalmology and Visual Sciences, University of Louisville

Content in natural scenes is typically anisotropic, with more at horizontal (H) and vertical (V) orientations (and with H>V). Corresponding perceptual and neurophysiological biases have also been reported. In addition,

some (Zeki 1999, Latto etal 2000) have linked aesthetics judgments to this neural bias and one study (Latto, Perception 2000) specifically tested this by varying the orientation of highly anisotropic paintings by Piet Mondrian. We investigated this issue further by manipulating the spectral characteristics of images, including Mondrian paintings, and obtaining judgments of aesthetic preference. We addressed whether the preference for H/V content was due to 'artistic' arrangement or to the general predominance of H/V content, and, secondly, the particular H/V bias (e.g., natural scene-like) most preferred.Subjects viewed eight rotations (45^o steps) of a stimulus simultaneously and ranked them by aesthetic preference. The patterns included images of Mondrian paintings (four each in square and diamond frames) located on a circular (50^o) gray field on a black wall (viewed from 1.4m). Experiment 1 largely served as a replication of Latto's experiment. Experiment 2 used both monochrome, cropped circular versions of four Mondrians, and randomized-phase versions (all as 8.5^o edge-blurred circles). In Experiment 3 circular, random-phase stimuli (like Experiment 2) were used but with altered amplitude spectra, consisting of a range of relative H/V anisotropies (e.g., H=V, H>V, natural scene bias).We conclude that images with a predominance of H/V content are judged as more aesthetically appealing, whether the content is artistically placed as in the original Mondrian paintings, or randomized.

J52 *1076* Target visibility determines the extent of visual field inhomogeneities

E. Leslie Cameron[1] (lcameron@carthage.edu), Andrew D. Rathje[1]; [1]Psychology Department, Carthage College, Kenosha, WI

Performance on basic visual tasks is not homogeneous across the visual field. In particular, performance is best for stimuli presented on the horizontal meridian, poorer for stimuli on the vertical meridian, and worst for stimuli presented directly above fixation (the *north effect*). The north effect is most pronounced for high spatial frequency Gabor patches. Last year at VSS we reported that, surprisingly, performance was homogenous for Landolt squares (which contain high spatial frequencies). Here we further investigate the effect of stimulus type on visual field inhomogeneity.

Methods: Stimuli were presented alone at 4.5 deg eccentricity at one of 8 locations in the visual field. Observers performed orientation discrimination tasks for gratings and line stimuli, gap localization for Landolt squares and letter discrimination tasks (E vs. F and N vs. Z). We manipulated stimulus characteristics so that discrimination performance was approximately 80% correct.

Results: We found that the north effect was most pronounced for Gabor patches and low contrast Landolt squares, and least pronounced for lines, letters and high contrast Landolt squares. Using a rating scale, we determined the visibility of all targets, and found that the extent of the north effect was negatively correlated with visibility.

Conclusion: These results suggest that visual field inhomogeneities impact perception most at detection threshold. Interestingly, while the spatial frequency content is clearly a relevant factor in this effect, visibility is critical. We are currently investigating the interaction between spatial frequency and visibility on the extent of the north effect.

J53 *1077* ADVANTAGE OF THE UPPER VISUAL FIELD FOR LATERAL INTERACTION OF HIGH-SPATIAL FREQUENCY

Yasuto Tanaka[1] (ytanaka@po.nict.go.jp), Satoru Miyauchi[1], Masaya Misaki[1], Takara Tashiro[2]; [1]Brain Information Group, National Institute of Information and Communications Technology, Japan, [2]Department of Psychology, Sohai University, Japan

Long-range interaction was found to be extended at the upper visual hemifield (Tanaka et al, 2005; VSS). Here we examined the effect of the spatial frequency for the asymmetrical long-range interaction between upper and lower visual fields. A Gabor target was presented on the vertical meridian either at the upper or lower visual field at the 3.2 deg eccentricity. Eyes were fixated at the central spot. Two collinearly configured (=horizontal) Gabor stimuli were flanked simultaneously at the left and right sides of the target. Different spatial frequencies (2,4,8 cpd) of Gabor patch were tested in different sessions with lateral interaction scaled according to the spatial frequency (distance=16lambda). Contrast detection threshold was measured for the target using the temporal 2AFC staircase method. (Results) At the upper visual field, detection threshold decreased significantly (=facilitation, -0.35+-0.06 log units, 3 observers) for interaction with the high-spatial frequency patches. Threshold reduction was less prominent for interaction with the low-spatial frequency (average: -0.12+-0.03 log units). At the lower visual field, long-range facilitation was more salient with low spatial frequency (average: -0.16+-0.04 log units) as compared with high spatial frequency (average: -0.09+-0.03 log units). The discrepancy between upper and lower visual fields in terms of spatial frequency modulation cannot be explained by cortical magnification factor, thus the results point to an advantage of the upper visual field in terms of lateral interaction of high spatial frequency.

J54 *1078* The role of magnocellular and parvocellular visual pathways in altitudinal visual hemifield anisotropies

J. Jason McAnany[1] (jmcana1@uic.edu), Michael W. Levine[1]; [1]University of Illinois at Chicago, Dept. of Psychology & Laboratory of Integrative Neuroscience

Visual capabilities such as contrast sensitivity, spatial resolution, and color perception are inhomogeneous across the visual field. Sensitivity is typically reported to be greater in the lower visual field (LVF) than in the upper visual field (UVF). Here, we examine the neural mechanisms mediating these differences under conditions that favor either the magnocellular or parvocellular visual pathway.Gabor patch contrast threshold was obtained at four different isoeccentric locations across the visual field (1, 5, 7, and 11 o'clock), using two paradigms: a steady-pedestal paradigm (brief stimulus presentation on a steady luminance pedestal) and a pulsed-pedestal paradigm (simultaneous brief presentation of the stimulus and luminance pedestal). For low spatial frequencies, the steady- and pulsed-pedestal paradigms bias processing toward the magnocellular and parvocellular pathways, respectively; at high spatial frequencies, sensitivity is likely mediated by the parvocellular pathway under both paradigms.Under the pulsed-pedestal paradigm (presumably parvocellular pathway mediated), for low spatial frequencies threshold was slightly, but significantly, lower in the LVF than in the UVF. No asymmetry was observed under the steady-pedestal paradigm (presumably magnocellular pathway mediated). For high spatial frequencies, threshold was 0.2 log unit lower in the LVF than in the UVF under both paradigms. No condition produced significant left-right differences.Results indicate that, contrary to some reports, visual field sensitivity differences are not restricted to the vertical meridian. Also, in accordance with other reports, sensitivity differences are greater at high spatial frequencies. The asymmetries result from processing in the PC pathway.

URL: http://tigger.uic.edu/~mikel/

J55 *1079* Influence of Roll-Tilt, Interpoint Separation, and Length of Linear Points-Arrays on a Frontoparallel Plane on Visually Perceived Eye Level (VPEL)

Leonard Matin[1] (lm11@columbia.edu), Wenxun Li[1], Linda Li[2], Adam Y. Shavit[1]; [1]Department of Psychology, Columbia University, New York, [2]Stuyvesant High School, New York

The physical elevation required for a target to appear at eye level (VPEL) changes systematically with the pitch of a complexly-structured visual field or a visual field consisting of as little as 1 or 2 pitched-from-vertical lines in darkness. Measured by the slope of the VPEL-vs-pitch function, the influence increases with the length of the inducing line along a negatively-accelerated exponential function. The present experiments show that a variable-length roll-tilted line or linear array of equispaced points on a frontoparallel plane exerts similar influences. Our investigation was conducted in a dark room with the inducer located at 25° horizontal eccentric-

ity viewed at 1 meter distance. The length of the inducer was varied from 2.67° to 64° (9 values) in different sessions. Monocularly viewing subjects made VPEL settings while the inducer varied from -15° CCW to +15° CW. For the continuous line, the space constant of the exponential length function was 22.9°. For points-arrays with interpoint spacing of 2.67° and 5.33° the space constants of the exponential length functions were 25.8° and 33.4°, respectively. The increased influences on VPEL obtained by either increasing the length of the array or reducing the interpoint separation is quantitatively predicted by a model (Multiscale Dipole Model) which assumes that each pair of points in an array generates a response from all stimulated orientation-sensitive receptive fields that are appropriately located and oriented whose lengths are equal to or greater than the interpoint separation.

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J56 *1080* The relationship between physical tilt, apparent tilt and acuity

Joshua A Solomon[1] (J.A.Solomon@city.ac.uk); [1]Optometry Department, City University, London EC1V 0HB

Last year (Solomon & Morgan, VSS 2005) oblique flanks were shown to reduce acuity for an oriented target in central vision, impairing comparisons with horizontal. One possible reason for this is that, because of the tilt illusion, the target must have a physical tilt in order to appear horizontal. Even without flanks, acuity for tilted targets is worse than acuity for horizontal targets. This is the oblique effect for acuity. Thus, previously described acuities may simply reflect the targets' physical tilts. This suggestion is not consistent with Meng & Qian's (Vis. Res. 2005) conclusion that the oblique effect depends on perceived, rather than physical, orientation. Whereas Solomon & Morgan used an adaptive staircase to hold the target's (average) apparent orientation constant, Meng & Qian held its physical orientation constant. I conducted an new experiment designed to reveal whether a target's physical tilt or its apparent tilt has a greater influence on acuity. Nine viewing conditions were selected to produce a variety of physical and apparent tilts. Results are consistent with Meng & Qian's finding that acuity for a slightly tilted target depends on whether the tilt illusion makes it look more or less vertical. Nonetheless, when apparent tilt is compared with physical tilt, the latter turns out to be the better predictor of acuity. This suggests that the tilt illusion arises relatively late in the sequence of visual processing stages. At least some of the computations responsible for the oblique effect (e.g. disproportionate sampling, anisotropic additive noise) must precede it.

J57 *1081* ATTRACTION OF FLASHES TO MOVING DOTS

OZGUR YILMAZ[1] (oyilmaz@mail.uh.edu), SAUMIL S. PATEL[1,2,4], SRIMANT TRIPATHY[1,3], HALUK OGMEN[1,2]; [1]University of Houston, Department of Electrical and Computer Engineering, [2]University of Houston, Center for Neuro-Engineering & Cognitive Science, [3]University of Bradford, Department of Optometry, [4]University of Houston, College of Optometry

Purpose: When a flash is briefly presented in the vicinity of a moving grating, the perceived location of the flash is shifted in the direction of motion of the grating (Whitney, 2002). The purpose of this study was to investigate directional specificity of the influence of moving objects upon the position of static objects.**Methods:** A 31 msec flash (12.5 cd/sq-m) was presented 21 arcmin to the right of the final position of the trajectory of two horizontally moving dots (9.5 deg/sec). The vertical position of the flash was in between the two motion trajectories and was presented 19 ms after the offset of the moving dots. One of the moving dots had higher luminance (50 cd/sq-m) than the other and the luminance ratios ranged from 1 to 5. From trial to trial, the vertical position of the flash was varied according to the method of constant stimuli. The observers' (N=3) task was to indicate the moving dot that was perceived to be closer to the flash. In a control experiment, the moving dots were replaced by flashed dots.**Results:** The flash was perceived on average 2.3 arcmin closer to the high luminance moving dot for luminance ratio of 5. The average illusory vertical shift increased systematically as the luminance ratio increased. No illusory vertical shift was observed in the control experiment.**Conclusions:** Moving objects can exert a luminance dependent shift on the position of flashed objects in a direction perpendicular to the direction of motion.

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J58 *1082* Dynamic Distortion of Visual Space around a Moving Object

Kenji Yokoi[1] (k.yokoi@aist.go.jp), Katsumi Watanabe[1,2]; [1]National Institute of Advanced Industrial Science and Technology, Japan, [2]Shimojo Implicit Brain Function Project, ERATO, Japan Science and Technology Agency

The relative visual positions of briefly flashed stimuli are systematically modified in the presence of motion signals. Previously, we investigated the two-dimensional distortion of relative-position representations between moving and flashed stimuli and found that the perceived position of a flash is not uniformly displaced but shifted toward a single convergent point that is fixed behind the moving object. In the present study, we have examined the temporal dynamics of this anisotropic distortion of visual space. While observers fixating a stationary cross, a black disk appeared, moved along a horizontal trajectory, and disappeared. A white dot was briefly flashed at various positions relative to the moving disk and at various timings relative to the onset of motion. As expected, the anisotropic two-dimensional distortion of visual space occurred during the disk's motion. However, significant spatial distortion was observed even before the onset of motion. Furthermore, the space ahead of the moving disk tended to be affected (i.e., distorted) earlier than the space behind it. Evidently, the mislocalization of a flash relative to a moving object cannot be explained by spatially (and temporally) homogeneous process. Instead, the visual space around a moving object is dynamically distorted in an anisotropic manner.

J59 *1083* What Determines the Perceptual Distance between Low Contrast Letter-Like Patterns

Lei Liu[1] (lliu@lighthouse.org), Hillary Gauthier[1]; [1]Arlene Gordon Research Institute, Lighthouse International, New York, NY

Twelve characters were created. They all had the 3 horizontal bars of a block-E letter, and differed in the way the 4 end gaps were sealed. For example, sealing the upper left and lower right end gaps produced a square “5”, and sealing all 4 end gaps created a square "8". The stroke width was 10'. Contrasts that yielded 55% correct recognition for 100, 200 and 1500 msec stimulus durations were determined for three normal subjects (23-38 yrs). More than 700 recognition trials/character were collected at these contrasts. Results were parsed into confusion matrices (CM's). Each cell of a 12x12 CM contained the probability of the occurrence of a stimulus/response combination. A model was developed that used the number of different gap seals between two characters (d) as a measure of the perceptual distance, and s=exp(-d) as the measure of confusability. For example, d=4 between square 2 and 5, d=3 between E and square 9, and d=1 between square 3 and 9. Correlations between confusabilities produced by this model (0 parameter) and observed confusions were 0.858, 0.864 and 0.836 for 100, 200 and 1500 msec durations. Models that took into consideration the differential contributions of adding and deleting a gap seal (1 parameter) or the differential contributions of common, stimulus-character only, and response-character only gap seals (2 parameters) improved correlations only slightly (0.860, 0.867, 0.856 for 1-parameter and 0.872, 0.872, 0.858 for 2-parameter). Therefore, perceptual distance between low contrast patterns is likely determined by the absolute number of different features.

1084 Abstract 1084 moved to Spatial Vision II talk session, May 7, 8:00 am.

J60 *1085* **Eccentric Fixation and Perceptual Filling-In in Patients with Macular Hole**

Walter Wittich[1,2] (walterwittich@sympatico.ca), Olga Overbury[1,2,3], Michael A. Kapusta[3], Donald H. Watanabe[1], Jocelyn Faubert[4]; [1]Concordia University, Psychology, [2]Lady Davis Institute for Medical Research, [3]McGill University, Ophthalmology, [4]University of Montreal, Ecole d'Optometrie

Patients with Macular Hole (MH) must fixate eccentrically due to the central defect. Previous work has shown that fixation occurs at or near the hole margin above the MH, resulting in decreased acuity and distortions. It was investigated whether a vertical line stimulus is perceived symmetrically broken or thinned (fixation above the MH) or as distorted (fixation to the right or left) before and after MH surgery.MH diameter was measured in 21 eyes with Optical Coherence Tomography. An equiluminant line (4th derivative of Gaussian) measuring 1 X 3 dva was presented for 500 ms before as well as 1 to 3 months after MH surgery. Participants were asked to describe their perception of the line. Responses were classified as solid, thinned or broken (symmetrical) or bent right/left (asymmetrical).MH diameter ranged from 200 to 900 microns (~ 0.8 to 2.7 dva). The line was perceived as broken by 10 (48%) and thinned by 7 (33%) eyes, while 4 (19%) reported asymmetrical distortions preoperatively. After anatomically successful surgery, 14 (67%) eyes perceived an undistorted line while 7 (33%) eyes reported residual distortions. The latter group had significantly larger MH diameter pre-operatively, $p < .02$.The perceptual reports indicate that the majority of MH patients fixate along the vertical axis, resulting in symmetrical perception. Of particular interest is the group reporting thinning of the line preoperatively, as the centre should be perceptually missing. Patients seem to fill in the information, resulting in perception of a thinner line at the centre.

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J61 *1086* **Adult age difference of ignoring offset distractors at fixation**

Kazuma Ishimatsu[1,2] (ishimatsu.crps@mri.tmd.ac.jp), Takatsune Kumada[2]; [1]Medical Research Institute, Tokyo Medical and Dental University, [2]National Institute of Advanced Industrial Science and Technology

Although distractor interference effects are well-studied, little is known about the effect of distractor offsets, especially those at fixation. We examined whether task-irrelevant distractors at fixation can be ignored, by comparing the effects of partial- and full-offset of an object at fixation in young and older adults. Participants performed a simple detection task, while ignoring a transient change at fixation. Each trial began with a fixation display, which consisted of a central fixation square with a digital figure-eight placeholder and two circles in the left and right of the fixation. A white spot target was presented at one of two circles following distractors at fixation. In the partial-offset block, distractors appeared with a beep by removing two segments of the figure-eight, and remained until a participant's response. In the full-offset block, the figure-eight was disappeared with a beep. As no distractor baseline blocks, only a beep was presented without any changes at fixation. Reaction times (RTs) were larger both in partial- and full-offset blocks than those in no distractor blocks in both age groups. In young adults, there was no difference between partial- and full-offset distractors. However, in older adults, RTs to a target were slower in the full-offset condition than in the partial-offset condition. These results showed that task-irrelevant transient offset at fixation disrupted target detection in both young and older adults. Older adults were harder to ignore full-offset distractors than partial-offset distractors, suggesting that offset of a whole object had special impact on capturing attention for older adults.

J62 *1087* **Egocentric and allocentric reference frames for eye movements - an fMRI study.**

Flavia Filimon[1] (ffilimon@cogsci.ucsd.edu), Jonathan D. Nelson[2], Martin I. Sereno[1]; [1]University of California, San Diego, [2]Computational Neuroscience Laboratory, Salk Institute, La Jolla, CA

Human spatial representations have been postulated to use various spatial reference frames. These fall broadly into two categories: egocentric (body-centered) reference frames, where locations of objects in space are represented relative to one's body; and allocentric (object-centered) reference frames, where an object's location is represented relative to another object. "Egocentric" can further be divided into various subcategories, e.g. eye-centered, head-centered, or hand-centered. Recordings in macaques have revealed object-centered representations in area SEF (Olson, 2003).To extend Olson's findings to humans, we used fMRI to investigate the neural correlates of egocentric and allocentric spatial representations in the context of eye movements. During the experiment, subjects fixated on a central fixation cross while a target appeared on a peripheral horizontal bar displayed at random locations in the visual field. The target and bar then disappeared and the bar without a target reappeared at a different retinal location. In the allocentric condition, subjects saccaded to the location on the bar where the target had appeared, thus using an object-centered spatial representation. In the egocentric condition, subjects saccaded to the former location of the target relative to their fixation point, thus using eye-centered coordinates. During baseline, subjects continuously maintained fixation.Both egocentric and allocentric eye movements activated the intraparietal sulcus, FEF, SEF, MT, precuneus, V1, and ventral premotor areas. Although the two conditions yielded very similar activation patterns, some differences were observed in SEF, posterior parietal cortex and the anterior cingulate. Differences and similarities between egocentric and allocentric activations and postulated representations will be discussed.

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Visual Representations in Memory

J63 *1088* **Increasing perceptual difficulty reveals implicit spatial memory**

Jongsoo Baek[1] (jongsoob@usc.edu), Do-Joon Yi[2], Min-Shik Kim[3]; [1]Laboratory of Brain Processes (LOBES), University of Southern California, Los Angeles, CA, USA, [2]Department of Psychology, Yale University, CT, USA, [3]Department of Psychology, Yonsei University, Seoul, Korea

Although various forms of visual memory have been documented, it is not yet clear how such top-down knowledge is dynamically implemented in a given visual task. Here, we propose that perceptual difficulty might be critical in determining the extent to which current behavior benefits from prior experience. This possibility was tested in a contextual cueing experiment (Chun & Jiang, 1998), in which 24 spatial layouts of a T-shape target and 15 L-shape distractors were repeated 10 times for learning and four times for testing. Perceptual difficulty was manipulated by the size of offset in the line junction of distractors. Half of the repeated layouts had the distractors of the same offset size for both learning and testing (either small or large), whereas the other half had different offset sizes in the learning and testing phase (either small to large or large to small). We predicted that, when the perceptual quality of visual inputs suffered from increased offset, visual search would become more dependent on prior experience with a given layout, thus producing greater contextual cueing. As a result, during the learning phase, search responses were not faster for the repeated layouts than for the novel layouts, possibly due to great similarity among our search layouts. Importantly, however, during the testing phase, the repeated layouts produced significantly faster search responses than novel layouts only when the size of offset in distractors increased after training. This finding suggests that perceptual difficulty influences the manifestation of top-down guidance from prior visual experience.

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J64 *1089* The units of visual statistical learning: Features or objects?

Phillip J. Isola[1] (phillip.isola@yale.edu), Nicholas B. Turk-Browne[1], Brian J. Scholl[1], Teresa A. Treat[1]; [1]Yale University

The visual system has the remarkable ability to extract and exploit subtle statistical regularities in our sensory input. In particular, studies of visual statistical learning (VSL) have revealed rapid and robust learning of temporal statistical relationships in sequences of shapes. However, by using objects that vary only along one dimension (shape) these studies leave open the question of whether VSL extracts relationships between feature values or objects. Here we contrast these two possibilities by studying how VSL operates over compound objects: twelve shapes, each paired with one of twelve colors. Observers watched a six minute familiarization sequence of shapes appearing one at a time, and then completed a series of 2AFC familiarity judgments between two smaller test sequences that varied only in terms of their transitional probabilities from familiarization. Critically, shapes in the test sequences were presented monochromatically for one group of observers, and in their original colors for another group. If the underlying units of VSL are unbound features, then learning should be expressed at test in both groups; in contrast, if VSL is object-based, then learning should be expressed only when the colors are maintained. The results supported this latter possibility: when color was maintained at test, observers chose the test sequence with the higher transitional probability more than 80% of the time. In contrast, when the identical familiarization sequences were later tested monochromatically, observers performed at chance (52%). Thus the underlying units of VSL are objects rather than unbound features.

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URL: http://www.yale.edu/perception/

J65 *1090* You compare the apple, but do you remember orange? Failure to compare features in memory research

X.A.N.D.R.A. van Montfort[1] (X.A.N.D.R.A.v.Montfort@tm.tue.nl); [1]Technische Universiteit Eindhoven

A growing amount of evidence suggests that even when an unexpected change is not detected, people often remember some properties of the pre-change item. This implies that poor change detection performance might be caused by a failure to compare, and is not necessarily evidence for limited memory. Previous research from our lab demonstrates that small pictorial changes affecting the gist of an image (Gist Changes) are detected twice as often as other (pictorially larger) changes (Feature Changes) in a Same/Different memory experiment. From these findings we concluded that the gist of an image is remembered and compared. The current research sets out to explore whether the relatively small accuracy for Feature Changes found in our previous studies was likely to be caused by insufficient memory for features or insufficient comparison of features. In two experiments memory for previously studied clip-art images was tested. One tested memory with a Four Alternative Forced Choice (4AFC) task. The four alternatives consisted of the studied (Target) image, a Gist Change image, a Feature Change image and an image with both types of changes. The other tested memory with a Same/Different task. Comparison of false recognition rates (4AFC) and accuracy (Same/Different task) for Feature Change images indicates that some of the poor detection of Feature Changes might have been caused by failure to compare. This suggests that more is remembered than is compared, even when people are aware that something might be different.

J66 *1091* The Invariance of Visual Long-term Memory to Geometric Transformation

Heidi Lam[1] (hllam@cs.ubc.ca), Tamara M Munzner[1], Ronald A Rensink[1]; [1]Department of Computer Science, University of British Columbia, Vancouver, Canada

This study investigated the extent to which visual long-term memory (vLTM) is invariant to geometric transformation. Observers were sequentially presented with 8 target figures, each constructed by lines between 15 randomly-placed dots, and each presented for 12 seconds. A set of 8 test figures was then sequentially shown, 50% of which were in the target set. Observers were asked to determine whether each was in the target set. Baseline performance was measured in terms of accuracy and response time (RT) for untransformed figures. This was compared with test figures transformed in some way, including scaling, rotation, and rectangular and polar fisheye transformations. We also investigated the effect of grids superimposed on the figures. Twenty observers were tested in each condition.Results show that scaling had no effect up to a reduction factor of at least five. There was no effect of rotation up to 45 degrees, with rotations of 60 degrees or more causing increased RT and decreased accuracy. When grids were present, no significant degradation was found for rotation, even up to 90 degrees. The fisheye transformations also exhibited thresholds beyond which performance decreased significantly, with the polar fisheye transformation degrading considerably less than the rectangular one. Interestingly, the addition of grids helped with the rectangular fisheye transformation but interfered with the polar one. Thus, it appears that vLTM has a considerable amount invariance to geometric transformation, and that the polar fisheye transformation is a relatively natural one. Furthermore, the presence of grids can boost this invariance for some transformations.

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J67 *1092* Preferential representation of interobject spatial relations that are aligned with employed reference directions

Björn Rump[1] (bjoern.rump@vanderbilt.edu), Timothy P. McNamara[1]; [1]Department of Psychology, Vanderbilt University

Prior research suggests that spatial layouts are mentally represented with respect to frames of reference that are intrinsic to the represented layouts themselves (Mou & McNamara, 2002). The particular intrinsic reference directions employed are selected based on egocentric experience, spatial and non-spatial properties of the objects, and the availability of salient axes in the environment. When accessing memory, object locations can be retrieved more efficiently from imagined headings that are aligned with the reference directions that underlie the representation. The present experiments investigated whether the selection of a particular intrinsic reference frame at the time of learning also results in the preferential representation of interobject spatial relations that are aligned with the employed reference directions, such that pointing directions aligned with the selected reference frame are benefited. Participants studied a configuration of nine objects from one of two viewpoints that were aligned with the walls of the surrounding rectangular room. As anticipated, performance on subsequent judgments of relative direction was best for imagined headings that were aligned with the walls of the room, indicating that an intrinsic reference frame defined by the walls of the room was used to represent the layout. Within aligned imagined headings, performance was best for aligned target object directions, lending support to the notion that interobject spatial relations are preferentially represented when they coincide with employed reference directions. No such effect was observed for misaligned headings. The results are discussed in the context of Mou, McNamara, Valiquette, and Rump's (2004) model of spatial memory.

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J68 *1093* How Change-Detection is Related to Visual Search: A Change in a Remembered Object is Like a Simple Feature

Joo-Seok Hyun[1] (joo-seok-hyun@uiowa.edu), Andrew Hollingworth[1], Steven J. Luck[1]; [1]University of Iowa

Change detection is like a search task in which subjects search for the presence of a difference between the test array and a memory representation of

the sample array. To explore this analogy, we compared a traditional change-detection task in which subjects looked for a difference between the sample and test arrays (analogous to a search for feature presence) with a task in which all or all-but-one of the items change and subjects look for a no-change item ("any-sameness" task; analogous to a search for feature absence). Just a RTs are slower and more set size-dependent when subjects search for the absence of a feature as when they search for the presence of a feature, we found that RTs were slower and increased more rapidly as set size increased in any-sameness task than in the traditional change-detection task. These results suggest that the presence of a change is like the presence of a unique feature, and can be detected by an unlimited-capacity process. We further tested the hypothesis of unlimited-capacity change detection by asking subjects to make a saccade to the location of a changed item in a change-detection task. Saccadic onset latencies increased only slightly as set size increased from 2 to 4 items, with a slope of 12ms/item, which is in the typical range for efficient visual search performance. Together, these results support a close analogy between visual search and change detection.

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J69 *1094* Change blindness during multiple interactions with a single object

Alan E Robinson[1] (robinson@cogsci.ucsd.edu), Jochen Triesch[2], Mary M Hayhoe[3], Jason A Droll[4], Brian T Sullivan[3]; [1]UC San Diego, USA, [2]Frankfurt Institute for Advanced Studies, Germany, [3]University of Rochester, USA, [4]UC Santa Barbara, USA

In the course of repeated interactions with an object in an ongoing task, do multiple fixations on the object lead to enhanced representations in working memory? Subjects performed a task in a Virtual Reality with haptic feedback.Subjects first placed a brick on one of four corners of a virtual tabletop. Then they were cued to pick up the brick again and move it to another corner. The correct corner depended on the brick; for instance "if the brick is tall, move it to the back of the table; if short move it to the left". These sorting instructions changed after each brick movement, and subjects moved each brick four times per trial. On some trials a saccade contingent change was made to the brick. Subjects missed 40% of changes, despite being told they would occur. Undetected changes were universally sorted by the old, pre-change feature, even though sorting required multiple fixations directly on the brick. Even when subjects detected changes, detection often occurred only after having made several erroneous sorting decisions. The rate of change detection did not depend on how many times the subject sorted a brick before it changed, suggesting that subjects did not enhance their internal representations of the brick when they refixated it. Our results suggest that visual information available in the scene is often disregarded in favor of information acquired early in a task and stored in working memory. This may be an efficient strategy for deployment of limited attentional resources in this task.

URL: http://csclab.ucsd.edu/~alan/pub/vss06_rep_int/

J70 *1095* Dual Visual Systems and Working Memory for Object and Spatial Properties

Thomas Sanocki[1] (Sanocki@usf.edu), Jennifer Kaltreider[2]; [1]University of South Florida, [2]University of Wales, Bangor

Two systems theory posits a ventral stream for object processing and a dorsal stream for spatial processing. Does this division of labor have consequences for working memory (WM)? We examined WM for object and spatial properties. In different blocks, the two relevant properties were from one stream or from both. Depending on assumptions, different two-systems predictions can be made. One prediction is that elements within one stream are encoded or output easier than elements from different streams. An alternative to two-systems theory is the hypothesis that elements are encoded independently and only the difficulty of elements matters. We used a VWM task with displays of four items varying on both object and spatial properties (object: pattern, shape identity; spatial: orientation, location). In the two within-system blocks, participants reported the two object or two spatial properties. In each of the four between-system blocks, one property from each system was reported (e.g., pattern and location). In Experiment 1, a symbolic response was required (letters corresponding to properties). In Experiment 2, a more analog action response was required (shorthand drawings). In each experiment, there were reliable differences in the ease of reporting particular properties (p's<.001). However, there were no effects of grouping -- mean trial recall was 1.89 properties for within-system blocks and 1.90 for between-system blocks (F<1; the within-subject Standard Error of 0.01 indicates high experimental sensitivity). Thus, difficulty of independent properties drove performance, not two-systems architecture.

J71 *1096* The role of topological change in object persistence

Maya U. Shankar[1] (maya.shankar@yale.edu), Jonathan I. Flombaum[1], Brian J. Scholl[1]; [1]Yale University

Coherent visual experience requires computations that allow us to perceive objects as persisting individuals through time and space. How is this achieved in a world where objects are regularly occluded by other objects? A key generalization from previous work in vision science and cognitive development is that the underlying rules which control object persistence are *spatiotemporal* in nature, and do not take objects' surface features into account. We tend to see objects as persisting whenever they traverse spatiotemporally continuous paths through occlusion, for example, even if their colors and shapes change dramatically. Here we report a striking exception to this generalization, based on a surface feature which is rarely considered in studies of persistence — topological structure. We employed a dynamic change detection paradigm as an implicit measure of persistence (Flombaum & Scholl, 2004, *VSS*). Subjects viewed displays in which objects oscillated behind occluders on spatiotemporally continuous trajectories. Some items changed topologically (gaining or losing a hole) during occlusion, while others changed shape in other ways equated for overall salience, but preserving topology. Observers were worse at detecting additional color changes across occlusion when they accompanied topological changes, apparently because this forced the construction of a new object representation rather than the updating of a previous representation. This indicates that topological structure is not only especially salient, as has been previously demonstrated (see Chen, 2005, *Visual Cognition*), but that it also serves to define persistence over time. Thus the view that only spatiotemporal dynamics drive object persistence is full of holes.

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URL: http://www.yale.edu/perception/

J72 *1097* Iconic memory revisited: a plea for a distinction between a retinal and cortical icon

Ilja G. Sligte[1] (I.G.Sligte@uva.nl), Victor A.F. Lamme[1,2], H. Steven Scholte[1]; [1]Dept. Psychology, University of Amsterdam, [2]The Netherlands Ophthalmic Research Institute

The common conception of visual memory is one which encompasses a very short (~300 ms) sensory store with unlimited capacity, and a durable, limited-capacity working memory store. We plea for a distinction in this short sensory store between a *retinal icon* and a *cortical icon* . In our experiments, we modified the change blindness (or delayed match-to-sample) paradigm used by Landman et al. (2003) by introducing cues during the interval. Cues could be delivered 10 ms after off-set of the sample display, 1000 ms after off-set of the sample display or 100 ms after on-set of the match display. We varied the usability of context information in the sample display (exp.1), set size (4 - 32 figures, exp. 2), the extent to which the stimuli evoke retinal afterimages (high-contrast black-white vs. isoluminant red-grey; exp. 2), and the length of the interval between off-set of the

sample display and the application of the cue (exp. 3). Furthermore, we applied masks and brief flashes of light before cuing (exp.4).Our combined experiments argue for a tripartite division of sensory memory: 1. the traditional working memory store, 2. a 'cortical icon' that has much higher capacity than working memory, is not overwritten by a uniform flash of light, and can still be accessed after several seconds, and 3. a 'retinal icon' of even higher capacity, that lasts only several milliseconds and is overwritten by an uniform flash of light.

J73 *1098* On the Nature of Perceptual Representations That Are Transformed Into VSTM Representations

Adam T Niese[1] (adam-niese@uiowa.edu), Steven J Luck[1]; [1]University of Iowa

Visual working memory representations are formed from perceptual representations in a process called short-term consolidation. However, a backward mask appearing shortly after a stimulus can disrupt the perceptual representation before the transformation into a working memory representation is complete (Vogel, Woodman, & Luck, in press). The locus of this effect has not yet been identified. The present study used a change-detection paradigm in which a mask array followed the sample array and manipulated the mask's characteristics to explore the nature of the disrupted perceptual representation. The first experiment manipulated the similarity between the sample and the mask to judge how sensitive the masking effect is to low-level perceptual characteristics. It demonstrated that a bar presented at one orientation can effectively prevent consolidation of the color of a bar presented at a different orientation. The second and third experiments manipulated the proximity of the masks to the sample items. The second experiment showed that fine manipulations of proximity produced little to no impact on masking. Experiment 3 used a large-scale proximity manipulation and showed that an effective mask can occur anywhere within the to-be-stored object's hemifield, with no masking for a mask in the opposite hemifield. We conclude that the perceptual representations underlying visual working memory representations are stored in an area with large, complex, and abstract receptive field properties, such as inferotemporal cortex.

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Reading

J74 *1099* Potent features for letter identification

Caroline Blais[1,2] (caroline.blais@umontreal.ca), Daniel Fiset[4], Catherine Ethier-Majcher[1,2], Karine Tadros[1,2], Martin Arguin[1,2,3], Frédéric Gosselin[1,2]; [1]Université de Montréal, Département de Psychologie, [2]Centre de Recherche en Neuropsychologie et Cognition, [3]Centre de recherche, Institut Universitaire de Gériatrie de Montréal, [4]University of Glasgow, Department of Psychology

A dynamic version of the Bubbles technique (Gosselin & Schyns, 2001; Vinette & Gosselin, 2002) was used to reveal the potent features of letters through time in a letter identification task. Six participants had to identify each letter, presented for a duration of 100 ms, 1,000 times on average. The stimuli were the 26 uppercase letters of the alphabet (Arial font), presented in a random order and subtending 1.0 x 1.2 deg on average. The stimuli were sampled in space-time by 3D Gaussian bubble (space std = 0.14 deg and time std = 40.8 ms). Accuracy was maintained at 51% correct (chance level is approximately 4%) by adjusting, on a trial-by-trial basis, the number of bubbles using QUEST (Watson & Pelli, 1983). For each individual letter, a linear regression was performed on the participants' accuracy and the corresponding sampling noise volumes. The results show which features are useful to recognise each letter of the alphabet, and reveal a clear modulation of the effective use of these features through time. For example, to successfully recognise the letter "O", subjects first used the region allowing the distinction between an "O" and a "C" or a "G" (i.e. the right middle part of the letter) and subsequently used the region allowing the distinction between an "O" and a "Q".

J75 *1100* Effects of Polarity, Time, and Memory Processes on Reading

Faith L. Florer[1] (fflorer@barnard.edu), E. Corey Lawrence[1], Jemma Lampkin[1], Veronique Salvano-Pardieu[2]; [1]Barnard College, Columbia University, NY, NY, [2]Université de Tours, Cedex, France

We confirmed and extended our VSS 05 finding -- memory for text was better when the time elapsed between text and test was shorter, when memory was explicitly vs implicitly tested, and when text was read on paper vs the computer. Participants read black text on white background or white text on black background; worked on a distractor task; then participated in a 20 word explicit or implicit memory test. We tested 163 subjects on one-minute delay and on two new conditions: 1) no delay between reading and test and 2) word stem completion task without reading text. We found memory was better for shorter retention intervals $F(2, 260) = 25.75$, $p < .05$. The memory benefit conferred by explicit memory disappeared at no delay. Also at no delay, we found an effect of polarity, $F(3, 288) = 4.90$, $p < .05$; for text and test of the same polarity (color background on reading and test were the same), the mean proportion correct was .34; for text and test that differed in polarity (color on reading and test differed), .30. Proportion correct on the answer sheet without reading text was .12, significantly lower than when reading paper, or computer $F(2, 278) = 10.04$, $p < .05$, indicating that participants remembered the text. Our findings suggest more strongly that the nature of cognitive processing and passage of time affects memory for text more than previous findings of preference and comfort for black test on white backgrounds suggest.

J76 *1101* Crowding limits reading

Denis G Pelli[1] (denis.pelli@nyu.edu), Katharine A Tillman[1]; [1]Psychology and Neural Science, New York University

When a word is presented in the periphery, the letters crowd each other unless they are far apart. Crowding also affects the more-peripheral letters of a centrally-presented word. However, increasing letter spacing does not improve reading rate. We present theoretical and empirical results that resolve this seeming paradox. We measured RSVP reading rates for ordered and unordered text as a function of letter spacing at central and peripheral locations. We show that two assumptions, introduced by Bouma and Legge, predict how reading rate depends on letter size and spacing. In all conditions tested (all spacings and sizes, central and peripheral, ordered and unordered) crowding limits reading.

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URL: http://psych.nyu.edu/pelli/posters.html

J77 *1102* Effect of Letter Spacing on Legibility, Eye movements, and Reading Speed

Yu-Chi Tai[1] (tai.30@osu.edu), James Sheedy[1], John Hayes[1]; [1]The Ohio STate University, College of Optometry

Purpose: Previous studies have shown that word legibility at threshold size is poorer than single letter legibility, probably due to lateral inhibition. Therefore the magnitude of inter-character spacing in words should affect legibility. This study investigates the effects of character spacing upon legibility and upon eye movements and reading speed. Methods: Forty-two subjects participated in the study. The inter-character spacing of Verdana 10-point font was condensed and expanded in a step-wise manner from default. Effects of spacing on word legibility were measured with a visual acuity method. Reading performance and eye movements were measured for default spacing and 4 levels each of condensed (0.5, 1.0, 1.5, and 1.75 points) and expanded (0.5, 1.0, 1.5, and 2.0 points) spacing. Results: Word legibility significantly improved as letter spacing increased, but never exceeded single letter legibility. Eye movement measurement showed that mean fixation duration decreased from 300 msec to 250 msec and the mean saccadic amplitude changed from 2.2 to 3.4 degrees across the condensed/expanded spacing range. Reading speed was unaffected by character spacing and words/fixation was largely unaffected. Conclusions: With con-

densed spacing legibility is decreased and the visual system adapts by increasing the fixation duration. With expanded spacing legibility increases and the visual system adapts by decreasing fixation duration and increasing the mean saccadic size. Words/fixation is largely unchanged - indicating that cognitive content may govern the eye movements and ultimately limit reading speed. Spacing changes are compensated by changes in eye movements with no net change in reading speed.

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J78 *1103* Is reading serial?

Katharine A Tillman[1] (kat@villanelle.org), Denis G Pelli[1], Marialuisa Martelli[2], Jeffrey Stott[3], Jason Rosenblatt[4]; [1]Psychology and Neural Science, New York University, [2]Dipartimento di Psicologia, Università di Roma La Sapienza, [3]St. John's College Santa Fe, [4]Plainview Old Bethpage John F. Kennedy High School

We read words one at a time. Crowding has shown that words are recognized by parts. Are these parts also recognized one at a time? When you have more information (context) about what the next word might be, you need fewer parts to identify it. We find that the time required to recognize the next word is roughly proportional to the log of the number of possibilities. Results with RSVP presentation of letters, digits, and words reopen the question of serial letter recognition that was thought to be closed one hundred years ago.

Acknowledgment: R01-EY04432

URL: http://psych.nyu.edu/pelli/posters.html#2005

J79 *1104* Character Size Affects Reading Comprehension, Not Reading Rate, in Children

jenie kurian[1] (jeniek@gmail.com), Jemma Lampkin[2], E. Corey Lawrence[2], Faith Florer[2]; [1]Stuyvesant High School, New York, NY, [2]Barnard College, Columbia University, New York, NY

How does character size affect reading rate and comprehension in children? Do the effects change as children age? We measured the reading rate and errors of 40 third grade participants, on two passages and two character sizes: one similar to the text size of everyday reading materials (one degree of visual angle) and one larger (four degrees). Results showed that third graders read almost equally quickly at the smaller angular character size, mean = 117 WPM, as they did at the larger, mean = 114 WPM, $F(1, 39) = .12$ $p > .05$. Comprehension suffered at the larger character size and was significantly lower for the reading materials that were four rather than one degree of visual angle -- .73 vs 1.25 mean error rate, respectively, $F(1, 39) = 4.54$ $p < .05$. Following the testing of third grade participants, we tested 12 eleventh graders on sample reading sections from the GREs under the same conditions in order to examine how the effects of angular character size change, as children age. The results showed little change in reading rate 118.25 vs 120.45 mean WPM for 1 vs 4 deg, $F(1, 11) = .05$ $p > .05$; results were inconclusive for reading comprehension 1.83 vs 2.00 mean error rate, $F(1, 11) = .19$ $p > .05$. This research shows that younger children may have a wide optimal range for character size, like older children, but may need small, familiar-sized, text to sufficiently comprehend the information when reading.

J80 *1105* Developmental changes in the size of the visual span for reading: Effects of Crowding

M.Y. Kwon[1] (kwon0064@umn.edu), G.E. Legge[1]; [1]University of Minnesota, USA

Kwon et al.(2005) showed that the size of the visual span-the number of adjacent letters reliably recognizable without moving the eyes-increases with grade level. Crowding of adjacent letters is likely to affect the size of the visual-span. Here, we ask if the developmental growth of the visual span is associated with a developmental decrease in crowding. Groups of 10 children in 3rd, 5th, and 7th grade, and 10 adults were tested. Visual-span profiles were based on letter-recognition accuracy for trigrams (random strings of three letters) centered at letter positions 0 to 5 left and right of the fixation point. We refer to the center letter of the trigram as the 'middle,' the one nearest the midline as the 'inner,' and the farthest from the midline as the 'outer.' The visual-span profile, a plot of percent-correct recognition vs. letter position can be decomposed into component profiles for 'inner', 'middle', and 'outer.' We define the visual-span size as the area under the profile, transformed to bits of information transmitted. Crowding is defined as the difference in the information transmitted for the component profiles for the outer and middle. The data revealed children showed a greater crowding effect than adults: 5.38(±0.32) bits for children, and 2.89(±0.52) bits for adults. Regression-analysis using crowding in bits as a predictor showed that about 52% of the variability in visual-span can be explained by crowding. Our findings suggest that the age-related decrease in crowding plays a role in explaining larger visual-spans and faster reading by adults.

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URL: http://vision.psych.umn.edu/~gellab/

J81 *1106* Flicker Fusion as a Correlate of Word Decoding Ability

José E. Sr. Náñez[1] (jnanezsr@asu.edu), Steven R. Holloway[1], Caitlin Donahoe[1], Aaron Seitz[2]; [1]Arizona State University, [2]Boston University

Critical flicker fusion (CFF) threshold is the lowest level of continuous flicker that is perceived as a steady source of light. CFF thresholds have also been shown to be impaired in populations with reading disorders, such as dyslexics. While CFF and reading scores have been compared between normal reading and dyslexic populations, few studies, if any, have compared CFF and reading within a normal reading population. This study investigates the relationship between visual temporal processing and reading ability in a normal reading population. 76 Subjects (aged 18-35) were recruited at Arizona State University. CFF thresholds were assessed on a macular metrics densitometer, using the method of limits by a 1-deg diameter green (peak = 570nm) test field. Reading was measured using the Bader Reading and Language Inventory: Reading-word Decoding Test (1998). The results show a high correlation ($r=0.76$, $p<<0.001$) between CFF thresholds and scores on the reading-word decoding test. The outcome of this study suggests that reading, specifically the ability to decode words, may be dependant on cortical processing in the dorsal stream. These results imply that the efficiency at which the elements of the visual cortex involved with temporal modulation and spatial processing function, may affect the ease at which people read. Future research should consider the possibility that a perceptual learning paradigm that is known to increase temporal processing may have benefits for patient populations who have diminished CFF thresholds, such as, those who suffer from dyslexia and other reading disabilities.

J82 *1107* How The Word Length Effect Develops With Age

Cayla B Bergman[1] (Caybabe88@aol.com), Denis Pelli[2], Cristina Burani[3], Pierluigi Zoccolotti[4], Marialuisa Martelli[4]; [1]Plainview Old Bethpage John F. Kennedy High School, [2]Psychology and Neural Science, New York University, [3]Istituto di Scienze e Tecnologie della Cognizione, CNR Roma, [4]Dipartimento di Psicologia, Università di Roma La Sapienza

It is well known that vocal reaction time increases with word length for beginning readers of highly regular languages (transparent). However, little is known about the development of the word-length effect in English readers, a language with highly irregular rules for pronunciation (opaque). The length effect is interpreted as the signature of a reading strategy based on letter by letter decoding (alphabetic reading), and it is extremely large in dyslexic readers of transparent languages. English is thought to be acquired through holistic word recognition, and the word length effect has not been systematically investigated on normal and dyslexic English read-

ers. Here we test the effect of word length on word naming latency for third and fifth grade English average readers. The length effect is present in both age groups (75 ms and 26 ms per letter, R2=0.70 and 0.88 respectively) and surprisingly similar to that found in age-matched Italian readers. Contrary to what is generally thought for English reading acquisition, we conclude that at least up to fifth grade, reading is mediated by a letter by letter decoding strategy in opaque (English) as it is in transparent (Italian) languages. This result is important for understanding typically developing and dysfunctional reading acquisition.

J83 *1108* A difference of moments (DoM) model for small Chinese and English letter recognition

Cong Yu[1] (yucong@ion.ac.cn), Jun-yun Zhang[1], Shu-guang Kuai[1], Feng Xue[2], Stanley A Klein[3], Lei Liu[4]; [1]Institute of Neuroscience, Chinese Academy of Sciences, Shanghai, [2]Fudan University EENT Hospital, Shanghai, [3]UC Berkeley School of Optometry, [4]Lighthouse International, New York

Background: Previously we estimated acuity thresholds for Sloan letters and six groups of Chinese characters (CC1~CC6, 2-4~16-18 strokes) based on six subjects' 109,200 trials (VSS05). This data set allowed a detailed analysis of human errors to reveal the psychophysical mechanisms underlying recognition of Chinese characters and English letters near acuity. **Methods:** Confusion matrices (CMs) were constructed for seven groups of stimuli using results from experimental sessions with 50~60% correct rates (~8,000 trials each). The off-diagonal elements (incorrect responses) were fit with a difference of moments (DoM) model, in which **a)** a letter or character was described by its lower-order geometric moments (e.g., ink pixel number (0th), mean (1st), variance (2nd), skewness (3rd), kurtosis (4th)) in horizontal, vertical, and diagonal directions; **b)** the perceptual distance between two letters *(D)* was determined by the sum of weighted differences of corresponding moments; and **c)** confusability *(C)* was defined as C=exp(-D). **Results:** Fitting data with a 5-moment (0th plus 2nd and 3rd H and V moments) model produced correlations from 0.94 (CC1) to 0.61 (CC6) (mean r=0.76). Adding 4th–order H and V moments (7-moment model) slightly improved correlation (r=0.78). Adding six diagonal moments (13-moment model) improved fitting by ~10% for most groups and by 20% for CC6 (r=0.84). DoM model fitting was better than fitting by template model (r=0.41) and blurred template model (r=0.56). **Conclusions:** Recognition of near acuity Chinese characters and English letters is most likely based on global stimulus properties, as represented by the lower-order moments in our model.

J84 *1109* Age Effects on Reading Speed and Visual Span in Peripheral Vision

Deyue Yu[1] (yuxx0207@umn.edu), Sing-Hang Cheung[2], Susana T.L. Chung[3], Gordon E. Legge[1]; [1]University of Minnesota, U.S.A., [2]Stanford University, U.S.A., [3]University of Houston, U.S.A.

Purpose: Our interest in reading with peripheral vision centers on its relevance to people with central-field loss, which becomes more prevalent with old age. It has been proposed that the size of the visual span – the number of letters recognized reliably without moving the eyes – is a visual factor limiting reading speed. In this study, we asked whether the size of the visual span and reading speed show similar dependence on age in peripheral vision.Methods: Seventeen normally sighted young adults (aged 19 to 30 yrs, averaged 23.8) and old adults (aged 55 to 76 yrs, averaged 66) participated. Performance was assessed 10° from fixation in the upper and lower visual fields. Rapid-Serial-Visual-Presentation (RSVP) reading speed was measured. Visual span profiles, measured with trigrams (strings of 3 random letters), are plots of letter-recognition accuracy as a function of letter position. Size of the visual span was defined as the area under this profile, converted to bits of information transmitted. Results: Visual-span size was larger (27.1 vs. 24.4 bits; p=0.011), and reading speed was higher (191 vs. 124 wpm; p<0.0005) in young than older participants. Visual-span size was larger (26.4 vs. 25.1 bits; p=0.001), and reading speed was higher (169 vs. 146 wpm; p=0.003) in the lower than upper field.Conclusions: The covariation of reading speed and visual-span size across age and visual-field location supports the view that the size of the visual span is an important factor determining reading speed.

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J85 *1110* Magno- and Parvocellular Psychophysiology in Normal Children and those with Dyslexia and Asperger Syndrome.

David P Crewther[1] (dcrewther@bsi.swin.edu.au), Sheila G Crewther[2]; [1]Brain Sciences Institute, Swinburne University of Technology, [2]Psychological Science, La Trobe University

An M-pathway deficit has often been associated psychophysically with dyslexia. However there are few physiological studies testing this or attempting to determine the first locus within the visual pathway of any abnormal processing. Thus Magno (M) and parvocellular (P) function was assessed, following Klistorner et al (1997) using second order Wiener kernels of the multi-focal non-patterned visual evoked potential (mfVEP) at short interaction times (sensitive to M) and at longer interaction time (sensitive to P). The subjects included 24 normally reading children (6–12yrs) 14 dyslexics and 3 poor readers with Asperger syndrome. Transient attention was assessed using a custom designed change detection task (requiring parietal activation) and mfVEPs were measured (VERIS system) at luminance contrasts of 24% and 94%. Although the dyslexic children generally showed a ratio of P/M amplitudes similar to those of normal children of similar ages, the mfVEPs of the Asperger group were characterised by short latency larger amplitude more mature M waveforms and a large latency difference (40 msec) between M and P peaks for children of similar age. Change detection was significantly reduced in the dyslexic population compared with normal (Rutkowski et al, 2003) but was normal for the Asperger group.

Poster Session K

Tuesday, May 9, 2006

Temporal Processing (1111-1121), Attention: Temporal Selection (1122-1138), Biological Motion and Animacy (1139-1150), Complex Motion (1151-1166), Facial Expression Perception (1167-1176), Face Perception: Models (1177-1184), Synesthesia (1185-1187), Attention: Interactions with Memory (1188-1193)

Poster Session: 4:30 - 7:30 pm ***Municipal Auditorium***
Author presents: 6:00 - 7:00 pm

Temporal Processing

K1 *1111* Linking Impulse Response Functions to Reaction Time: Rod and Cone RT Data and a Neural Model

Dingcai Cao[1] (d-cao@uchicago.edu), Andrew J. Zele[1], Joel Pokorny[1]; [1]Department of Ophthalmology and Visual Science, The University of Chicago, 940 East 57th Street, Chicago, IL, 60637

Purpose: We measured reaction times (RT) for inferred rod and cone ON and OFF pathways. A neural model for RT was developed based on rod and cone impulse response functions. Method: A rod or cone (L+M+S) isolating stimulus (2° center, 13°surround, 7.5° eccentricity) was presented using a 2-channel, 4-primary colorimetric system. Retinal illuminance spanned a 5-log unit range (0.002-200 Td). RTs were measured at 5 contrasts, using 1-sec rapid-on or rapid-off ramp waveforms. The measured RTs were modeled based on rod and cone impulse response functions derived from published psychophysical temporal contrast sensitivity data, and a decision-making process that depended on the integrated neural signals. Results: RTs decreased with increasing contrast and retinal illuminance. RTs to incremental and decremental cone-isolating stimuli were similar at all light levels. At low light levels (= 0.2 Td), rod responses for decrements were faster than for increments. RTs for rod and cone stimuli were comparable at 2 Td; cones responded faster than rods at light levels =20 Td. Our model described the data using a single value across conditions specifying the irreducible minimum reaction time, and one free parameter for each increment/decrement/light level condition.Conclusion: The reaction times of cone ON and OFF pathways were similar. Rod OFF pathway responses were faster than ON pathway responses at low light levels. Cones were faster than rods only above high mesopic light levels. Our impulse-response-function based model captures all attributes of the RT data with a limited number of free parameters.

K2 *1112* Apparent asynchrony between the perception of color and motion: An issue of different latencies or of attention?

AO Holcombe[1,2] (holcombea@cardiff.ac.uk), P Cavanagh[3]; [1]School of Psychology, Cardiff University, United Kingdom, [2]School of Psychology, University of Sydney, Australia, [3]Department of Psychology, Harvard University

In a color-motion pairing task with red dots moving inward alternating with green dots moving outward, red inward is most likely to be reported when red is delayed ~100 ms relative to the inward motion appearance (Moutoussis & Zeki, 1997). Enns & Oriet (VSS 2004) reported that this perceptual asynchrony could be reversed by instructing participants to attend to color before attending to motion. However, our Experiment 1 found that this variation of instructions and endogenous attention only reduced the asynchrony rather than reversing it. In contrast, Experiment 2 manipulated exogenous attention and found a large effect. In Experiment 1, 7 observers monitored for inward motion and reported the associated color, and 7 monitored for redness and reported the associated motion. For those monitoring for inward motion, the most consistent pairing occurred when red followed the inward motion by ~134 ms. In the other group, red also had to follow inward motion, by ~100 ms. A reversal in the asynchrony was not obtained for any observer. In Experiment 2, an exogenous attentional cue (a ring) encircled the stimulus at various delays relative to the motion and color changes. Results indicated that optimal timing of inward and red varied with ring timing. In some observers, the best delay for red relative to inward was driven to zero. In summary, attentional cues modulate and in some cases eliminate the feature asynchrony, arguing against differential latencies.

URL: http://www.cf.ac.uk/psych/holcombea/research/asynchronyVSS06/

K3 *1113* Detection and prediction to changes in color and direction of motion

Tadayuki Tayama[1] (tayama@psych.let.hokudai.ac.jp); [1]Department of Psychology, Graduate School of Letters, Hokkaido University

It is known that changes in direction of motion are perceived after changes in color when they occur synchronously. This illusion is explained on the basis of neural response latencies or by the faulty match between color and position transitions. Apparently, this asynchrony occurs only by the delay of perceived changes in direction of motion. The present study investigated to what degree detections of changes in direction of motion are delayed by detection and prediction tasks. Detection task: Plaid patterns were used as stimuli. Test patterns abruptly reversed color and direction of vertical motion synchronously and the observer quickly pressed a button to the reversal. The response time was measured as the detection time. Changes in color (no change, red to green, green to red) and direction of motion (downward to upward, upward to downward, no change) were variously combined. Detections of color-change were faster than those of direction-change to the same test patterns. Prediction task: Conditions for the number of alternations and temporal period of test patterns were added to those in detection task. After a test pattern alternated color and direction of motion synchronously, the pattern disappeared and the observer was asked to pressed a button when the temporal period of 1 Hz has passed. Prediction times for color-change were shorter than those for direction-change. The velocity effect was also observed in both tasks. These results seem to shed light on the causes of the illusion.

K4 *1114* A Comparison of the Pulfrich and Flash-Pulfrich Effects

Christopher R.L. Cantor[1] (dalek@berkeley.edu), Clifton M. Schor[1,2]; [1]Vision Science Program, University of California at Berkeley, USA, [2]School of Optometry, University of California at Berkeley, USA

Last year (VSS 2005) we introduced a novel stereo-illusion, which we called the Flash-Pulfrich effect (FPE). While the classical Pulfrich Effect (PE) describes depth perceived when the half-images of a moving object have unequal brightness, the FPE describes depth perceived when one of

the half-images is intermittently strobed, while the other is presented continuously. We now ask whether and how the FPE and PE are related. Our data shows that the magnitude of the FPE is greater than that of the PE. This does not, however, preclude the possibility that a single mechanism might account for both. Accordingly, we have developed a computational model for the FPE based on the basic response properties of LGN neurons. The model filters the input (in space and time) with a DoG spatial filter and the biphasic temporal impulse response of LGN neurons. We show that this model predicts differences in magnitude between the PE and FPE. We also examine how the magnitudes of the PE and FPE vary when basic stimulus parameters are changed (spatio-temporal frequency and retinal illuminance). We show that the trends in the stimulus dependence of the two effects are predictions of the model.

K5 *1115* Temporal contrast sensitivity during smooth pursuit eye movements

Karl R. Gegenfurtner[1] (gegenfurtner@psychol.uni-giessen.de), Elias Delipetkos[1], Doris I. Braun[1]; [1]Dept. of Psychology, Giessen University, Germany

During smooth pursuit eye movements, stimuli other than the pursuit target typically move across the retina, and this might have an effect on their detectability. We used a 2AFC paradigm to measure detection thresholds for 1 cpd vertical Gabor stimuli of temporal frequencies between 1 deg/s and 24 deg/s, which moved horizontally within a Gaussian window. Observers had to indicate whether the Gabor targets were displayed 4 deg above or below the center of the screen. Observers kept fixation on a small target spot that was either stationary or moved at a speed of 8 deg/s in the same or opposite direction as the Gabor. We found that temporal contrast sensitivity was mainly limited by the temporal frequency on the retina. The high temporal frequency cutoff was shifted from 21 Hz under fixation to 15 Hz when the eyes and target moved in opposite directions and to 27 Hz when eyes and target moved in the same direction. However, there were significant sensitivity differences at the peak temporal frequency. Sensitivity was greatest for the fixation condition, reduced by 8% for the condition when eyes and Gabor target moved in the same direction, and reduced by 16% when they moved in opposite directions.The loss in sensitivity for peripheral targets during pursuit could be due to the attentional demands of pursuit or the jitter of the target on the retina caused by small fluctuations in the speed of eye movements.

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K6 *1116* Temporal resolution of visual processing in action video game players

Renjie Li[1] (rli@bcs.rochester.edu), Uri Polat[2], Walt Makous[1], Daphne Bavelier[1]; [1]Center for Visual Science, Univerisity of Rochester,Rochester,New York, 14627, USA, [2]Goldschleger Eye Research Institute, Tel-Aivi University, Sheba Medical Center,52621 Tel-Hashomer, Israel

Video game playing alters several visual skills and, in particular, leads to faster recovery of visual attention over time. Here, we investigate whether action video game playing changes the temporal resolution of visual processing. The effects of action video game playing on the temporal characteristics of visual processing were first tested by comparing gamers and non-gamers in a forward and backward masking paradigm (SOAs = ±120ms, ±90ms, and 0ms). The stimuli and design were similar to those of Polat & Sagi (in press) and consisted of a foveally-viewed Gabor patch target, which was either alone or masked collinearly by two flanking Gabor patches. The threshold contrast of the target was measured by a 2-alternative forced-choice (2AFC) staircase. Video game players showed reduced masking, especially backward masking; that is, gamers extracted visual information more readily than non-gamers. Critical flicker fusion thresholds (cff) were then compared between gamers and non gamers to assess whether this temporal advantage extends to other, low level visual functions. Cff for a circular 1° spot within a 2° steady surround, both at a mean luminance of 70 cd/m2, were measured with square wave flicker and a 2AFC staircase. That cffs for gamers were reliably higher than for non-gamers suggests differences in temporal resolution at a low level in the visual pathway. These results establish that the visual processing of avid action video game players has different temporal characteristics, but whether action game playing causes such a change remains to be determined.

K7 *1117* Duration estimation is affected by stimulus magnitude information in non-temporal dimensions

Xiangchuan Chen[1,2] (chenx248@umn.edu), Bin Xuan[2], Daren Zhang[2], Sheng He[1]; [1]University of Minnesota, [2]University of Science and Technology of China

Representation of magnitude information, such as the size of a square or number of apples in a box, is an important function of the human brain. Previous studies reported that magnitude information belonging to different categories could generate a Stroop-like interference effect, suggesting a common mechanism underlying the magnitude representation. In the present study, we investigated whether the estimation of temporal duration could be influenced by the magnitude information expressed by the stimuli that were used to mark the events. These marker stimuli included digits (larger or smaller), dots (more or less), squares (bigger or smaller), and luminance (higher or lower). Subjects were required to judge which one of two stimuli was presented for a longer (or shorter) duration, or which one of two intervals defined by three sequential stimuli was longer (or shorter). In the first experiment, subjects performed faster and more accurately when a "smaller" stimulus (e.g., digit 1) was presented for a shorter duration and a "larger" stimulus (e.g., digit 8) was presented for a longer duration (congruent condition). In the second experiment, subjects also performed better when the shorter interval was defined by two stimuli with a "smaller" difference (e.g., digits 9 and 8) and the longer interval was defined by two stimuli with a "larger" difference (e.g., digits 8 and 2). These results suggest that temporal duration estimation shares some components with the representations of magnitude information in non-temporal dimensions.

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K8 *1118* Masking can Improve Temporal Integration

Dan J. Swift[1] (dswift@umich.edu); [1]Behavioral Sciences Department, University of Michigan-Dearborn

Hogben and DiLollo (VR, 1974) displayed two sets of dots in succession. If superimposed, the two sets formed a 5x5 matrix with one missing location. The task was to determine that location, and has been interpreted as a test of the duration of visual persistence. Dixon & DiLollo (Cognitive Psychology, 1994) developed a temporal correlation model that accounted for a large amount of data with varying stimulus durations. The model has two main components: (1) computation of the neural response to each set of dots (which is both delayed and prolonged as compared to the actual stimulus), and (2) determination of the overlap/non-overlap ratio of the two neural response functions. Greater relative overlap predicts a higher probability of temporal integration, which in turn predicts a higher probability of detection of the empty location.The present study was designed to test the model in a novel way. If the non-overlapping trailing portion of the temporal response to the second interval can be eliminated or reduced, the relative overlap of the two intervals will increase. A mask stimulus, consisting of random static noise, was presented at two different delay durations following the second set of dots: 0 ms and 60 ms. Detection of the missing dot position was significantly better with the shorter delay. Presumably, the mask being dissimilar to the set of dots erased the neural response to the second set of dots, thereby increasing the relative overlap of the first two sets of dots.

K9 *1119* **The effect of feature-based attention on time perception**

Fuminori Ono[1] (fuminori@hiroshima-u.ac.jp), Jun Kawahara[2]; [1]Juntendo University, [2]Hiroshima University

The present study investigated the influence of selective feature-based attention on temporal perception. Although it has been shown that space-based attention modulates temporal perception, it is unclear whether feature-based attention influences temporal perception. The present study combined a visual selection task (Raymond, Fenske, Tavassoli, 2003) with a temporal interval production task to determine whether feature-based attention interacted with temporal perception. In the selection task, the display consisted of a pair of stimuli positioned to the left and right of fixation. Participants located the target stimuli as quickly as possible by pressing the left or right arrow keys. This selective response directed participants' feature-based visual attention to one of two stimuli, and was followed by a temporal production task. In the temporal production task, a single test stimulus was presented and participants pressed a key when they judged that the pre-specified interval (e.g., 2000ms) had elapsed from the onset of the test stimulus. The test stimulus was one of the stimuli that had been presented in the immediately preceding selection trial. The results indicated that temporal perception of visual stimulus depended on whether the same stimulus was attended to or ignored in a previous visual selection task: The perceived duration of previously ignored stimuli was longer than the perceived duration of either previously attended to or novel stimuli. This is the first demonstration of the effect of feature-based attention on later temporal perception. This finding indicates that temporal perception is affected by what one has previously ignored.

1120 Abstract 1120 moved to poster B45.

K10 *1121* **Parallel processing is much harder for temporal duration than for spatial length.**

Michael J Morgan[1] (m.morgan@city.ac.uk), Enrico Giora[2], Joshua A Solomon[1]; [1]The Henry Wellcome Laboratories for Vision Sciences, City University London, [2]Department of General Psychology, Padua University

Consider a set of n (0 < n < 9) horizontally-oriented lines in the x-y plane, all of the same standard length (w), except for an uncued target, in a random y position, that is shorter or longer (w +/- Äw). The lines have random offsets along the x axis, sampled from a uniform distribution of width w. Spacing on the y axis is fixed. Without a postmask, there appears to be no capacity limit for deciding whether the target is larger or smaller than the standard; accuracy can be well-modelled by the 'max' rule of signal detection theory. Now re-label the x axis as t, so that the horizontal lines represent durations of the stimuli rather than length in space. The standard duration was 2 sec. Accuracy with n=1 was comparable to that of the spatial task, when expressed as a Weber Fraction. However, with multiple stimuli, the task was very hard indeed. Even with n=2, predictions of the max rule fail dramatically. We conclude that observers have access to only a single clock for timing visual stimuli, which is started by a shift of attention, and which stops when attention shifts from the stimulus. A multi-resolution model of timing is proposed to account for the linear increase in the threshold Äw with w.

Attention: Temporal Selection

K11 *1122* **Attention can alter the temporal capacity of object processing in high-level visual areas**

Thomas J McKeeff[1] (tmckeeff@princeton.edu), Frank Tong[2]; [1]Princeton University, Department of Psychology, Princeton, NJ, USA, [2]Vanderbilt University, Department of Psychology, Nashville, TN, USA

Attention has an important role in our ability to individuate objects across variations in both space and time. Many studies have investigated how attention can dynamically alter the spatial tuning properties of visual neurons, but much less is known about whether attention can alter the temporal properties of the visual system. Previously, we have shown that temporal tuning functions of individual human visual areas can be reliably measured with fMRI. Here, we investigated whether spatial attention can enhance the temporal processing capacity of cortical visual areas during object processing. Subjects were instructed to attend to one of two simultaneously presented RSVP sequences of face and houses, which were presented to the left and right of central fixation. Presentation rate varied from 2-30 items/second. Spatial attention led to an overall increase in response amplitudes in early areas V1–V3, but did not alter the temporal frequency response profile of these areas. In V4v and the fusiform face area, attention not only led to enhanced response amplitudes but also led to a rightward shift in the temporal frequency response profile, indicating a shift in peak sensitivity toward higher temporal rates. In comparison, the parahippocampal place area showed weak evidence of attentional modulation. Our results suggest that spatial attention is capable of altering the temporal processing capacity of some high-level visual areas. These results may be of functional significance when an observer must identify an object under temporally demanding conditions.

K12 *1123* **Activation of primary visual cortex during the Attentional Blink**

Mark A Williams[1,2] (markaw@mit.edu), Troy A. W. Visser[3], Ross Cunnington[4], Jason B. Mattingley[2]; [1]McGovern Institute for Brain Research,, [2]Cognitive Neuroscience Laboratory, University of Melbourne, Parville, Australia, [3]University of British Columbia, Okanagan, Canada, [4]Howard Florey Institute, Melbourne, Australia

When two targets are presented in rapid succession, identification of the first target is nearly perfect while identification of the second is severely impaired at shorter inter-target lags, and then gradually improves as lag increases. This second-target deficit is known as the attentional blink (AB). Numerous studies have implicated competition for access to higher-order processing mechanisms as the primary cause of the AB. However, few studies have directly examined how the AB modulates activity in specific brain areas. To this end, we used fMRI to measure activation in the occipital cortex during an AB task. Participants were presented with an initial target of oriented line segments embedded in a central stream of letter distractors. This central target was followed 100 - 700 ms later by a peripheral 'X' presented at one of four locations along with three '+' distractors. All peripheral items were presented in the centre of a small field of moving dots. Participants made non-speeded judgments about gabor orientation and the location of the second target at the end of a trial. The results showed a robust AB characterised by a linear improvement in second-target accuracy as lag increased. This pattern of behavioural results was mirrored by changes in activation patterns across a number of visual areas indicating robust modulation of brain activity by the AB.

K13 *1124* **Electrophysiological Evidence for Modulation of Semantic Processing During the Attentional Blink**

Barry Giesbrecht[1] (giesbrecht@psych.ucsb.edu), Jocelyn Sy[1]; [1]University of California, Santa Barbara

When two masked targets are presented in rapid succession, correct identification of the first (T1) leads to impaired identification of the second (T2). Behavioral and electrophysiological studies have demonstrated that during this 'attentional blink' (AB), T2 is processed to a semantic level even though discrimination accuracy is impaired. The purpose of the present work was to test whether electrophysiological indices of semantic processing during the AB are modulated by the manipulation of T1 task difficulty. Eight participants performed a T1 task that involved indicating the direction of a central arrow that was flanked by arrows pointing in the same direction (easy) or in a different direction (hard). The T2 task involved indicating whether a word presented either 300 ms or 700 ms after T1 was related or unrelated to a context word presented at the very beginning of

the trial. Each subjects' electroencephalogram was recorded using 32 electrodes and the event-related potential time-locked to the T2 word was extracted. Consistent with previous studies, during the 300-500 ms after the T2 word there was a larger negative response to unrelated words than to unrelated words. Unlike previous studies, however, the size of this negativity changed as a function of the interval between T1 and T2 in the difficult target task. The present results constrain current models of the attentional blink such that although semantic processing can occur during the attentional blink, it is not obligatory and depends on task difficulty.

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K14 *1125* An EEG study of masking effects in RSVP

Patrick Craston[1] (pc52@kent.ac.uk), Brad Wyble[1], Howard Bowman[1]; [1]Centre for Cognitive Neuroscience and Cognitive Systems, University of Kent, Canterbury, UK

We present an EEG study that investigates how target items are processed when presented in Rapid Serial Visual Presentation (RSVP). The RSVP task was similar to the well-known Attentional Blink experiment [Chun and Potter, 1995], however, the stream contained only one target. To increase task difficulty, the presentation rate was doubled to 47ms SOA. Half the targets were followed by a blank to test the effects of backward masking. A skeletal task [Ward et al., 1997] allowed study of targets presented without surrounding distractors (except a following mask). Subjects' EEG waves were recorded at 20 electrode sites.The study was motivated by predictions made on the basis of the ST^2 model of temporal attention and visual working memory [Wyble and Bowman, 2005] concerning the influence of masking and task difficulty on target processing. In line with our predictions, the following results are observed:We find delayed processing of targets in RSVP streams compared to targets that are presented stand-alone (skeletal). In RSVP streams we do not observe accelerated processing of masked compared to unmasked targets as suggested by Kessler et al. (2005). A categorisation of target letters based on subject performance ('hard' or 'easy') modulates target ERPs, in particular the P3 component. Finally, we investigate the 'all-or-none' issue of conscious perception [Sergent et al., 2005] by correlating subjects' task performance and P3 amplitude using EEG single-trial analysis.

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K15 *1126* Spatial selection either improves or impairs temporal selection in a RSVP task.

Hee-Young Choo[1] (neurotheque@gmail.com), Min-Shik Kim[1]; [1]Department of Psychology, Yonsei University, Korea

The detection or identification of the second of two targets in a rapid serial visual presentation (RSVP) task is often impaired—a phenomenon known as attentional blink (AB). Several researchers have demonstrated that spatial and temporal selection impairs each other (Jiang & Chun, 2001; Marois, Chun, & Gore, 2000). We examined how spatial and temporal selection interact using a RSVP task with or without spatial-distractors in different attentional control settings (ACS): Compatible, Incompatible, and Neutral ACS. In this study, participants should report two targets from temporal-distractors while ignoring spatial-distractors. In the compatible ACS condition, spatial-distractors shared either the category (Experiment 1-3) or the features (Experiment 4) of temporal-distractors instructed to ignore. In the incompatible ACS condition, spatial-distractors either shared the category or the features of targets instructed to select. In the neutral ACS condition, spatial-distractors neither matched the targets nor the temporal-distractors. The magnitudes of the AB in trials with spatial-distractors (with-distractor condition) and in trials without spatial-distractors (without-distractor condition) were compared to estimate the effects of spatial selection on temporal selection. In the incompatible ACS condition, a larger AB was produced in the with-distractor condition than the without-distractor condition. In the compatible ACS condition, on the contrary, a smaller AB was observed in the with-distractor condition than the without-distractor condition. In the neutral ACS condition, no difference was observed between the two distractor conditions. This study suggests that whether temporal selection is improved or impaired by spatial selection depends on the compatibility of their ACS.

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K16 *1127* Masking modulates (and may even eliminate) the attentional blink

Fook K Chua[1] (fkchua@nus.edu.sg), Jason W M Ng[1]; [1]Department of Psychology, National University of Singapore

When two target letters (T1 and T2) are embedded among distractors and the items presented sequentially at 100 ms each in a single-stream RSVP task, identification of the second target (T2) is poor if it lags the first (T1) by 200-500 ms. This attentional blink (AB) effect has been attributed to the processing demands of the T1. We present data from experiments that speak against this account. The main manipulation is an 8x8 noise matrix overlaying the RSVP letters. In Experiment 1, we contrasted (a) the standard single-letter stream against (b) a constant noise matrix, and (c) a noise matrix that changed every frame. AB was virtually eliminated in (c). Indeed, performance was better in the constant-matrix condition than the standard condition. In Experiment 2, we established that the critical frame was the T1-trailing (T1+1) frame. T2 performance was better when the noise matrix of the T1+1 frame was made distinct from the preceding noise matrices. In Experiment 3, we contrasted inserting a blank in the T1+1 frame with overlaying the T1+1 distractor with a noise matrix, and showed that T2 performance was better in the latter condition. We argue that the AB is caused when attention cannot disengage rapidly from the T1 stimulus. Visual cues that inform the visual system that the T1 episode is over facilitates attentional disengagement and thus modulates the blink.

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K17 *1128* Missing T1 and missing T2 in an RSVP stream: does T2's presence help T1 identification?

Alejandro Lleras[1,2] (alleras@uiuc.edu), Micheal S. Ambinder[1,2]; [1]University of Illinois at Urbana-Champaign, [2]Beckman Institute

In a single-target RSVP task where participants were asked to identify the only white letter in a sequence of blue letters, Ariga & Yokosawa (2005) found that targets are usually missed when they appear early in the stream. They interpret this effect as a modulation of temporal attention, with attentional tuning gradually increasing over the first few hundred milliseconds of the search stream. Here, we tested whether similar mechanisms are at play in this effect and in the attentional blink (AB). Specifically, we asked whether the start itself of an RSVP stream leads to a blink-like effect on T1. Whereas in the AB, processing of T1 impairs the identification of a second target (T2) presented shortly after T1, we hypothesized that processing the onset itself of the letter stream could cause an analogous impairment to identification of targets presented shortly after the onset of the stream. We modified Ariga & Yokosawa's task to include two targets and manipulated location of T1 in the stream and T1-T2 lag (2 or 8). We found strong modulations of T1 identification accuracy by T1 location, with impairments for early T1s, replicating Ariga & Yokosawa. We also observed a robust AB at all T1 locations. Surprisingly, we also found that early in the RSVP stream T1 accuracy was modulated by both T2 lag and T2 accuracy. Subsequent experiments looked at the role of the leading item in the RSVP stream (T1, letter or non-letter mask) and at lag-one sparing early in the RSVP stream.

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K18 *1129* Distractor word meaning the target-defining color elicits the attentional blink

Atsunori Ariga[1] (ariga@L.u-tokyo.ac.jp), Kazuhiko Yokosawa[1]; [1]The University of Tokyo

When two targets are inserted in the RSVP stream, accuracy is nearly perfect for detecting the first target but is reduced for the second (attentional blink; AB). Recent studies have reported that even if only one target (e.g., a red-colored letter or a word meaning 'fruit') is inserted in the RSVP stream, AB occurs due to a preceding critical distractor whose feature is similar to that defining the target, perceptually (e.g., a red-colored digit) or semantically (e.g., a word meaning 'vegetable'). That is, the target-like distractor operates as the first target and contingently captures observers' attention, which would elicit AB. Focusing on the occurrence of AB, this study examined what contingently captures observers' attention when observers are waiting for appearance of only one target in the RSVP stream. This approach would reveal characteristics of observers' attentional set to process the target. In our experiment, only one target was defined perceptually (e.g., a red-colored word), which was preceded by a critical distractor that never possessed the same color as the target but induced the semantic activation of the same color (e.g., a word meaning 'red'). Even in this condition, the target was often missed, i.e. AB occurred. Therefore, attentional set to process the target-defining color would not be restricted only to the corresponding perceptual feature. Instead, it could be wide-open for other tempting events, which would be related to the critical distractor word meaning the target-defining color in this study.

K19 *1130* Interference during the attentional blink is feature-based rather than object-based.

Edward Awh[1] (awh@uoregon.edu), Harpreet Dhaliwal[1]; [1]University of Oregon

For several hundred milliseconds after a target (T1) is processed, the discrimination of a second target (T2) is impaired, a phenomenon that has been labeled the "attentional blink" (AB). One fundamental question concerns whether the AB reflects competition for a unitary resource for target processing (e.g., working memory "consolidation"). Previously, Awh et al. (2004) argued against this central bottleneck hypothesis by showing that a T1 digit discrimination elicited long-lasting AB interference for T2 letters, but had no effect on T2 faces. We proposed a "multi-channel" hypothesis that asserted both configural and featural processing channels for the T2 faces, only the latter of which was impaired by the T1 digit discrimination. This hypothesis, however, carries the assumption that one dimension of a stimulus can be lost during the AB while other dimensions are unaffected. That is, the multi-channel hypothesis asserts that AB interference is feature-based rather than object-based. We tested this hypothesis with T2 faces that varied in terms of both texture (a "featural" dimension) and identity (a "configural" dimension). When both attributes had to be discriminated within each trial, a T1 digit discrimination elicited AB interference for the textures but not for the identities of these faces. By contrast, when T1 was a face both dimensions of the T2 faces suffered from AB interference. These data suggest that AB interference does not impair the processing of entire object files. Instead, the fate of each T2 dimension is independently determined by its overlap with the dimensions processed in the T1 stimulus.

K20 *1131* Examining the interaction between WM and the attentional blink

Werner Vogels[1] (wwavogels@gmail.com), Stephen Johnston[1], Kimron Shapiro[1], David Linden[1]; [1]University of Wales, Bangor

Impaired report of a masked second target about 500 ms after successful identification of a masked first target is known as the attentional blink (AB). The cause of this impairment has been attributed to a failure to consolidate information in working memory. Previous studies investigating the relationship between AB and WM have reported inconclusive results with respect to the effect of load and content on the AB-effect proper (for example, Akyürek & Hommel, 2005) but have consistently shown that concurrent WM tasks impair overall performance. To further validate this conclusion, we used an AB paradigm to test whether WM maintenance has a detrimental effect on successful identification in an AB task. Participants performed a 3AFC AB task whilst maintaining 1 or 3 objects in WM that were either T1-related, T2-related or neutral. Results showed that WM content, not load, affects the AB. T2-related WM content yielded the largest AB. Together these findings suggest task-relevant information in working memory, not capacity, affects dual-target demands on attention.

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K21 *1132* Can task irrelevant distraction attenuate an auditory attentional blink?

Stephen Johnston[1] (s.johnston@bangor.ac.uk), Kimron Shapiro[1]; [1]Centre for Cognitive Neuroscience, University of Wales, Bangor, Bangor, UK

When participants are asked to recognise two masked stimuli presented within approximately 500ms of each other, the second stimulus often fails to be successfully reported. This phenomenon has been labelled the attentional blink (AB; Raymond, Shapiro & Arnell, 1992), and has been attributed to an inability to deploy attention to the second target when presented in such close temporal proximity to the first. Many studies have examined this phenomenon and it has been shown to be robust not only in the visual domain but in other modalities, such as the auditory domain (Arnell & Jolicoeur, 1999). A new and exciting development in the AB literature suggests this limitation in deployment of temporal attention can be attenuated by adding task irrelevant distraction as participants perform a typical AB task (Olivers & Nieuwenhuis, 2005; Arend, Johnston & Shapiro, submitted). Principally, these initial studies have examined the effect of visual and auditory task irrelevant distraction on a visually presented AB task. Here we present data that examines the generality of this finding by determining whether task irrelevant distraction in the visual and auditory domains can attenuate an AB task in the auditory modality. These data extend present hypotheses regarding the mechanism by which attentional resources are allocated in dual-task paradigms.

K22 *1133* Perception of three targets in dual RSVP streams: resource depletion or a temporary loss of control?

Jun Kawahara[1] (jkawa@hiroshima-u.ac.jp), Takatsune Kumada[2]; [1]Hiroshima University, [2]AIST

Identification of the second of two brief targets is impaired when inter-target lags are short (attentional blink, AB). The present study tested two explanations for the AB. Two streams of distractor digits were presented on either side of a fixation point. The number of distractors, and hence the lag, was manipulated between three letter targets. The targets appeared in either the left or right stream with equal probability. According to the resource-depletion hypothesis, longer lags provide more time for processing the leading target, thus releasing resources for the trailing target. If so, performance on the trailing targets would be impaired when the lag was short, irrespective of whether trailing targets appeared in the same or different streams. According to the temporary-loss-of-control (TLC) hypothesis, intervening distractors disrupt the current attentional set, producing a trailing-target deficit. Thus, the performance for the third target would be unimpaired if the immediately preceding target appeared in the same stream, because the preceding target produces the optimal attentional set for target identification. Such sparing should not occur when the preceding target appears in the other stream. Identification accuracy for trailing targets was unimpaired at Lag 1 (conventional Lag-1 sparing) and also at later lags, when preceded by another target in the same stream, supporting the TLC hypothesis but not the resource-depletion hypothesis. We concluded that the AB is caused by a disruption in attentional set when a distractor is presented while the central executive is busy processing the leading target.

K23 *1134* Why Are Faces Resistant to the Attentional Blink?

Ayelet N. Landau[1,2] (ayeletlandau@berkeley.edu), Cassandra LaBouff[1], Lynn C. Robertson[1,2]; [1]University of California, Department of Psychology, Berkeley, CA, [2]Veterans Administration Medical Research, Martinez, CA

Stimuli presented in rapid serial visual presentation (RSVP) at lags shorter then half a second produce a phenomenon known as the Attentional Blink (AB) (i.e., a second target, T2, is poorly reported when close in time to a first target, T1). The AB occurs with almost every type of stimulus category. One exception is faces (Awh et al., 2004, Landau and Bentin, submitted). In the present study we investigated basic visual information that may lead to the face-AB-resistance phenomenon (fABr). We devised a mixed model design, manipulating spatial frequency of the stimuli in the RSVP as a between-participant factor with three levels: Low-pass, High-pass and Broadband. Each group participated in the same design; only the stimulus frequencies were varied. T2-type (face/watch) and Lag (1, 3, 7) were manipulated as within-participant factors. Participants performed a size discrimination task on T1 and a detection task on T2. There was a significant second-order interaction between spatial frequency range, T2-type and Lag. Specifically, while removing high spatial frequencies did not change the fABr effect, removing low spatial frequencies produced the AB phenomenon for faces. These findings suggest that the differential AB effects found for objects and faces may be attributed at least in part to differences in the spectral analysis by the visual system. The results will be discussed in the context of face specificity at both perceptual and attentional levels (Landau and Bentin, submitted).

K24 *1135* Randomized Temporal Stimulus Onset Attenuates the Attentional Blink

Elwyn W. Martin[1] (elwynmartin@hotmail.com), Kimron L. Shapiro[1]; [1]University of Wales, Bangor School of Psychology

The Attentional Blink (AB) paradigm demonstrates that when instructed to detect two targets presented in a rapid visual stimulus stream of distracters, the second target (T2) is often undetected if presented 200-500ms post onset of the first target (T1). Unlike conventional AB tasks, which present stream items with constant inter stimulus intervals (ISI), we present both distracter and target items with randomly varying ISI values, thus allowing a novel temporal onset for each stream item. Our results reveal an absence of an AB, presumably induced by the series of novel temporal transient events. We suggest that processes underlying "attentional capture" may allow the information processing system to operate at a level immune to the dual-task deficits reflected by the AB. Our results and conclusions are discussed within the framework of limited resources capacity models of the AB.

K25 *1136* Modulation of the Attentional Blink by Task Relevance and Target Relationship

Jocelyn L. Sy[1] (sy@psych.ucsb.edu), Barry Giesbrecht[1]; [1]University of California, Santa Barbara

When two masked objects are presented in close temporal succession correct identification of the first target (T1) leads to a severe impairment in identification of the second (T2). Although the precise mechanism that underlies this 'attentional blink' (AB) has been debated, there is consensus that the AB reflects the temporal distribution of attention and that it occurs because of a single resource or capacity limitation that is occupied with T1 processing. Recently, it has been proposed that there are multiple resource channels available for processing selected information. According to this view, the severity of the AB is dependent on the channels required by T1 and T2, such that the AB will be less severe if the target objects require different channels for processing. The purpose of the present experiment was to test whether this reduction in the AB depends on whether the dimension on which the targets are similar is task-relevant. Participants were presented faces in RSVP. Face gender, emotional valence (neutral and fearful), and T1-T2 lag (240ms and 560ms) was manipulated factorially. Task-relevance was manipulated by having participants report the gender or valence of T1 and T2. The AB was most severe when T1 and T2 were the same task relevant dimension relative to when they were not. This pattern did not hold for the task irrelevant dimension. The results support the conclusion that the relationship between T1 and T2 can modulate the AB, but only when that relationship is task-relevant.

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K26 *1137* Repetition Advantage: Effects of inter-target and target-distractor discriminability

Yetta K. Wong[1] (yetta.wong@vanderbilt.edu), William G. Hayward[2]; [1]Vanderbilt University, [2]University of Hong Kong

When items are repeated within a single RSVP stream, the second appearance is often missed by observers. This phenomenon is called repetition blindness (RB), and has been widely studied. In some situations, however, repetition enhances recall of the second item; Dux and Coltheart (in press) called this effect repetition advantage (RA; see also Chun, 1997). In this study, we investigated two possible contributing factors to RA, (i) inter-target distinctiveness (manipulated by presenting targets in the same colour, or two different colours), and (ii) target-distractor distinctiveness (manipulated by presenting distractors in one consistent colour or multiple colours). Two target letters (either repeated or non-repeated) were displayed in either red or green among letter distractors that were either all black or all in different colours. Item lag between targets was 2, 3, or 4 items. Results showed that both factors affected RA; same-colour targets produced more RA than different-colour targets, and all-black distractors led to greater RA than all-colour distractors. The advantage of repetition also increased with increasing lag. These results supported that RA could be found under the paradigm of RB with simple manipulation of the stimuli. Based on these results, the condition for RA and the possible relationship between RA and RB were discussed.

K27 *1138* Repetition Blindness is Immune to the Central Bottleneck

Paul E. Dux[1] (paul.dux@vanderbilt.edu), René Marois[1]; [1]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University

The attentional blink (AB) and repetition blindness (RB) phenomena refer to subjects' impaired ability to detect the second of two different (AB) or identical (RB) target stimuli in a rapid serial visual presentation (RSVP) stream if they appear within 500 ms of one another. Despite the fact that the AB reveals temporal limits of conscious visual perception, it is at least partly due to limitations at central stages of information processing. Do all forms of time-based attentional limits to conscious perception depend on this central bottleneck? To address this question, we investigated whether RB is affected by online response selection, a cognitive operation that requires central processing. Subjects searched for two target letters presented in RSVP streams containing either digit or computer symbol distractors. Targets were either identical (RB trials) or different (AB trials), and the first target was responded to either as soon as it was detected (speeded condition) or at the end (unspeeded condition) of each stream. The results showed that the AB, but not the RB, is exacerbated under online response conditions. These findings demonstrate that RB is independent of central processing limitations, and imply that attentional limits to conscious perception can occur at multiple stages of information processing.

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Biological Motion and Animacy

K28 *1139* Body form and position influence the perceived speed of human gait

Maggie Shiffrar[1] (mag@psychology.rutgers.edu), John Franchak[1]; [1]Rutgers Uni-

versity-Newark

Outside of the lab, people usually move relative to other moving people. Moving and stationary people perceive human movement differently (Jacobs & Shiffrar, 2005). Here we examine the cues that walking observers use to compare their own gait speed to the gait speed of a nearby walker. Naive subjects walked on a treadmill set at various speeds ranging from 2 to 3 mph. On each trial, the gait of the projected walker was 0.3 mph faster or slower than the subject's own gait speed. Subjects reported whether they walked faster or slower than the projected walker. To determine whether body form influences the perception of relative gait speed, the projected walker was depicted as either a point-light walker or a fully embodied humanoid. Gait speed discrimination performance was superior with the embodied walker suggesting that body structure contributes to gait perception. Normally, faster walkers change their position relative to slower walkers. To determine whether perceived gait speed depends upon a perceived walker's position relative to a walking observer, the projected walker slowly translated forward or backward while walking. Gait speed discrimination was influenced by walker position at large but not small position changes. Finally, gait speed discriminations with near and far walkers were compared. Performance was best with near walkers. Taken together, these results suggest that body form and location contribute to the visual analysis of human gait by walking observers.

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K29 *1140* Pattern analysis of biological motion selectivity

Alison J Wiggett[1] (a.wiggett@bangor.ac.uk), Marius V Peelen[1], Paul E Downing[1]; [1]University of Wales, Bangor

One of the most important roles of vision is to provide information about the actions, intentions and identities of other individuals and so to enable successful interactions in a social environment. Critical regions in the human brain for perceiving others have been shown to include (but are not limited to) the posterior fusiform gyrus (Kanwisher et al., 1997; Peelen & Downing, 2005) and the posterior inferior temporal sulcus (Downing et al., 2001). This fMRI study examines the response in these cortical regions to biological motion using point-light walkers. We show that functionally defined body- and face-selective areas in posterior fusiform gyrus, and body- and motion-selective areas in inferior temporal sulcus all respond significantly to "point-light" human motion. We then apply voxel-by-voxel analyses of the response patterns to different stimuli in order to disentangle body-selective from face- and motion-selective responses in our regions of interest. Our analysis shows that, on a voxel-by-voxel basis, only body selectivity is correlated with biological motion selectivity. Biological motion selectivity is not related to motion or face selectivity. We conclude that: i) biological motion, through the process of structure-from-motion, engages areas involved in the analysis of the static human form; ii) body-selective regions in posterior fusiform gyrus and in posterior inferior temporal sulcus overlap with, but are distinct from, face- and motion-selective regions; iii) the interpretation of region-of-interest findings may be substantially altered when multiple patterns of selectivity are considered in parallel.

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K30 *1141* Sensitivity to motion features in upright and inverted point-light displays

Sandhitsu R Das[1] (sudas@seas.upenn.edu), Maciej T Lazarewicz[1], Robert C Wilson[1], Leif H Finkel[1]; [1]Department of Bioengineering, University of Pennsylvania

Biological motion recognition in point-light displays exhibits a well-known inversion effect (Grossman and Blake, 2001; Pavlova and Sokolov, 2000) – analogous to inversion effects in other expert recognition systems like face recognition (Yin, 1969). We measured human observers' sensitivity to perturbations of intermediate level spatiotemporal features in point-light displays of upright and inverted walkers. We found that observers are more sensitive to perturbation of certain features in upright displays but more sensitive to other features in inverted displays. The features with greater sensitivity in upright displays describe the relative motion of adjacent limb segments (e.g., left thigh/right thigh, and thigh/leg). In contrast, perturbations to a feature that describes the angular velocity of the limbs result in greater sensitivity in inverted displays.We hypothesize that certain intermediate level features are used by the visual system for biological motion recognition (Casile and Giese, 2005). Detection of these features may be orientation sensitive and therefore observers more sensitive to perturbations of these features in upright displays. On the other hand, if a feature is not used for recognition, the sensitivities may be the same under upright and inverted conditions, and may actually be higher in inverted displays because of greater impact of local attentional mechanisms in the absence of global high level integration.

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K31 *1142* Masking biological motion compared to masking structured and unstructured non-biological motion.

Eric J Hiris[1] (ejhiris@smcm.edu); [1]St. Mary's College of Maryland

Purpose: Biological motion has been considered a special type of motion. However, few studies have explicitly taken into account that biological motion consists of structured motion when comparing biological motion to non-biological motion. **Method:** Across experiments, five target motions of three different sizes were used: biological, unstructured translational, unstructured rotational, structured translational, and structured rotational. Unstructured motions were created by randomly plotting target dots within the target area and structured motions were created by plotting target dots to form a rectangle (translational) or square (rotational) within the target area. From 22 to 1408 mask dots were added to the target displays. Percent correct data were obtained and masking functions created for each condition. **Results:** It is more difficult to mask biological motion compared to unstructured translational and unstructured rotational motion. However, there were only small differences in masking biological motion compared to structured translational and structured rotational motion. The data also showed that mask dot effectiveness depends on the size of the target display regardless of target type. **Conclusions:** The addition of structure in non-biological motion displays strongly influences performance in a masking paradigm. Given that structure is inherent in biological motion displays, comparing biological motion to structured non-biological motion seems to be a more reasonable comparison. In a detection task using a masking paradigm, there is little difference between biological motion and structured non-biological motion.

K32 *1143* Why is the average walker male?

Nikolaus F Troje[1] (troje@post.queensu.ca), Sandra Szabo[1]; [1]Queen's University, Kingston, Ontario

The arithmetic mean of the same number of male and female biological motion point-light walkers represented in a morphable, linear walking space is perceived to be male. The perceptually neutral walker corresponds to a point in the female part of the space. It is not clear, though, if this "male bias" is a genuine phenomenon or an artifact of the specific walker space and its underlying metric. Here, we present a number of experiments in which observers reported the perceived sex of a series of walkers while we varied the range and the distribution from which the walkers were sampled. We observe a pronounced range effect: If we sample from a distribution which is shifted toward the female part such that it is now centered around the walker that appeared to be sexually neutral before, observers adapt to the new range and still perceive more walkers to be male than female. On the other hand, if we sample from a larger range with the same mean the observed "male bias" changes only marginally.

We conclude that the "male bias" is not an artifact of the motion space used but a genuine phenomenon. We discuss different possible causes and particularly the question of whether the "male bias" is stimulus-specific or rather a more general phenomenon.

K33 *1144* Intention Recognition in Autistic Spectrum Condition (ASC) using Video Recordings and their corresponding Animacy Displays

Phil McAleer[1] (p.mcaleer@psy.gla.ac.uk), Lawrie McKay[1], Judith Piggot[2], David R. Simmons[1], Frank E. Pollick[1]; [1]Department of Psychology, University of Glasgow, [2]Cardiff University

People with Autistic Spectrum Condition (ASC) are known to be deficient in visualizing the intent of others, especially in "Theory of Mind" tasks involving displays of animated geometric shapes. Research shows they will use fewer words of intent to describe animacy displays than neuro-typicals. Here we examine the ability of people with ASC to determine intention using a technique previously developed and reported by the authors (McAleer et al, VSS 2005). This technique allows us to study intention recognition using either the original video displays of actors or the corresponding animacy displays. In this study, we employ a six alternative forced choice intention recognition task to compare ASC and neuro-typical adult participants, looking specifically at the six intentions of chasing, fighting, flirting, following, guarding and playing. Each intention was shown as a video recorded display and as an animacy display, from the two perspectives of overhead and side-on. Preliminary results reveal an overall difference in ability to recognise intentions between the groups, with the ASC group performing lower than the neuro-typicals in both the video and animacy displays. Furthermore, there was a consistent pattern of results for the neuro-typical group showing that intention recognition improves when viewing video displays and viewing actions from the overhead perspective. However, a different pattern of results was obtained for the ASC group, suggesting that the ASC group had difficulty in discriminating intentions in the video displays shown from the overhead perspective.

K34 *1145* Biological Motion Processing in Autistic Spectrum Conditions: Perceptual and Social Factors

Lawrie McKay[1] (lawrie@psy.gla.ac.uk), Jennifer Mackie[1], Judith Piggott[2], David R Simmons[1], Frank E Pollick[1]; [1]Department of Psychology, University of Glasgow, [2]Cardiff University

It is known that Autistic Spectrum Conditions (ASCs) are associated with perceptual difficulties, and it has been suggested that the perception of motion may be affected. Since human bodies in motion provide a source of information about instrumental and social aspects of behaviour, we examined the perception of human activity from minimal displays of recorded actions with ASC and neuro-typical adults. We developed several tests to compare the perceptual performance of both groups using displays that spanned a range of visual information processing requirements. Task 1 (detection) compared low level processing of visual motion information, and measured participants thresholds for the detection of point light displays (PLDs) of human movement in noise. Task 2 (action recognition) tested differences in the ability to discriminate between PLDs of action blends constructed from knocking and lifting movements, and tapped the ability of both groups to process instrumental human actions. Task 3 (emotional style recognition) tested differences in the ability to recognise the affect of actors performing throwing actions in an angry, happy, neutral and sad manner, from PLDs of human arm movements. Preliminary results suggest atypical processing on all tasks for the ASC group. Motion-processing deficits were apparent in that participants in the ASC group required more signal information than the neuro-typical group to accurately detect human movement. Differences between the groups were clearer on the emotion task than on the action task, consistent with the findings of dissociable neural pathways for perception of expressive and instrumental gestures.

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K35 *1146* Neural correlates of degraded complex motion perception

Javier O. Garcia[1] (jogarcia@uci.edu), John A. Pyles[1], Emily D. Grossman[1]; [1]Department of Cognitive Sciences, University of California, Irvine

Background. Visual information is largely processed via two parallel pathways: one specialized for motion information (M-pathway) and the other specialized for form information (P-pathway). By manipulating luminance and color contrast, we altered the contribution of the M-pathway, thereby systematically degrading perception of simple and complex motion, and measured the corresponding changes in neural responses. Our analysis targeted several brain areas including MT+ and STSp (a brain area selective for complex, biological motion). **Method.** In a blocked fMRI experiment, observers viewed animations depicting three types of motion of varying levels of complexity: (1) coherent motion in random dot kinematograms (RDKs), (2) collinear triplets masked in fixed-path noise, and (3) biological motion (Johansson, 1973) masked in vector-matched noise. Displays were rendered as yellow dots on a gray background. Luminance contrast was set at 10%, 5% or 0% (defined perceptually as the point of perceived isoluminance). Coherence levels (RDKs) and number of masking dots (collinear triplets and biological motion) were fixed individually to ensure threshold (82%) performance for each level of contrast. **Results.** Neural responses in MT+ were largely contrast-dependent with the exception of the coherent motion RDKs, for which BOLD levels also depended on coherence. BOLD responses in STSp maintained biological motion-selectivity, regardless of luminance contrast. **Conclusions.** These results demonstrate the relative contributions of the M-pathway to the global neural responses of motion-driven cortical areas, and a competitive interaction between stimulus properties, such as coherence, contrast and complexity.

1147 Abstract 1147 moved to Biological Motion talk session, May 9, 8:00 am

K36 *1148* Backscroll illusion in far peripheral vision

Kiyoshi Fujimoto[1] (kys.fujimoto@kwansei.ac.jp), Akihiro Yagi[1]; [1]Department of Psychology, Kwansei Gakuin University

Backscroll illusion is apparent motion perceived in backgrounds of movie images that present locomotive objects such as people, animals, or vehicles (Fujimoto & Sato, in press, *Vision Research*). Here we report that the backscroll illusion can occur in far peripheral vision at retinal eccentricity of more than 30 deg. This was confirmed by psychophysical experiments in which we presented a walking person in profile against an ambiguously moving background of vertical counterphase grating. This stimulus, which subtended 15 x 15 deg of visual angle, was projected on a hemispheric screen and positioned at horizontal eccentricity between 0 and 50 deg at intervals of 10 deg. The eccentricity was changed randomly trial by trial and stimulus duration was as short as 360 ms, so that observers could not move their eyes to the stimulus effectively. Six observers viewed the stimulus monocularly or binocularly and reported a perceptual impression for the grating in a three alternative forced choice procedure: drifting left, drifting right or flickering. Results showed that the grating appeared to move in the opposite direction of walking in more than 77% of trials on average at 0-40 deg eccentricity. The percept was stronger in peripheral vision than in central vision. Even at 50 deg eccentricity, the illusion occurred at 60% levels. Additional experiments confirmed that walking action could be recognized from the far peripheral stimulation. Our findings suggest that the visual system uses high-level object-centered motion signals to disambiguate low-level retinocentric motion signals in the whole visual field.

URL: http://backscroll.jp/

K37 *1149* Ground Cues Influence the Visual Perception of Rolling

Songjoo Oh[1] (songjoo@psychology.rutgers.edu), Maggie Shiffrar[1]; [1]Rutgers University-Newark, USA

Traditional theories assume that the visual system solves the correspondence problem by defaulting to the shortest path connecting any two points. As a result, two points in apparent motion appear as a single point translated back and forth along the shortest trajectory. Yet, outside of the laboratory, object motion is constrained by the environment. Psychophysical studies of the perceived motion of a circle were used to compare the relative impact of environmental constraints and shortest-path constraints on the perception of object motion. Observers viewed computer generated displays of a circle undergoing smooth displacement. Given the circle's homogeneous structure, its displacement could be interpreted as rolling (orientation change)or translating (no orientation change). Across experiments, observers viewed various displays and reported whether the circle appeared to roll or translate. In Experiment 1, a single horizontal line was added to the display. When the line was located directly below the displacing circle, the circle appeared to roll along this "ground". When the line was located directly above the circle, the circle was more likely to appear to translate. In Experiment 2, the line was tilted. When the circle moved from the top to the bottom of the tilted line, it appeared to roll down a sloped "ground". When the line was vertical, the circle appeared to translate. These results suggest that cues supporting the presence of a ground surface significantly impact motion percepts. This conclusion supports theories that suggest that visual perception reflects an internalization of universal environmental constants (Shepard, 1982).

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K38 *1150* Optimal Bayesian integration of components during the visual recognition of emotional body expressions

Claire L. Roether[1] (claire-louise.roether@student.uni-tuebingen.de), Lars Omlor[1], Martin A. Giese[1]; [1]ARL, HCBR, Department for Cognitive Neurology, University Clinic Tuebingen

Visual recognition of complex shapes might be accomplished by the integration of information from simpler components (e.g. fragments, or geons). Equivalent components might exist also for the recognition of complex body movements. This is suggested by results in motor control showing that complex motor behavior is organized in terms of simpler components (synergies) that depend only of subsets of the available degrees of freedom (joints). Our experiment tested how the visual system integrates information from components of emotional body movements that were either congruent or incongruent with components recovered from motor behavior. METHOD: Based on motion capture data from lay actors performing actions with different emotional affects, we extracted spatio-temporal components that are specific for the expression of individual emotions (applying an algorithm that combines ICA and sparse feature learning). We generated point light stimuli specifying variable amounts of information about emotional style for different joint combinations. These components did or did not match the components extracted from the motor behavior. By comparing perceptual performance with predictions from a Bayesian cue fusion model, we assessed if subjects' perception integrated the information components in a statistically optimal way. RESULTS: Performance was very close to an ideal Bayesian integration of information components, while compatibility of the components with motor behavior seems not to be critical. This suggests that Bayesian cue integration might be relevant for the visual recognition of emotion. However, the relevant information components might be different from the components that are relevant in motor execution.

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Complex Motion

K39 *1151* Independent fMRI adaptation for first-order and second-order motion

Hiroshi Ashida[1] (ashida@bun.kyoto-u.ac.jp), Angelika Lingnau[2,3], Matthew B Wall[2], Andrew T Smith[2]; [1]Kyoto University, Japan, [2]Royal Holloway, University of London, UK, [3]University of Trento, Italy

There is still no firm conclusion about whether the brain mechanism for second-order motion is separate from that for first-order motion. While initial fMRI work suggested that second-order motion is coded later in the visual pathway (Smith et al., J Neurosci 1998), more recent studies reported that both types of motion can be represented as early as V1 (Nishida et al., J Neurophysiol 2003; Seiffert et al., Cereb Cortex 2003). To overcome the relatively coarse spatial resolution of fMRI, we used a fast event-related fMRI adaptation paradigm that allows dissociation of different neural populations within a particular area. We examined the time course of the BOLD signal to a stimulus sequence (S1 of 2s, blank of 2s, and S2 of 1s) obtained using a 3T MR scanner (Siemens Trio). S1 and S2 consisted of a radial luminance-modulated (first-order) or contrast-modulated (second-order) grating that rotated clockwise or counterclockwise. In the MT/V5 complex, direction-selective adaptation was found when the stimulus order was the same for S1 and S2, that is, signals were smaller when the motion directions of S1 and S2 were the same than when they were opposite. No such difference was found when the stimulus order changed between S1 and S2. In other words, cross-adaptation between the two types of motion did not occur while order-specific adaptation did. Our results indicate that separate neural populations are responsible for first-order and second-order motions, even if these populations are located in the same visual areas.

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K40 *1152* Separable temporal stages for motion integration within and between hemifields revealed by TMS

Bahador Bahrami[1,2] (bbahrami@ucl.ac.uk), Nilli Lavie[1,2], Vincent Walsh[1,2]; [1]Institute of Cognitive Neuroscience, [2]Department of Psychology, University College London

Motion in distant locations beyond the extent of classical V5/MT receptive fields (CRF) influences motion processing for within CRF stimuli (Allman, Meizin, McGuinness, 1985). Here, we report two experiments investigating the characteristics of such long range motion interaction in humans. In a first, behavioral experiment, we showed a congruency effects in direction of motion discrimination for a peripheral, target random dot pattern (RDP) when a distractor RDP (with similar noise level to target) was displayed in the symmetrical location across the vertical meridian (RDP size: 8 degrees; center-to-center distance: 20 degrees). In a second experiment, this congruency effect was eliminated by the application of transcranial magnetic stimulation (TMS) on human V5/MT if (1) early TMS (120ms after motion onset) was applied over the hemisphere contralateral to the distractor or (2) late TMS (160ms after motion onset) was applied over the hemisphere ipsilateral to the distractor. This result confirms that interactions between left and right human V5/MT are necessary for motion integration across the vertical meridian. Moreover, they argue for separable temporal stages for integration of motion signals within and between hemifields.

K41 *1153* Perceived direction of plaid motion is not predicted by component speeds

Rebecca A Champion[1] (r.a.champion@soton.ac.uk), Stephen T Hammett[2], Peter G Thompson[3]; [1]School of Psychology, University of Southampton, UK, [2]Department of Psychology, Royal Holloway University of London, UK, [3]Department of Psychology, University of York, UK

It has been shown previously that the perceived direction of a plaid with

components of unequal contrast is biased towards the direction of the higher contrast component (Stone, Watson and Mulligan, 1990). It was proposed that this effect is due to the influence of contrast on the perceived speed of the plaid components and this lead to the conclusion that perceived plaid direction is computed by the intersection of constraints (IOC) of the perceived speeds of the components rather than their physical speeds. We tested this proposal at a wider range of component speeds, across which the effect of contrast on perceived speed is seen to reverse. Plaid stimuli were composed of two orthogonal sinusoidal gratings (1 c/deg), of unequal contrast (60% and 30%) drifting at speeds ranging from 2 – 16 deg/sec. Subjects judged whether the plaid was drifting to the left or right of vertical and the direction error was estimated for each component speed. In addition the relative perceived speeds of the individual grating components were estimated to allow prediction of plaid direction errors based on contrast induced errors in component perceived speed. We find that although predicted errors are increasingly biased toward the lower contrast component as component speed increases, the observers' perceived direction is increasingly biased towards the *higher* contrast component as component speed increases. This result is not predicted by an IOC model using either physical or perceived component speed.

K42 *1154* Contrast gain control moderates bias of perceived motion in Type 2 plaids

SA Collier[1] (shawn.collier@umit.maine.edu), AB Cobo-Lewis[1]; [1]University of Maine, Orono

Purpose: Previous research has supported a Bayesian model of motion combination for the perception of moving Type 2 plaids. When one component grating provides a more reliable motion signal than the other, perceived direction of the plaid is biased in the direction of the more reliable grating. Our previous research offered evidence for 1) bias of perceived plaid direction toward the grating of higher spatial frequency (SF), 2) bias of perceived plaid direction toward the grating of higher contrast when overall contrast was low, with little or no bias toward the grating of higher contrast when overall contrast was high. We hypothesized that contrast gain control was obscuring the effect of contrast-ratio manipulation. Our current research provides an analysis of the effect of contrast ratio under differing overall contrast conditions. Methods: Subjects viewed Type 2 plaids whose component gratings drifted in directions separated by 15 degrees and whose speeds differed by a factor of sqrt(1.5). We manipulated the ratio of the gratings' contrast in conditions with different baseline contrasts. Subjects pointed an arrow in the direction of the perceived drift of the plaid. Results: The effect of contrast-ratio manipulation differed with baseline contrast. Under high-contrast conditions there is little effect of contrast-ratio manipulation. Under moderate and low contrast conditions, the perceived drift of the plaid pattern becomes biased in the direction of the higher-contrast component. These results offer evidence for an effect of contrast gain control in moderating the bias of perceived plaid motion.

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K43 *1155* An oblique effect for transparent-motion detection: Implications for population encoding

John A Greenwood[1] (john.greenwood@anu.edu.au), Mark Edwards[1]; [1]School of Psychology, The Australian National University, Canberra, Australia

Transparent motion can be perceived when two objects move within the same region of space simultaneously. Though it is clear that the global-motion stage is crucial to transparent-motion detection, the exact means by which global-motion activity is decoded to yield multiple signal directions remains elusive. An important constraint on this process is the smallest angular separation (Äè) that gives rise to transparency. However, there is considerable variation in the literature concerning this value. It is also unclear whether Äè thresholds would be affected by the oblique effect that influences unidirectional processing. Observers in our task were required to discriminate between transparent-motion and global-flow stimuli. The latter contained a range of directions equal to the angle between the comparison transparent-motion signals. This ensured that performance was based on detection of transparency rather than relative motion. Thresholds were lowest around the cardinal axes, particularly horizontal, where the minimum Äè was around 25deg. This increased to around 35deg for the oblique axes. Thresholds were elevated when signal intensities were lowered, though the oblique effect remained. Direction-specific analysis of thresholds obtained with both signal intensity levels indicates that this oblique effect depends upon the mean direction, rather than the component directions of transparent motion. This suggests that transparent-motion detection relies heavily upon the central aspect of the population activity distribution. That is, global-motion units with preferred directions between the two component directions may offer the most insight into the mechanisms of transparent-motion detection.

K44 *1156* Motion Strength is Not What is Summed in the Vector Summation Computation of Plaid Motion

Danting Liu[1] (dantingl@uci.edu), George Sperling[1]; [1]Department of Cognitive Sciences, University of California, Irvine

First-order motion is assumed to be detected by "motion energy" or equivalently "Reichardt Detectors." The output of such detectors is "motion strength", a quantity that is proportional to the square of the contrast of a moving sinewave grating. When two sine gratings of possibly different contrasts and orientations move together (a plaid), do the component motion strength vectors sum to determine perceived direction of the plaid? To investigate this question, we did a series of experiments using two component gratings with various spatiotemporal frequencies, different angles between component gratings, different durations of presentation, and a wide range of contrasts for the component gratings. In plaid sinewave stimuli in which the contrasts of the components differed by less than a factor of about 4, the two components contributed equally to the combined motion. When the contrast of one component grating exceeded the other by more than 4, it masked the motion of the lower-contrast grating and only the larger component contributed to the combined motion. The results indicate that motion-strength vectors are not what is summed in plaid motion perception.

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K45 *1157* Velocity constancy in natural images

Andres Martin[1] (amartin@herrera.unt.edu.ar), Jose F Barraza[2], Luis A Issolio[2]; [1]Departamento de Luminotectina, Luz y Vision. Universidad Nacional de Tucuman - Argentina, [2]Departamento de Luminotectina, Luz y Vision. Universidad Nacional de Tucuman and CONICET- Argentina

Purpose. Previous experiments showed that for realistic artificially generated stimuli depth cues such as parallax motion, disparity, size, perspective, and texture are necessary for velocity constancy. However, the relative size produced by relative distances would be sufficient to rescale retinal velocity. An ambiguity appears because a more distant object may be also interpreted as a smaller object located at the same distance unless one knows that those are the same object that did not change its size. Natural images provide this certainty. We investigated whether size is sufficient for velocity constancy in natural images. Methods. We performed a matching speed experiment to evaluate velocity constancy in natural images. Stimuli were generated by filming from different distances an athlete walking on a platform, which could move forward or backward at variable speeds. We processed the movies to remove all the cues except the size. Results. Results show high constancy factors for all subjects (ranging from 80 to 90%) with 83% mean. Although a little bias towards retinal velocity appears in this experiment, this is smaller than those obtained in the same condition using artificial stimuli. Conclusion. The relative size produced by the relative distance between objects provides more than 80% of the information used for velocity constancy in natural images. This suggests that the visual system would trust more on size information in natu-

ral than in artificial images perhaps, because in nature objects do not change its size.

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K46 *1158* Spatial selectivity of local motion affects global motion after-effect

Yutaka Nakajima[1] (nakajima@l.u-tokyo.ac.jp), Takao Sato[1]; [1]University of Tokyo

To examine the influence of the spatial frequency/orientation selectivity of low-level (local) motion after-effect (MAE) on global MAE, we measured the duration of global MAE induced by rotating pseudo-plaid patterns comprised of four gabor patches (cf. Takeuchi,1997; e.g. Bex, Metha &Makous, 1999). First, we presented rotating pseudo-plaid pattern for 30 s for adaptation (patch size = 1.4 deg x 1.4 deg; total size = 2.8 deg x 2.8 deg, spatial frequency = 1.4 c/d, velocity = 1.4 d/s). Then, we presented a test pattern of static pseudo-plaids with varied spatial frequency and/or orientation. Subjects were asked to keep pressing a key while they perceive global MAE. We also measured the duration of local MAE by using the same procedure but using only one gabor patch. We found that the duration of both global and local MAE depended on the spatial frequency/orientation of test stimuli; higher similarity in spatial properties between adapting and test stimuli resulted in longer durations. The durations of global MAE were about twice as long as that of local MAE regardless of similarities. When the spatial properties were the same for adapting and test stimuli, the duration was longest and the difference in the duration between local and global MAE was largest. These results indicate that, although the long durations at the optimal points may reflect the selectivity for global-motion, spatial selectivity of local motion detectors is crucial to the magnitude of global MAE.

K47 *1159* Perception of motion transparency after depth contingent motion aftereffect

Lisa O'Kane[1] (lisao@psy.gla.ac.uk), Pascal Mamassian[2]; [1]University of Glasgow, UK, [2]CNRS, Universite of Paris 5, France

Transparent motion can result in bistable percepts because of an ambiguity about which surface is in front and which one is behind. Previous work has shown that observers have an idiosyncratic bias for perceiving one particular direction of motion in front (Mamassian & Wallace, VSS'03) and that segregation cues, such as contrast, can influence the temporal dynamics of the alternation of which surface is perceived in front (McArthur & Mamassian, VSS'05). Here, we looked at the effect of adaptation to motion in depth (Anstis & Harris, 1974) on an observer's bias for transparent motion. On both pre- and post-adaptation sessions, observers were presented with brief random–dot kinematograms (RDKs) where two transparent planes were displayed in the zero-disparity plane. Their task was to report the direction of motion of the plane perceived in front. In the adaptation period, observers were presented with an RDK that alternated between leftward motion in front and rightward motion behind. To prevent eye movements, two such movies were presented out of phase, above and below fixation. We found that observers' biases for which direction of motion moved in front were different between the pre- and post-adaptation sessions, in a manner mostly consistent with a depth contingent motion aftereffect. These results emphasize the critical role of neural structures sensitive to both motion and binocular disparity in the perception of motion transparency.

K48 *1160* Perceived trajectory direction of an approaching object

Simon K. Rushton[1,2] (rushtonsk@cardiff.ac.uk), Philip A. Duke[1]; [1]School of Psychology, Cardiff University, Cardiff, UK, [2]Centre for Vision Research, York University, Toronto, Canada

Pairs of projectiles travelling on parallel trajectories produce differing patterns of retinal motion when they originate from different distances. For an observer to recognise that the two trajectories are parallel she must "factor out" the effect of distance on retinal motion. A similar problem occurs when physically parallel trajectories originate at different lateral positions; here direction must be "factored out". We report the results of two experiments designed to determine if observers can do this. The observers' task was to judge whether the direction of travel of an approaching sphere (test trajectory) was to the left or right of parallel to a previously shown trajectory (reference trajectory). In the first experiment the reference and test trajectories started from different lateral positions. In the second experiment they started from different distances. From the pattern of judgements we determined a set of physical trajectories that were perceptually parallel. Perceptually parallel trajectories deviated significantly from physically parallel. The results can be explained by assuming that observers did not use explicit estimates of either distance or direction in this task. We identify a retinal speed ratio on which observers appear to be basing their judgements. We propose that the brain is sensitive to this ratio and show that it is potentially useful information for the visual guidance of action.

K49 *1161* Optimal Aperture Size of Local Motion Estimators Depends on Velocity

Tal Tversky[1,2] (tal@cs.utexas.edu), Wilson Geisler[2]; [1]University of Texas at Austin, Computer Science Department, [2]University of Texas at Austin, Center for Perceptual Systems

Most models of local motion estimation in human and computer vision assume translational motion. For this class of models, the accuracy of velocity estimates depends on several factors including the sensor noise, magnitude of the stimulus velocity, extent to which the motion breaks the assumption of translation, ambiguity of the stimulus (e.g. the aperture problem), and spatial area (aperture) over which information is pooled. When the aperture size of a motion estimator increases, the signal to noise ratio improves and the probability of encountering an ambiguous motion stimulus decreases. On the other hand, the larger the aperture, the greater the likelihood of complex motions that break the assumption of translational motion. Therefore, we propose that there is an ideal aperture size at each velocity that will balance these two constraints. The size of this pooling area depends on the frequency and nature of the non-translational motions that occur in the world.In order to measure how aperture size should vary with velocity, we have developed a simple world model based on the statistics of natural scenes and have rendered movies from this world using a ray tracer. For locomotion through this world we calculate the error in local velocity estimates as a function of aperture size. For this particular world and measurement task, we find, as predicted, that the ideal aperture size increases monotonically with velocity magnitude. This principle may be used by biological visual systems and may be a useful addition to machine vision systems.

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K50 *1162* Is Motion Perception Completely Determined by Experience with Moving Objects?

William T. Wojtach[1] (wtw3@duke.edu), Kyongje Sung[1], Dale Purves[2]; [1]Center for Cognitive Neuroscience, Duke University, [2]Center for Cognitive Neuroscience, Department of Neurobiology, Duke University

The inverse optics problem presents a significant challenge for any explanation of visual perception. Using the same statistical approach that has successfully rationalized our percepts of brightness, color, and form (Purves & Lotto, 2003; Long & Purves, 2003; Howe & Purves, 2005), here we test the hypothesis that the human visual system generates all of its motion percepts probabilistically, based on what a stimulus sequence has most often signified in the accumulated past experience of observers. To test whether this hypothesis is correct, we have constructed a computer model using the principles of projective geometry to generate stimuli on an image plane from simulated objects moving in a virtual environment. From this motion database of image/source relationships, we then repeat-

edly sampled the image plane with templates configured in accord with the spatiotemporal parameters of sequential stimuli that have traditionally been used to investigate motion perception. The cumulative probability density functions from these samples were calculated, allowing us to make quantitative predictions about the motion phenomenology human subjects should perceive when presented with sequential displays of the same configuration as the templates. By comparing these predictions with psychophysical data acquired by standard CRT display testing and non-standard testing in a back-projected three-dimensional virtual reality environment, we were able to explain human motion perception of sequential stimuli. These results indicate that human motion perception is likely to be generated entirely on an empirical basis.

K51 *1163* Dot polarity in dynamic Glass patterns

Dawn Vreven[1] (vreven@uwosh.edu), Timothy Petersik[2], Jim Dannemiller[3], Jamie Schrauth[1]; [1]University of Wisconsin, Oshkosh WI, [2]Ripon College, Ripon WI, [3]Rice University, Houston TX

Each frame of a Glass pattern consists of a random placement of dots and a spatially shifted copy of this pattern. Thus, each dot has a partner, forming dot-pair dipoles. When shown in succession, motion is perceived along the axis of the spatial shift. The perception of motion in dynamic Glass patterns is believed to be a two-stage process: first, local orientation detectors respond to the orientation signal in the dot-pair dipole; and second, global detectors integrate local orientation signals. We examined the ability to detect rotation in dynamic Glass patterns whose dipoles contained a) the same polarity, b) opposite polarity within a dipole, and c) opposite polarity between dipoles. We also manipulated the extent of spatial shift between the dots in a dipole. A two-interval forced procedure was used, and the proportion of dipoles spatially shifted to be consistent with rotation was varied. The task was to determine which interval (noise or signal + noise) contained rotation. When both dots in a dipole were the same polarity, rotation detection thresholds increased with increasing dot separation. The same pattern was found when dot polarity differed between dipoles. Thresholds were significantly elevated, however, when dot polarity differed within a dipole. Unlike other reports (Wilson, Switkes & DeValois, 2004), we find that observers are capable of discriminating between Glass patterns and random noise even when dot-pair dipoles are of opposite polarity. This outcome suggests an additional role for global mechanisms in the perception of motion from dynamic Glass patterns.

K52 *1164* Perceived speed and center-surround organization

Maarten J. van der Smagt[1] (M.J.vanderSmagt@fss.uu.nl), Chris L.E. Paffen[1], Frans A.J. Verstraten[1]; [1]Psychonomics Division, Helmholtz Instituut, Universiteit Utrecht, The Netherlands

The perceived speed of a moving stimulus is known to decrease with decreasing contrast as well as increasing stimulus size. Similar effects of contrast and stimulus size have led to the hypothesis that the inhibitory influence of a moving surround acts by decreasing effective contrast in the center. However, at low contrasts center-surround interactions are generally facilitatory. We thus investigated the interaction between contrast, surround size and speed perception. In a two interval forced choice paradigm, participants judged which of two central moving gratings (radius 1 deg) moved faster. The 'standard' moved at 4 deg/s in one of eight directions, had no surround, and had a contrast of 25%. The 'probe' had a contrast between 1.5 and 99% and had either no surround or was surrounded by an annulus of 5 or 10 degrees outer radius. The speed of the probe was varied. A staircase procedure determined the point of subjectively equal speed between standard and probe.Both decreasing contrast and increasing surround size decreased the perceived speed of the moving central grating. The magnitude of the surround effect, however, was much larger than that of the effect of contrast. Interestingly, the effect of adding a surround on perceived speed was similar for very low as well as higher contrast stimuli. This result is at odds with studies on direction discrimination that have shown surround facilitation at low contrasts, and adds to the evidence suggesting independence between direction and speed processing.

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K53 *1165* Spatial characteristics of center-surround antagonism in motion discrimination

Lisa R Betts[1,2] (bettslr@mcmaster.ca), Allison B Sekuler[1,2,3,4], Patrick J Bennett[1,2,3,4]; [1]Department of Psychology, Neuroscience and Behaviour, McMaster University, [2]CIHR Strategic Training Grant on Communication and Social Interaction in Healthy Aging, [3]CIHR Research Group on Sensory and Cognitive Aging, [4]Center for Vision Research, York University

In young observers, the stimulus duration required to correctly discriminate the direction of low contrast moving targets decreases (i.e., performance improves) as stimulus area increases (spatial summation). However, at high contrast stimuli, duration thresholds increase with increasing stimulus size (spatial suppression), a result thought to be linked to center-surround antagonism in non-classical receptive fields (Tadin et al., 2003). Previous research from our lab suggests that such center-surround antagonism changes across the life span, as inhibitory mechanisms in visual cortex decline (Betts et al., 2005). Here we examine the extent to which spatial summation and suppression, and age-related changes in both, depend on stimulus spatial frequency. Stimulus duration thresholds for 0.5, 1, 2, and 4 c/deg Gabors drifting at 2 deg/s were measured over a range of contrasts (2.8% - 46%) and sizes (0.7-5 visible cycles) for younger (19-30 years) and older (63-75 years) observers. In younger observers, spatial summation and suppression occurred in all spatial frequency conditions, with summation occurring over a larger range of cycles as frequency increased for low contrast stimuli, and similar levels of suppression across all frequencies for high contrast stimuli. Older observers showed a similar pattern of results at low contrast, but as contrast increased, suppression was reduced compared to younger observers across all spatial frequencies. Our results suggest that patterns of spatial summation and suppression are preserved across low and medium spatial frequencies, and that the age-related reduction in spatial suppression is independent of stimulus spatial frequency.

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K54 *1166* Abstract withdrawn.

Facial Expression Perception

K55 *1167* I like the way you move: Personality perception in animated talking heads

Lisa N. Jefferies[1] (ljefferies@psych.ubc.ca), Ali Arya[2], James T. Enns[1]; [1]University of British Columbia, Vancouver, Canada, [2]Simon Fraser University, Burnaby, Canada

Humans form stable impressions of others' personalities, even after only a brief social exchange. But on what dynamic features are these impressions based? Previous research has focused on ratings of human actors trying to convey different personalities. In the present research we examined this question with three-dimensional animated heads that were programmed to display various emotions and dynamic movements during the delivery of an approximately 15-second voice-track that was the same in all conditions. These heads can be programmed independently at the level of morphology, emotional expression, and dynamic movement (e.g., nodding, blinking, turning). We designed four different personality types by combining two levels of affiliation (low, high) and two levels of dominance (low, high) (Wiggins et al., 1988). As a first approximation, we associated two basic emotions with each of these personalities (e.g., surprise and joy with high-affiliation, high-dominance; fear and sadness with low-affiliation, low-dominance) and we associated two dynamic head moves with each level of dominance and affiliation (e.g., frequent blinking and nodding with low dominance). Participants in Experiment 1 watched 8 different head morphologies acting out each of these 4 personalities and rated

them using a standard personality adjective scales. Other participants in Experiment 2 rated the strength of the emotions. The results indicated that it is possible to implement plausible and stable personality differences in animated heads using this combination of emotional expressions and dynamic head movement.

K56 *1169* Facial Expression of Emotion Mediates Gaze Cuing

Chelsea M. Heveran[1] (cheveran@lclark.edu), Mark W. Becker[1], Ian P. Rasmussen[1], Brian Detweiler-Bedell[1]; [1]Department of Psychology, Lewis & Clark College, Portland, OR.

Another person's gaze is an effective attentional cue. Here we investigate whether gaze cuing is mediated by the emotion expressed by the face. Logic suggests that the gaze of a fearful face should be a more effective cue to attention since it would allow one to rapidly allocate attention to potential threats. However, Hietanen & Leppänen (2003) found no evidence that gaze cuing was more effective with fearful faces and Mathews et al. (2004) found that a fearful faces gaze was more effective only for highly anxious subjects. In both experiments, a single face cue was presented in isolation, providing an unambiguous gaze cue which might have produced a ceiling effect regardless of the emotional expression. In this experiment two faces cues were flanked (500msec later) by two letters (a T and an L). Subjects hit a key which corresponded to the side of the screen which contained the T. Across trials the emotion expressed by each face varied between happy, neutral, or fearful. In addition, one face gazed toward the T(valid) and the other gazed toward the L(invalid). Given that the two faces cued conflicting directions, we were able to determine the relative cuing effectiveness of different emotional expressions. By using this method we were able to demonstrate that the gaze of a fearful face is a more effective cue to visual attention than a neutral face, and that the gaze of a neutral face was a more effective cue than the gaze of a happy face.

K57 *1170* Negatively Valanced Facial Expressions Elicit Panicked Scanning

Mark W. Becker[1] (mbecker@lclark.edu), Brian Detweiler-Bedell[1], Ian P. Rasmussen[1], Laura Koch[1]; [1]Lewis & Clark College, Department of Psychology, Portland, OR.

In three experiments we tracked eye movements to investigate whether the facial expression of negative emotion attracts visual attention. In all experiments, participants passively viewed scenes comprised of 4 upright or 4 inverted Ekman faces. In the first experiment, one face depicted fear or happiness while the other three faces depicted the opposite emotion. In experiment 2, there was one target face (fear, happy) among 3 neutral faces. Experiment 3 was similar to experiment 2 except that it included a condition in which an angry face was sounded by neutral faces. In all three experiments, negatively valanced faces were fixated earlier, but not because they drew attention to their location (i.e. the ordinal number of the first fixation on the fear face was the same as on the happy face). Instead, it seems that the presence of an upright negatively valanced face precipitates "panicked scanning" which results in shorter fixation durations which reduces the time taken to initially fixate fear faces. However, the scan path to a negatively valanced face is no more direct than to a control face. These results suggest that the facial expression of emotion is analyzed prior to the initial fixation on the face and when the valance of the a face is negative it speeds the overall search process, without providing the spatial coordinates of the negative face to the saccade guidance system.

K58 *1171* Do facial expressions help face recognition in prosopagnosia?

Jason JS Barton[1,2,3] (jasonbarton@shaw.ca), Rebecca Hefter[2,3]; [1]University of British Columbia, [2]Harvard Medical School, [3]Beth Israel Deaconess Medical Center

Functional imaging suggests the presence of divergent face processing streams. The fusiform face area may be preferentially involved in recognizing identity, and the superior temporal sulcus in perceiving social signals like facial expression. However, this distinction may not be complete: some identity-related processing might occur in the superior temporal sulcus, for example. This is of interest as most prosopagnosic patients have medial occipitotemporal lesions that spare the superior temporal sulcus. We tested the hypothesis that the recognition of faces by prosopagnosic patients would be aided by the use of faces with emotional expressions. We administered four tests to five prosopagnosic patients. One was the standard Warrington recognition memory test, in which smiling or neutral faces are used to test short-term memory for faces. The second test used a similar procedure but with 48 afraid, sad or happy faces. The third was a test that used angry or happy faces during the encoding phase, but neutral faces for the recognition phase, and the fourth test reversed the phases of the third. Prosopagnosics with fusiform face area lesions performed worse with the emotional variant of the Warrington procedure, compared to the standard test. They were also worse when encoding emotional faces for recognizing neutral faces, than when encoding neutral faces for recognizing emotional ones, primarily because of difficulty when encoding angry faces. We conclude that facial expression does not enhance face recognition in prosopagnosia, but may instead interfere with it, particularly during the encoding phase.

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K59 *1172* Facial expressions can be perceived from second-order motion.

Naoyuki Matsuzaki[1] (matsuzakinaoyuki@yahoo.co.jp), Takao Sato[1]; [1]The University of Tokyo

PURPOSE. Matsuzaki & Sato (1999) showed that facial expressions are perceived from purely dynamic components. In this study, we investigated the type of motion information used in the perception of facial expressions. METHODS. The stimuli were eighteen point-lights defined by luminance or contrast representing the eyebrows, the eyes and the mouth. The dynamic components, i.e. the differences between corresponding positions for natural and each emotional face (angry, happy, sad, and surprised) were calculated. Then, two types of point-light stimuli were generated. One was "FE1" made by shifting the points in neutral face by the amount of corresponding dynamic component. The other was "FE1+FE2" generated by shifting the points in FE1 further by the amount of corresponding dynamic component from another emotional face. In the experiment, the subjects were shown "FE1" and "FE1+FE2" successively and required to judge the facial expression of the stimuli. The inter-stimulus-interval (ISI) was manipulated in five steps. RESULTS. When the ISI was short, the subjects perceived the apparent motion and judged as FE2 corresponding to the dynamic component more often than FE1. However, the FE1 and the FE2 were perceived equally often for longer ISIs. This tendency was observed for both luminance-defined and contrast-defined stimuli, but the bias to the FE2 in the short ISI was smaller in contrast-defined than luminance-defined stimuli. CONCLUSIONS. These results indicate that, although it is less effective than first order motion, second order motion is certainly capable of supporting perception of facial expressions.

K60 *1173* Expressions as Dynamic Events: Using Action Unit Trajectories to Differentiate Positive Emotional Facial Expressions

Jesse B. Spencer-Smith[1] (jbspence@uiuc.edu); [1]University of Illinois

Emotional facial expressions have largely been studied using static images. Motion, however, makes expressions that would otherwise be invisible readily apparent. In addition, the current study demonstrates that positive expressions (e.g. happiness, pride in achievement, sensual pleasure, satisfaction) that were previously thought to share the same facial signal (the smile), can be differentiated based on the time course of the activation of the constituent action units. This suggests a new approach to studying emotional and social facial expressions--action unit trajectories. This study

describes a new, photo-realistic synthetic model of a face in which action units can be independently activated with arbitrary magnitudes and controlled in real-time using a joystick. In addition, the apparent gender, ethnicity, and age of the face can be altered. The current study employs this platform to study the perception of dynamic faces, quantifying the action unit trajectories which give rise to the perception of varying positive emotional states. Expressions are then represented as trajectories in action unit space, where dimensions are defined by action units. Trajectories provided by multiple participants for a single emotional state (e.g. sensual pleasure) are combined using functional data analysis resulting in a mean trajectory. Played back to a new group of observers, the trajectory is reliably identified in a forced-choice task.

K61 *1174* The effect of the facial motion on the recognition of facial expressions. -Analysis of observer's eye movement -

Motoyasu Honma[1] (mhonma@stu.rikkyo.ne.jp), Yoshihisa Osada[1]; [1]Rikkyo University

We examined the effect of facial motion in face processing by means of observer's eye movements. Face images were produced by morphing between neutral and expressive faces. A complete morph sequence lasted for 3360 ms. We created three additional sub-sequences culminating in 10%, 30% and 50% morphs, lasting for 336ms, 1008ms and 1680ms respectively. Morphing sequences and static faces were presented for identical durations. We used a 2 x 2 x 4 factorial design - presentation formats (dynamic or static), facial expressions (happy or sad) and final morph value 10%, 30%, 50% or 100%. A 2AFC task was employed. We monitored eye movements during tasks, and analyzed the data by means of FFS (Fixation-point of First Saccade) and VVF (Variance Value of Fixation-points). Our results showed that FFS was directed to centre of the face under all conditions. Moreover, VVF decreased for the moving faces in comparison to the static ones. This result suggests that facial motion may inhibit eye movement. Futhermore, VVF for happy faces was smaller than that for the sad ones. These results imply that facial motion affects eye movements after first-saccade. Maurer et al. (2002) have suggested that configural processing of faces can be divided into three type: first-order relations, holistic processing, and second-order relations. FFS could reflect acquisition of first-order relation, while VVF may reflect the analysis of second-order relations.

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K62 *1175* Inter-hemispheric cooperation for facial and bodily emotional expressions is independent of visual similarities between stimuli

Marco Tamietto[1] (tamietto@psych.unito.it), Giuliano Geminiani[1], Beatrice de Gelder[2,3]; [1]Department of Psychology and Center for Cognitive Science, University of Turin, Italy, [2]Martinos Center for Biomedical Imaging, Massachusetts General Hospital, HarvardMedical School, MA, USA, [3]Cognitive and Affective Neuroscience Laboratory, Tilburg University, The Netherlands

Reaction times are shorter when congruent emotional expressions are presented to both visual hemifields contemporarily than when just one expression is presented unilaterally to either the left or right hemifield. Here we tested whether the shorter latency in the bilateral congruent condition is present also when the two pictures show the same emotion but belong to two different classes of stimuli. Fearful and happy facial and bodily expressions were presented for 200 ms according to the following six conditions for each of the two emotions: unilateral left, unilateral right, bilateral congruent I (with both stimuli belonging to the same category and showing the same emotion; either both faces or both bodies), bilateral congruent II (with a face on one hemifield and a body on the opposite hemifield, both showing the same emotion), bilateral incongruent I (one happy and one fearful expression with both stimuli of the same class) and bilateral incongruent II (one happy face and one fearful body or vice-versa). We used a go/no-go task and the subjects were required to press a key when the target emotion (fearful or happy, depending on blocks) was presented on the screen (irrespectively of its position, number, or category). Subjects reacted faster to bilateral congruent I and II conditions as compared to unilateral left or right conditions. This difference in reaction times is consistent with an interpretation in terms of interhemispheric cooperation. The present results suggest that physical similarities between stimuli are not relevant for interhemispheric cooperation to occur.

Acknowledgment: Redundant Target Effect

K63 *1176* Body language influences perception of facial expression and voice prosody.

Jan Van den Stock[1] (j.vdnstock@uvt.nl), Beatrice de Gelder[1,2]; [1]Cognitive and Affective Neuroscience Laboratory, Tilburg University, The Netherlands, [2]Martinos Centre for Biomedical Imaging, Massachusetts General Hospital, Harvard Medical School, USA

Emotion research has focused mainly on perception of static facial expressions. Other common emotional signals are provided by body language. We performed two experiments, investigating the influence of whole body expressions on perception of facial expressions and voice prosody. In the first experiment, we presented subjects with a compound stimulus, consisting of a (morphed) facial expression on an emotionally congruent or incongruent whole body expression. The task was to rate the facial expression. The data show a clear influence of the bodily emotion on the perception of the facial expression. In the second experiment we simultaneously presented a face-blurred whole body expression and a vocal utterance. Subjects were to rate the emotional tone of voice. Results indicate an influence of the body expression on the perception of the vocal prosody. Taken together the results provide evidence for body language as an important affective signal.

Face Perception: Models

K64 *1177* Region-based representations of faces

Adrian Nestor[1] (adrian_nestor@brown.edu), Michael J. Tarr[1]; [1]Department of Cognitive and Linguistic Sciences, Brown University

A great deal of face recognition research is concerned with finding a robust method for identifying facial features and uncovering a plausible encoding scheme. We develop and test a representational scheme based on the idea of facial feature segmentation. Region-based segmentation (Fowlkes, Martin and Malik, 2003) is used to parse human faces into features, i.e., parts, at any given level of detail. The segmentation algorithm tested closely mimics human generated segmentations for front-view adult Caucasian faces. The validity of this scheme is further evaluated by using the surface properties, luminance and chrominance, of the facial features thus identified to predict facial gender. Both automatic gender discrimination and our ability to account for human gender discrimination are superior when we consider the properties of multiple facial features compared to average face properties, e.g. mean face luminance (Tarr et al., 2001). The representational scheme is thus relevant to the study of higher-level aspects of face processing, e.g., the involvement of surface properties in face categorization. In particular, automatic segmentation of faces offers a model of how face representations are constructed as well as a means to investigate some lower-level aspects of face processing, e.g., the role of color in face segmentation. In sum, region-based models show significant advantages in automatic face processing, as well as psychological plausibility in accounting for human face processing.

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K65 *1178* Holistic Processing of Faces: Bridging Paradigms

Jennifer J. Richler[1] (jennifer.j.richler@vanderbilt.edu), Isabel Gauthier[1], Michael J. Wenger[2], Thomas J. Palmeri[1]; [1]Vanderbilt University, [2]Pennsylvania State University

In a typical composite face task, participants judge whether the top (bottom) of a test face is the same as the top (bottom) of a study face, while ignoring whether the bottom (top) is the same or different. The standard finding is that the irrelevant part reliably affects responses about the relevant part. The question that arises is whether this reflects some type of perceptual holism. Wenger and Ingvalson (2002, 2003) used a different approach to this question. In their studies, participants simultaneously judged whether both the top and bottom of a test face were the same or different from the study face (a complete identification task). This task allowed them to analyze their results using the tools of general recognition theory (GRT, Ashby & Townsend, 1986), which makes a distinction between perceptual and decisional sources of stimulus integrality. Wenger and Ingvalson found consistent evidence for decisional influences, with very limited evidence for perceptual holism. The present experiment relates the composite face task to the complete identification task empirically and theoretically. Three participants completed five sessions of both a complete identification task (judging both parts simultaneously) and a variant of the more standard composite task (judging only one part at a time). Results for all participants for both tasks show consistent violations of decisional separability, with some violations of perceptual separability. Critically, there was no strong evidence for violations of perceptual independence. This work suggests needed refinements of the concept of holism in face perception and memory.

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K66 *1179* Feminine-looking Faces belong to Friendly and Helpful People - Stereotyping with a Parametric Image Model

Mirella Walker[1] (mirella.walker@stud.unibas.ch), Thomas Vetter[1]; [1]Departement Informatik, Bernoullistr. 16, 4056 Basel, Switzerland

Previous findings suggest that the gender-stereotypic physical appearance of a person influences how this person is regarded. In earlier studies, the physical appearance was manipulated by preselecting stimulus persons with feminine- or masculine-looking faces. In our study, we used a method of image-manipulation to produce the stimuli. Each image was analyzed by actively reconstructing it with a Computer Graphics based 3D Morphable Face Model. These images were manipulated by adding a gender-vector that was learned from exemplar human heads. All heads in the model are labeled male or female. The gender vector is the gradient vector of the regression function that describes the labeled data best. By applying this vector to an image, we synthesized two novel photo-realistic images: a more feminine- and a more masculine-looking one. The information in the model for specifying gender is not only effective, but effective enough to induce the well-known social psychological phenomenon of stereotyping of males and females. Participants were asked to judge the social skills and aptitude of leadership applicants on the basis of images and fictive job references. Thus sex, appearance and attributes were manipulated independently. The results indicate that feminine-looking applicants are judged to be more socially skilled than masculine-looking ones, independent of their sex and attributed characteristics. Furthermore, feminine-looking applicants seem to suit best to the job when characterized as dominant, masculine-looking ones, when characterized as socially skilled. Our novel method of image manipulation has the advantage to let us change one parameter of faces independent of identity information.

K67 *1180* Gender aftereffects in the perception of silhouetted face profiles

Nicolas Davidenko[1] (ndaviden@psych.stanford.edu), Jonathan Winawer[2], Nathan Witthoft[2]; [1]Stanford University, [2]Massachusetts Institute of Technology

Recent studies have shown figural aftereffects in the perception of faces, including gender, race, and identity aftereffects (e.g., Leopold et al., 2001; Webster et al., 2004; Witthoft & Winawer, 2005). In such studies, prolonged exposure to a face with a particular characteristic (e.g., female) temporarily biases subsequent perception of faces in the opposite direction in face-space (e.g., male). Here we report such adaptation in a brief, implicit adaptation paradigm using parameterized silhouetted face profiles that rely on 18 landmark points to specify each face (Davidenko, 2004). We constructed a set of 8 male and 8 female face silhouettes, and a gender-neutral silhouette produced by averaging 20 male and 20 female silhouettes. Subjects were unaware that there were separate adaptation and test conditions; they simply rated each of 9 silhouettes on one of four dimensions: age, race, attractiveness, or gender. The first 8 silhouettes were either all female (Condition 1) or all male (Condition 2), and the 9th face was gender-neutral. Gender was only rated on the 9th face. We report a dramatic gender aftereffect with face silhouettes: 97% of subjects in Condition 1 (57 of 59) labeled the neutral silhouette as male, compared to 39% in Condition 2 (24 of 62). To our knowledge, this is the first report of face adaptation using profiles. In addition, these effects further validate Davidenko's silhouette face-space.

URL: http://www-psych.stanford.edu/~ndaviden/silhouettes.jpg

K68 *1181* Generation of Sketch-like Feature Encodings in Oriented Faces – A Neural Model

Ulrich Weidenbacher[1] (ulrich.weidenbacher@uni-ulm.de), Pierre Bayerl[1], Heiko Neumann[1]; [1]University of Ulm

One challenging task in face recognition is the identity-independent estimation of head pose from single images across a wide range of pose angles. An essential part of many approaches is the extraction of sparse facial features such as eyes, nose or mouth (Gee, Cipolla, 1994, *Image & Vision Computing 12(10)*). However, when the face is rotated *in depth*, distinct features may partly be occluded or disappear completely. Given the changes in appearance or visibility of individual features it remains unclear which features are suitable for pose estimation. Here, we present a neural model that creates an abstract representation of perceptually relevant features from single images of oriented faces. The major model stages are summarized as follows: **(1)** Oriented contrasts are detected utilizing oriented band-pass filters, followed by local competition. **(2)** Locally collinear features are grouped and enhanced by integrating context information from the extracted orientations. **(3)** Recurrent feedback from the grouping stage to initial responses iteratively accentuates filter responses that comprise smoothly curved flow patterns of image orientations. The model output can be visualized as a sketch-like drawing of a face emphasizing pose specific features which are important for feature-based head pose estimation. Furthermore, we evaluate our model by using the sketch representation as basis for existing feature-based head pose algorithms (Krüger et al., 1997, *Image & Vision Computing 15(8)*). In conclusion, our approach not only provides a tool for visualizing important features of faces, it also yields a sparse representation of faces which can be directly integrated into face recognition tasks.

Acknowledgment: This work has been supported in part by a grant from the Ministry of Science, Research and the Arts of Baden-Württemberg (Az: 23-7532.24-13-19/1).

K69 *1182* Explaining human facial attractiveness judgements

Philip Bronstad[1] (bronstad@brandeis.edu), Judith H. Langlois[2]; [1]Brandeis University, [2]The University of Texas at Austin

People from different cultural and economic backgrounds agree about which faces are attractive, suggesting that humans share an attractiveness "template." Much research in the last two decades has focused on the composition of this template, such as whether it is primarily sensitive to facial averageness, symmetry, or sexual dimorphism. However, we have little understanding of how different aspects of appearance codetermine per-

ceptions of attractiveness. Using a simple neural network model, we can reconstruct an attractiveness template from images of faces and attractiveness judgements of those images. The model solves the difficult problem of replicating and predicting human attractiveness judgements to images of faces. It reduces judgements into simpler image-based factors that are sensitive to aspects of facial appearance. These factors are strikingly similar to averageness, symmetry, and sexual dimorphism.

K70 *1183* **Can low level image differences account for face discrimination performance?**

Aleix M. Martinez[1] (aleix@ece.osu.edu), Danelle Wilbraham[1], James T. Todd[1], James Christensen[1]; [1]Ohio State University

Suppose that you see someone for the first time through a screen window, and later see the same person through a window with a different type of screen. For image-based models of face recognition, in which faces are represented in terms of raw pixel intensity values or the outputs of wavelet filters, the altered structure of the screen in this scenario would be expected to impair recognition performance. The present experiment was designed to test this hypothesis using a sequential matching paradigm. Each trial began with a brief presentation of a "sample" face with a neutral expression that was partially masked by a checkerboard grid of small black squares. This was followed in sequence by a pattern mask, and a new image of a "test" face that could be masked by the same checkerboard as the standard, a checkerboard that was shifted in phase by 90 or 180 degrees, or with no mask at all. The standard and test faces could depict the same or different individuals, and they could have the same or different facial expressions. Observers were required to indicate whether the two depicted individuals were the same or different by pressing an appropriate response key as quickly as possible.The results revealed that the different masking conditions had no effect on observers' judgments, and that the overall pattern of performance (classification error and reaction times) could not be predicted from low level differences in pixel intensity values of the outputs of Gabor filters.

Acknowledgment: Supported in part by a grant from NIH.

K71 *1184* **The effects of illumination and expression changes on the recognition of human faces**

Danelle A. Wilbraham[1] (wilbraham.1@osu.edu), Aleix M. Martinez[1], James T. Todd[1]; [1]Ohio State University

A match-to-sample paradigm was employed to investigate various factors that can influence the discrimination of facial identity. Each trial began with a brief presentation of a "sample" face with a neutral expression. This was followed in sequence by a pattern mask, and a pair of new images: A target image of the same individual as depicted in the standard but with a different facial expression and/or direction of illumination; and a foil image of a different individual. Observers were required to identify the target face by pressing an appropriate response key as quickly as possible. The relative similarity of the standard to the target and foil in terms of pixel intensities or Gabor filter outputs was systematically manipulated across trials. The results revealed that the relative similarity of the standard to the target and foil had a negligible effect on the speed and accuracy of the observers' responses, although there were significant differences in performance for different facial expressions.In an effort to compare observers' performance with a typical image-based model of face recognition, a PCA representation was computed from a large set of facial images different from those used in the behavioral study. This representation was then used to perform the match-to-sample task described above on the same stimuli images used with subjects. Although the overall accuracy of the model was similar to that of human observers, the correlation of the human and model performance across the different experimental conditions accounted for less than 5% of the variance.

Synesthesia

K72 *1185* **Are real and synesthetic colors mediated by shared neural mechanisms?**

Chai-Youn Kim[1] (chai-youn.kim@vanderbilt.edu), Randolph Blake[1]; [1]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University

Background: Individuals with color-graphemic synesthesia experience colors when viewing achromatic alphanumeric characters, and accompanying synesthesia is activation of color-responsive brain areas. Whether real and synesthetic colors arise from activation of the same population of neurons remains unknown, however, so we used rapid, event-related fMRI to address this question.

Methods: fMRI BOLD signals were measured while synesthetic observers saw two alphanumeric characters presented in rapid succession. *RC condition*: a colored, non-alphanumeric character was followed by another non-alphanumeric character either the same or different in color; none of the RC characters evoked synesthesia. *SC condition*: an achromatic letter evoking a given synesthetic color was followed by another achromatic letter evoking either the same or a different synesthetic color. To control attention, observers were required to categorize each character based on shape. BOLD signal time series were analyzed from individual, functionally defined, color-selective voxels.

Results & Conclusions: Same color pairs evoked BOLD responses that differed in amplitude from responses evoked by different color pairs, and this differential activation was equivalent for RC and SC conditions. Results suggest that perception of real and synesthetic colors is mediated by shared neural mechanisms.

Acknowledgment: EY14437

K73 *1186* **The influence of grapheme-color synaesthesia on eye movements**

Jonathan S. A. Carriere[1] (jcarrier@watarts.uwaterloo.ca), Daniel Smilek[1], Michael G. Reynolds[1], Mike J. Dixon[1], Philip M. Merikle[1]; [1]University of Waterloo

Grapheme-color synaesthesia is a condition in which ordinary black text is perceived in vivid colors. Some grapheme-color synaesthetes report that they dislike looking at a grapheme that is presented in the "wrong" color (i.e. a color that is incongruent with their synaesthetic experiences for the grapheme). We investigated the ramifications of grapheme color congruency by monitoring eye movements. In Experiment 1, D.E., a grapheme-color synaesthete, searched displays of colored graphemes for a specific target letter. Each display contained equal numbers of congruently and incongruently colored graphemes. The target grapheme was present on half of the trials and absent on the other half of the trials. On target present trials, D.E. was more likely to miss and re-fixate incongruently colored targets than congruently colored targets. On target absent trials, there was a trend for D.E.'s overall fixation times to be greater on congruent items than on incongruent items. In Experiment 2, D.E. was asked to freely view displays of colored graphemes for as long as he wished. Again, congruent items received more fixation time than did incongruent items. These findings indicate that not only does D.E. dislike looking at "wrongly" colored graphemes, but he also tends to ignore information that is inconsistent with his synaesthetic experiences.

Acknowledgment: The research was supported by NSERC

K74 *1187* **Do Synesthetes Excel Under Object-Substitution Masking? Type of Attention Matters.**

Abrie Schroeder[1] (aschroed@email.arizona.edu), Mary A. Peterson[1]; [1]University of Arizona

In synesthesia the presentation of alphanumeric characters can result in an

automatic perception of color, called a "photism". An object-substitution masking (OSM) paradigm was used to investigate the role of photisms in target identification. In OSM, a target surrounded by four dots is presented among a number of distractors and quickly removed while its surrounding dots remain. The dots can be an effective mask when they share the target's color. In two experiments, participants reported which of two targets (2 or 5) was present among non-digit distractors arranged on an 8.4° diameter ring (allowing attention to be distributed along the ring). All display items were surrounded by dots; the target disappeared after 20ms. We tested synesthetes (projector and associator) and = 30 control subjects (for a population estimate). In Experiment 1 controls' error increased with set size (2 - 8; $p < .01$). In Experiment 2 set size was constant (8 items); across counterbalanced blocks target duration varied in 6 steps between 20 and 40 ms. Controls' error decreased with longer display durations ($p < .01$). In both experiments, synesthetes performed within the same range as controls indicating that their photisms did not improve performance. Indeed, synesthetes reported they did not experience photisms during the task. We suggest that under some conditions of display configuration, brief exposure, and masking, shape information may survive without the generation of photisms. An experiment in progress examines whether focal attention is necessary for synesthetes to perceive and benefit from photisms.

Acknowledgment: NSF BCS: 0418179 to Mary A. Peterson, UA SBSRI grant to Abrie Schroeder

URL: http://www.u.arizona.edu/~mapeters/

Attention: Interactions with Memory

K75 *1188* Further Adventures with the Magical Number One

Ronald A Rensink[1] (rensink@psych.ubc.ca); [1]Departments of Psychology and Computer Science, University of British Columbia, Vancouver, Canada

Rensink (1999) found that visual search for the absence or conjunction of change had a capacity of about 1; this "magical number one" was taken as evidence for a nexus of attention that mediates change perception. The studies here explored this idea further, using arrays of horizontal and vertical rectangles under flicker conditions, where displays continually alternated between "on" (exposures of 160-800 ms) and "off" (blank fields of 120 ms). For simple change involving orientation, capacity for presence was 3.5, while capacity for absence was 1.2. When the rectangles were embedded in ellipses, capacity for presence decreased by 50%, while capacity for absence remained unaffected. Likewise, when an irrelevant background grid was placed between items, capacity for presence decreased by 50%, while capacity for absence remained unaffected. This supports the idea that detection of both presence and absence of change is mediated by a nexus, with the higher capacity for presence achieved via some form of configural organization.For compound change involving orientation and polarity, capacity for presence (i.e, conjunction of changing properties) did not exceed 1. Interesting, capacity for absence (i.e., a single change among conjunctions) was 40% higher. This indicates that the low capacities were not due to high levels of noise from the other items, but resulted from a structural limitation - viz., the nexus. It also suggests that the slight overunity excess for both absence conditions might be due to the use of a comparator that can be applied to 2 items at a time.

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K76 *1189* Memory Modulates Visual Search – Interactions of External and Internal Representations

Hansjoerg Neth[1] (nethh@rpi.edu), Christopher W. Myers[1], Wayne D. Gray[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute

Recent debates over the role of memory in visual search (Shore & Klein, 2000; Horowitz & Wolfe, 1998, 2001, 2003; McCarley et al., 2003) pose a dilemma: The emerging view of vision as 'just-in-time' processing (Hayhoe & Ballard, 2005) suggests that visual search is largely amnesic and routinely relies on external information. Simultaneously, it is clear that people build, and benefit from, internal representations of their visual environment.Despite notable exceptions (e.g., Thornton & Horowitz, 2004; Chun & Jiang, 1998) laboratory investigations of visual search typically involve brief and single stimulus presentations and hence do not address the gradual and incidental construction and subsequent use of internal representations. We investigate trade-offs between external and internal information acquisition using a serial search paradigm (Neth, Gray & Myers, 2005), which requires participants to locate a series of up to 20 targets on a display of 10 stable singletons. Thus, singletons assume the functional roles of both targets and distractors throughout a trial.Eye-tracking data was analyzed and compared to computational model predictions (ACT-R, Anderson & Lebiere, 1998). Strong evidence for memory processes supplementing visual search was found. Both repeated and novel targets were found with fewer fixations as a function of frequency, recency, and total dwell duration. As predicted by rational analysis (Anderson, 1990), the effects of memory are more pronounced as the cost for external information access increases. We conclude that memory processes operate routinely during visual search. The use of internal representations varies as a function of memory activation for both target and distractor information.

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URL: http://www.cogsci.rpi.edu/cogworks/

K77 *1190* Reactivation of attentional set after 1-day and 1-week delays

Andrew B. Leber[1] (andrew.leber@yale.edu), Yuji Gabari[2], Jun Kawahara[2]; [1]Yale University, [2]Hiroshima University

How does past experience guide visual search strategy (i.e., attentional set)? Leber and Egeth (in press) found that observers given the option to use more than one attentional set in a "test phase" consistently used the set they established in a directly preceding "training phase". While this result demonstrates a clear impact of past experience on attentional set, the question remains whether it reflects simple persistence with pre-established set or the formation of lasting associations that can be reactivated after intervening tasks. To examine these alternatives, and to probe the strength and duration of the learning, we introduced one-day and one-week delays between training and test. In a 320-trial training phase, observers assigned to a "singleton search" group were required to search for oddball color targets (selected randomly on each trial) in a rapid serial visual presentation of letters, while those assigned to a "feature search" group were required to search for targets of a specific, consistent color. In the 320-trial test phase, both groups of observers searched for a consistent color that was also a singleton; thus, both singleton and feature search strategies had become available to all observers. Test phase results revealed that observers in both one-day and one-week delay conditions used the same strategy that was required of them in the training phase. This long-term learning effect, arising from relatively short training (~30 minutes), could not have resulted from simple persistence; rather, attentional set can be reactivated when triggered by the appropriate task context.

K78 *1191* Local and Global Influences on Hypothesis Testing During Rapid Resumption of Visual Search

Timothy F. Brady[1] (timothy.brady@yale.edu), Justin A. Junge[1], Marvin M. Chun[1]; [1]Yale University

When subjects begin a visual search trial there is an initial delay in response, while the items are being initially processed and a hypothesis is generated. But on subsequent exposures to the same display, search can be rapidly resumed by testing a previously generated hypothesis against the

display (Lleras, Rensink, & Enns, 2005). Here we examine the nature of these hypotheses, looking in particular at their spatial extent. To do so, we looked at the effect of changing the location of 25% of the distractor items between search exposures in comparison to a no-change baseline. On each trial, a display was shown for 500ms and then disappeared for 1600ms. Then the display was shown again, and this cycle was repeated until the target was found. When items near the target moved during the blank period between exposures to the display, it interfered with hypothesis testing and significantly impaired subjects' ability to rapidly resume search. However, when items distant from the targets were moved between exposures, there was no detriment to rapid resumption. Thus, the hypotheses that guide rapid resumption of search are restricted to a local subset of items.

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K79 *1192* Visual memory for colors of tracked objects.

Philip C. Ko[1] (philip.c.ko@vanderbilt.edu), Adriane E. Seiffert[1]; [1]Vanderbilt University

The primary tenet of object-based theories of attention is that observers have access to all features of attended objects. In studies of visual short-term memory (VSTM), memory for arrays of color-shape conjunctions present no additional cost compared to memory for arrays of color features (Luck & Vogel, 1997). However, in dynamic settings, such as multiple-object tracking (MOT), maintenance of target locations may prevent storage of surface features, like colors. We investigated whether colors could be stored in dynamic objects with a VSTM / MOT dual-task paradigm. On each trial, participants encoded colors of three out of ten dots in a visual display (VSTM task). Colors were removed and participants attentionally tracked three target dots (MOT task). Either the same dots were used in the VSTM and MOT tasks (Within-objects condition) or different dots were tracked (Between-objects condition) while VSTM dots remained stationary. If object-based attention supports tracking, there should be less dual-task interference in the Within-objects condition. This hypothesis was confirmed, as the Within-objects condition produced higher percent correct in the VSTM task ($t(12) = 2.2$, $p<0.05$) and MOT task ($t(12) = 4.1$, $p<0.01$) compared to the Between-objects condition. Additionally, Cowan's formula (2001) revealed greater retention of information in the Within-objects condition ($K = 4.1$) than the Between-objects condition ($K = 3.4$). These results provide a first step towards confirming whether the key property of object-based attention, access to all object features upon selection, is common to visual memory and attention to dynamic objects.

K80 *1193* Familiarity modulates the within-field advantage for detecting repeated elements

Serena J Butcher[1] (sbutcher@wjh.harvard.edu); [1]Harvard University

Purpose: Previous research suggests that subjects are around 90ms faster detecting familiar letter presented unilaterally versus. Here we examine the question of whether previous knowledge of the stimulus class affects the within-field advantageMethod: Six subjects, 3 with no knowledge of the Arabic alphabet, 3 fluent in both the Arabic and Western alphabet, were tested in detecting repetitions of Western or Arabic letters via blocked design. Subjects indicated if there was a repetition of any two of four presented characters. Stimuli were placed in each quadrant. A repetition was present on half the trials and was either unilateral (the two repeated items within one visual hemifield, right or left), or bilateral (one of the two repeated items in each field).Results: When averaged together subjects were significantly faster at detecting repetitions for both that occurred within versus across visual fields for both Western characters (92ms, $p < 0.00$) and Arabic characters (70ms, $p < 0.00$). Subjects only familiar with the Western alphabet had a 76ms within field advantage for Western characters ($p <0.05$). For Arabic characters the 68ms advantage was not significant. Also these subjects were on average 150ms faster at detecting Western versus Arabic repetitions. Subjects familiar with both alphabets showed similar mean RTs and a significant with-in field advantage for both types of characters.Conclusion: These results suggest: 1) familiarity modulates the detection of repetitions, as western subjects were faster overall in detecting repetitions of familiar characters and 2) the within-field advantage may rely previous experience with the stimulus class.

Acknowledgment: Research supported by NSF graduate fellowship to SJB.

Wednesday Talk Sessions

Wednesday, May 10, 2006

Motion Perception (1194-1199), Visual Memory (1200-1205), Frontier Techniques (1206-1211), Attention: Costs of Divided Attention and Inattention (1212-1218)

Motion Perception

8:00 - 9:30 am

Hyatt Ballroom North

Moderator: Duje Tadin

8:00 *1194* Temporal summation in trajectory perception

Jeffrey B. Mulligan[1] (jmulligan@mail.arc.nasa.gov), Maite T. Trujillo[1]; [1]NASA Ames Research Center

Temporal summation in perception can arise from a variety of mechanisms. At the lowest level, sensory mechanisms integrate stimuli linearly, with time constants measured in tens or hundreds of milliseconds. For longer presentations, additional (sub-linear) integration may occur, sometimes attributed to probability summation, still within pre-attentive mechanisms. For the longest delays, explanations may be couched in terms of memory and cognitive decision processes, and temporal nonuniformities can be observed such as "primacy" and "recency" effects. Here we examine subjects' ability to discriminate clockwise and counter-clockwise circular trajectories when superimposed on a random-walk trajectory mask. A staircase procedure controlled the amplitude of the 4 Hz circular component, while the mask trajectory was generated by integrating Gaussian-distributed white velocity noise. Trajectories controlled the position of a bright circularly symmetric spatial Gaussian spot (contrast = 60%). Five durations (0.25, 0.5, 1, 2 and 4 seconds) were randomly interleaved within blocks of 150 trials. An ideal observer (with perfect knowledge of the stimulus frequency, but uncertain with regard to amplitude and phase) exhibits the familiar square-root law, with sensitivity increasing by a factor of 2 when the stimulus duration is increased by a factor of 4. Subjects, while less sensitive than the ideal observer, somewhat surprisingly show the same functional dependence on duration over the entire range tested. We consider models in which the subject integrates change-of-direction signals.

Acknowledgment: Supported by NASA's Airspace Systems and Aviation Safety programs.

URL: http://vision.arc.nasa.gov/personnel/jbm/home/presentations/vss06/

8:15 *1195* A computational theory for the perception of coherent motion:From ideal observer to generic models

Alan Yuille[1] (yuille@stat.ucla.edu), Hongjing Lu[2]; [1]Dept. Statistics, [2]Dept. Psychology

Motion perception depends on spatial integration of local motion signals, requiring a solution to the correspondence problem created by the ambiguity inherent in matching features between successive frames. We describe a computational theory of how the visual system solves the correspondence problem. We derived a Bayesian ideal observer for detecting coherent motion in random dot kinematograms, where a proportion of dots move coherently and the rest move randomly. We obtained Barlow and Tripathy's classic model as a good approximation to the Bayesian ideal within a certain intermediate range of dot densities. We confirmed previous findings that the ideal observer qualitatively predicts human performance change with increases in dot density, but that the human absolute level of performance is much worse than the ideal. To account for this discrepancy, we propose that humans use generic, general purpose, models of motion. In particular, we impose a prior constraint favoring slow and smooth motion patterns (consistent with the statistics of motion in the natural world). We found that the slow-and-smooth model not only predicts the qualitative pattern of human performance, but also provides a quantitative fit to the absolute level of performance. Most remarkably, the slow-and-smooth model achieved above 70% accuracy in predicting human perception of random motion stimuli. Our analysis shows the Bayesian framework allows derivation of the ideal observer for complex visual stimuli. Human performance on psychophysical tasks may be based on generic models with general prior assumptions, as exemplified by the slow-and-smooth model.

8:30 *1196* Global motion with multiple Gabors - A tool to investigate motion integration across orientation and space

Shin'ya Nishida[1] (nishida@brl.ntt.co.jp), Kaoru Amano[1,2], Mark Edwards[3], David R. Badcock[4]; [1]NTT Communication Science Laboratories, NTT Corporation, 3-1 Morinosato Wakamiya, Atsugi, Kanagawa, 243-0198, Japan, [2]Department of Complexity Science and Engineering, Graduate School of Frontier Sciences, University of Tokyo 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-0882, Japan, [3]School of Psychology, Australian National University, Canberra ACT 0200, Australia, [4]School of Psychology, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia

There are two streams of motion integration research. One, using plaid stimuli, examines how the visual system integrates ambiguous 1D motions across orientations to solve the aperture problem. The other examines how the visual system integrates local motions over space into coherent global motion using stimuli composed of independently moving 2D dots. Both types of motion integration are suggested to take place somewhere between V1 and MT/V5, but it remains open whether 1D motion signals are integrated over space (one-stage integration), or 1D motion signals are integrated locally, then the resulting 2D signals are integrated over space (2-stage integration). To test this, we introduced a novel global motion stimulus comprised of numerous Gabor elements (drifting sine-waves windowed by stationary Gaussians). While the orientations of Gabors were randomly determined, their drifting velocities were made consistent with a given 2D velocity: observers saw a rigid motion of the whole pattern. The global motion remained detectable even when more than half of the Gabor elements were given random 2D velocities (noise). These observations appear to support one-stage integration. However, we also found

that superposition of noise 1D motions on 1D signal motions (which turned the local elements into 2D plaids) severely impaired global motion perception. This implies that local 1D motion integration has priority over global integration, as expected from two-stage integration. Our results suggest that motion integration process has great flexibility, presumably for the purpose of correctly estimating complex optic flows in natural scenes.

Acknowledgment: KA is supported by the Japan Society for the Promotion of Science.

8:45 *1197* **Spatial Interactions in Fast and Slow Motion Mechanisms**

Joseph S Lappin[1] (joe.lappin@vanderbilt.edu), Jeffrey B Nyquist[1], Duje Tadin[1]; [1]Vanderbilt Vision Research Center, Vanderbilt University

Purpose: Visual motion mechanisms exhibit center-surround antagonism. Both psychophysical (Tadin et al., 2003, 2005) and physiological (Pack et al., 2005) experiments have found surround antagonism at high contrasts and spatial summation at low contrasts. These and other correspondences suggest that psychophysically observed surround suppression is a perceptual correlate of center-surround antagonism of MT neurons. MT neurons, however, prefer high velocities and are unresponsive below ~0.5deg/s. Therefore, suppression may vary with velocity. To find out, we quantified spatial characteristics for speeds from 0.06–30deg/s.Method & Results: Duration thresholds for direction discrimination (L/R) were measured for high-contrast Gabor patches of varied sizes, using a high-speed (200Hz) monitor. Duration thresholds decreased rapidly with increasing velocity, with lower thresholds for smaller stimuli. Importantly, surround suppression increased substantially with velocity, and was nonexistent at very slow speed. Slow-speed acuity and spatial summation: Spatial displacement thresholds were substantially better at low speeds in the preceding experiment. Functional specializations of fast and slow motion mechanisms were further studied in additional experiments. Spatial acuities for detecting slow relative motion exhibited spatial summation, improving with both size and contrast. Thresholds for high speeds, however, exhibited spatial antagonism at high contrast.Summary: Visual motion mechanisms have different functional characteristics at different speeds. The change in spatial antagonism with changing velocity seems to reflect changing functional demands associated with maximizing spatial vs. temporal resolution. These results are consistent with the apparent role of area MT in spatial antagonism.

Acknowledgment: Supported by: NIH grant R03-EY015558

9:00 *1198* **HIGH SPATIAL FREQUENCY SUPERIORITY OF MOTION AFTEREFFECT**

Satoshi Shioiri[1] (shioiri@riec.tohoku.ac.jp), Kazumichi Matsumiya[1]; [1]Research Institute of Electrical Communication, Tohoku University

[Purpose]We report a new type of motion aftereffect. The stimulus consists two overlapped sinusoidal gratings with different spatial frequencies. When the two gratings move in the opposite directions one from the other, motion of the low spatial frequency grating is seen. After the exposure to the moving stimulus, however, however, motion aftereffect (MAE) is seen in the opposite direction of unperceived motion of the high spatial frequency grating (high spatial frequency superiority of motion aftereffect). To investigate the underlying mechanism of the phenomenon, we measured MAE duration with variable combinations of spatial frequencies.[Experiment]Adaptation stimulus consisted two drifting gratings with different spatial frequencies, which moved in the opposite directions. The contrast of each grating was 30 times of the threshold contrast. The spatial frequency of one grating was fixed at 0.53 c/deg and the other varied between 0.13 and 2.13 c/deg. After 20 s of adaptation, the observer judged MAE duration in the stationary or the flicker (4 Hz) stimulus of the same gratings, by pressing one of two keys to indicate the disappearance of MAE and the direction of perceived motion. [Results]Stationary test showed high spatial frequency superiority of MAE whereas flicker test showed opposite results, i.e., MAE in the direction opposite to the low spatial frequency drifting grating.[Discussion]The results suggest that there are two motion mechanisms. One is sensitive to low spatial and high temporal frequencies and the other is sensitive to high spatial and low temporal frequencies.

9:15 *1199* **The transition from monocular to binocular vision: An eye-opening illusion of speed.**

Peter Thompson[1] (p.thompson@psych.york.ac.uk); [1]Dept of Psychology, University of York, York, UK.

It has been observed casually that when observing moving traffic from a high building the perceived speed of vehicles increases transiently (and dramatically) when viewing changes from being monocular to binocular. We have attempted to examine this effect in a series of experiments. We have determined that: (1) the illusion is apparent when observing objects moving from a horizontal as well as a vertical view-point; (2) the illusion is seen strongly when vision goes from monocular to binocular – but there is minimal perceived slowing when one eye is closed; (3) the effects are significantly bigger when viewing is initially with the non-dominant eye and then with both eyes; (4) the stronger the eye dominance, the bigger the effect; (5) the effect is of similar size for both left-to-right and right-to-left directions of motion; (6) generally faster speeds give larger effects; (7) although present in foveal vision, it is stronger with peripheral viewing.Speed matching experiments measuring the PSE (by PEST staircase) of pairs of vertical sinusoidal gratings drifting horizontally, one viewed monocularly, the other binocularly, indicate no difference between the perceived speed of monocularly and binocularly viewed grating stimuli over a wide range of speeds. Therefore a difference in speed perception between monocular and binocular viewing does not account for the illusion.Possible explanations of the effect and its similarity to aspects of the flash-lag effect will be discussed.

Visual Memory

8:00 - 9:30 am

Hyatt Ballroom South

Moderator: Yaoda Xu

8:00 *1200* **Is attention drawn to changes in familiar scenes?**

Hacer Uke[1] (hacer@ii.metu.edu.tr), Mary Hayhoe[2]; [1]Middle East Technical University, [2]University of Rochester

The limited bandwidth of attention places tight constraints on visual processing of natural, complex scenes. Although a substantial body of research on change blindness suggests that visual representations of scenes are very sparse, Henderson & Hollingworth (2004) argue that elaborate representations of scenes are built up in long-term memory. If so, such representations might serve as a basis for attracting attention to changed regions of scenes. We examined this hypothesis in an immersive virtual environment where 8 subjects were given time to become familiar with the environment while walking the same path 6 times. Distribution of gaze was examined during familiarization trials, and also following changes in the environment, including appearance, disappearance, movement, or replacement of an object. Results showed that the average duration of fixations on control objects is 534 ms while that on changed objects is 1083 ms for subjects who had 3 familiarization trials in the environment before the changes occurred. Without familiarization, however, fixations on changed objects were no longer than on control objects (645 ms and 729 ms on changed and control objects respectively). Fixations were longest on new or moved objects, and least on replaced or removed objects. These results are consistent with Brockmole et al (2004) with 2D images, and support the hypothesis that we learn the structure of natural scenes over time,

and that attention is attracted by deviations from the normal state. Thus, bottom up attention is defined with respect to learnt representations of scenes.

8:15 *1201* Primacy Effects in Contextual Cueing

Justin A. Junge[1] (justin.junge@yale.edu), Marvin M. Chun[1], Brian J. Scholl[1]; [1]Yale University

Over repeated exposure to particular visual search displays, subjects are able to implicitly extract regularities that then make search more efficient — a phenomenon known as contextual cueing (Chun & Jiang, 1998). Here we explore how the learning involved in contextual cueing is formed, maintained, and updated over training. Implicit learning could be rigid after initial formation, predicting a primacy effect biased toward early evidence. Alternatively, learning could be constantly updated, yielding a recency effect biased toward recent evidence. A third possibility is that the input could be averaged cumulatively, yielding no order effects. During training, subjects were exposed to 18 blocks of (24) predictive context displays, where distractor locations were perfectly correlated with the target location, and also 6 blocks of non-predictive context displays, where the very same contexts were not correlated with particular target locations. Subjects who received the predictive blocks first (followed by the non-predictive blocks) showed robust contextual cueing at a later test. However, no contextual cueing was observed in a different group of subjects who received non-predictive blocks first (followed by the predictive blocks). Since the overall exposure to predictive and non-predictive displays was identical for both groups, the significant difference at test is evidence for a primacy effect in contextual cueing. This links contextual cueing to primacy effects in classical conditioning, high-level causal reasoning (Denis & Ahn, 2001), and temporal visual statistical learning (Catena, Scholl, Isola, & Turk-Browne, under review).

Acknowledgment: Supported by NIH grant EY014193

8:30 *1202* Does Contextual Cueing Guide the Deployment of Attention?

Melina, A. Kunar[1,2] (kunar@search.bwh.harvard.edu), Stephen, J. Flusberg[2], Todd, S. Horowitz[1,2], Jeremy, M. Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham and Women's Hospital

Contextual cueing (CC) experiments show that when visual search displays are repeated, reaction times (RTs) to find a target decrease over time even when observers are not aware of the repetition. In other experiments, observers use information about features, like color, to guide attention to likely target locations. Do observers use implicit memory for the display to guide attention in the same manner in CC tasks? We compared CC effects to standard guidance. Firstly, guidance decreases the slope of RT x Set Size functions. When guidance is perfect (e.g. feature search for a red target among green distractors) slopes will be close to 0 msec/item. In contrast, contextually repeated trials showed little reduction in slope compared to trials that did not repeat context. Secondly, observers can use color to guide attention to multiple target locations. However, with the same training, observers could not prioritize more than two target locations in CC. Thirdly, in standard guided search there is little reduction in guidance if the location of a target on one trial is occupied by a distractor on the next. However, when a distractor appeared in a prior target location in a CC paradigm, a CC benefit was not found. Finally, even with perfect guidance (e.g., in a feature search), we found a small, but reliable additional CC effect. This suggests a contribution from other factors, such as response selection. Overall, the data suggest that the relationship between guidance and CC is weak.

Acknowledgment: Supported by NIMH MH56020

8:45 *1203* Visual working memory and attention in early visual cortex

Shani Offen[1] (shani@cns.nyu.edu), Denis Schluppeck[1,2], David J Heeger[1,2]; [1]Center for Neural Science, New York University, [2]Department of Psychology, New York University

Objective:Does early visual cortex (V1-V3) play a role in maintaining working memory and attention? Methods:Subjects were scanned (3T fMRI, BOLD) while performing each of four tasks designed to probe visual working memory, attention, or both. *Delayed comparison:* A high-contrast grating (randomized orientation and spatial frequency) was presented within an annulus (1-3°) around fixation followed, after a variable delay (1-16s), by a second high-contrast grating with near-threshold change in orientation and spatial frequency. Fixation point color then cued subjects to indicate either the orientation or spatial frequency change. *Cued detection:* Stimuli were nearly identical except the contrast of the final target grating was at detection threshold and subjects indicated its presence or absence. *Detection:* Same as cued detection except the probe and test orientations were chosen independently. *Discrimination:* Stimuli were identical to the detection task except the target had one of two orientations (tilted slightly right or left of vertical), and subjects indicated its orientation.Results:Despite the similarity between the stimuli and tasks, we found a striking difference in cortical activity. Areas V1-V3 exhibited no sustained activity during the delay period for the delayed comparison task (which required working memory for easily visible stimuli), but robust sustained activity for the other three tasks (which all had barely visible targets). Conclusions:The results imply a dissociation between working memory and attention. We hypothesize that attentional selection, critical for scrutinizing stimuli that are barely visible, is implemented by sustained boosting of relevant neuronal signals in early visual cortex.

Acknowledgment: Support contributed by: NEI (R01-EY11794), NIMH (R01-MH69880), NSF GRF, and the Seaver Foundation.

9:00 *1204* Brain mechanisms supporting visual short-term memory for multi-feature objects

Yaoda Xu[1] (yaoda.xu@yale.edu), Marvin M. Chun[1]; [1]Psychology Department, Yale University

Recent brain imaging studies showed that responses in the superior intraparietal sulcus (IPS) correlate with the number of object colors or shapes stored in visual short-term memory (VSTM). Because only single-feature objects were used in previous studies, it was not clear how multi-feature objects are stored. We measured whether superior IPS responses correlate with integrated object representations for which all features are stored or with object representations for which at least one feature is stored. To address this question, we conjoined a set of dissimilar color features with a set of similar shape features, and asked observers to retain such color and shape conjunctions. When both color and shape features are encoded together, behavioral measures yielded a VSTM capacity of about 3 colors and 1 shape. We examined responses in the superior IPS and two visual areas: the lateral occipital complex (LOC), which is involved in shape processing and whose activations also correlate with VSTM capacity for shapes; and area V4, which participates in color perception. Correlating with behavioral performance, V4 responses showed a capacity limit of 3 colors while LOC responses showed a capacity limit of 1 shape, indicating independent storage of color and shape features in these brain areas when both types of features are encoded together in VSTM. Superior IPS responses, interestingly, showed a capacity limit of 3, suggesting that this brain area represents the total number of remembered objects for which at least one feature is stored.

Acknowledgment: Supported by NIH grant EY014193 and NSF grant 0518138

9:15 *1205* **SFS for feature selective maintenance, IPS for simple maintenance in visual working memory**

Masahiro Kawasaki[1] (kawasaki@sk.q.t.u-tokyo.ac.jp), Masataka Watanabe[1], Jiro Okuda[2], Masamichi Sakagami[2]; [1]Department of Quantum Engineering and System Science, Graduate School of Engineering, University of Tokyo, Japan, [2]Brain Science Research Center, Tamagawa University, Research Institute, Tokyo, Japan

Visual working memory (VWM) is known to be a limited capacity system and recent neuroimaging studies have shown that the activations of the frontoparietal network which includes the superior frontal sulcus (SFS) and the intraparietal sulcus (IPS) are sensitive to VWM load (Linden, et al., 2003), although there are cases where subsets of this network are not sensitive under different conditions (Todd&Marois, 2004). In particular, it remains unclear in what conditions SFS is recruited into the network. Here, we focus on the effects of feature selection using multidimensional objects and attempt to dissociate these brain areas, with the use of functional magnetic resonance imaging (fMRI).We conducted a single-probe test of change detection task where sample arrays were presented simultaneously at different locations. The items were defined by colored dynamic random dots, which possess three features; color, shape and motion direction. In feature-selection condition, the stimulus arrays always varied in each feature dimension and the subjects were required to memorize only one relevant feature, but ignore the others. On the other hand, in no-feature-selection condition, irrelevant feature dimensions were held constant; "white" for color, "square" for shape and "down" for direction. As a result of the fMRI data analysis, the activation of IPS was sensitive to VWM load in both conditions. In contrast, SFS was load sensitive only in the feature-selection condition. These results suggest that the SFS plays an important role in feature selective maintenance, whereas the IPS may be associated to simple maintenance.

Acknowledgment: M.W. is supported by Grant-in-Aid for Scientific Research on Priority Areas -Higher-Order Brain Functions- from The Ministry of Education, Culture, Sports, Science and Technology (17022015)

Frontier Techniques

10:00 - 11:30 am

Hyatt Ballroom North

Moderator: Stanley Klein

10:00 *1206* **Using multifocal VEPs to extract retinotopic sources of activity**

Justin Ales[1] (ales@berkeley.edu), Sangita Dandekar[1], Thom Carney[1,2], Stanley A. Klein[1]; [1]Vision Science Graduate Group, School of Optometry, UC Berkeley, CA, [2]Neurometrics Institute, Oakland CA

We used multifocal VEPs to investigate retinotopically organized visual areas by localizing the sources of activation elicited from a high density multifocal stimulus. The VEP stimuli consisted of a dartboard pattern containing 192 checkerboard patches. The patches were arranged in 8 cortically scaled rings of 24 patches each. The stimulus extended from .5 to 8.5 degrees of eccentricity. Each patch was modulated according to a binary m-sequence and was scaled to activate about 15 mm^2 of primary cortex. Each subject viewed the stimulus wearing a cap with 96 recording electrodes. The evoked scalp topographies were consistent with the known general configuration of early visual areas. We then decomposed the data using singular value decomposition. The first two temporal components accounted for 80% of the variance. However, the components extracted by singular value decomposition do not necessarily correspond to physiological sources of activity. In order to find plausible sources we explored the space spanned by these components by taking linear combinations. We then used various source localization algorithms on each of these combinations, including cortically constrained methods. We also devised a source localization procedure that constrained sources to follow the known retinotopic layout of our stimulus. We compared the sources from each algorithm with standard fMRI retinotopic mapping data from the same subjects. When the proper components were chosen we found an agreement between the EEG and the fMRI. This demonstrates that EEG in combination with fMRI can be used to find fast temporal information from early visual areas.

Acknowledgment: NIH EY015825, NIH T32 EY07

10:15 *1207* **Identification of the Cortical Sources of the Steady-State Visual Evoked Potential: A VEP-fMRI Co-registration study**

Francesco Di Russo[1,2] (fdirusso@iusm.it), Sabrina Pitzalis[2], Alessandra Stella[1], Donatella Spinelli[1,2], Steven A. Hillyard[3]; [1]Dept. of Education in Sports and Human Movement, University of Motor Sciences (IUSM) -Rome, Italy, [2]Santa Lucia Foundation IRCCS, Rome - Italy, [3]Dept. of Neurosciences, UCSD, La Jolla - California USA

This study aimed to characterize the neural generators of the steady-state visual evoked potential (SSVEP) to 6 Hz pattern-reversal gratings. Multichannel scalp recordings (64 channels)of SSVEPs and dipole modeling techniques were combined with functional magnetic resonance imaging (fMRI) and retinotopic mapping in order to estimate the locations of the cortical sources giving rise to second harmonic of SSVEP. Dipole locations were seeded to visual cortical areas in which fMRI activations were elicited by the same stimuli. The results provide strong evidence that the major contribution to the SSVEP arises from activity in the primary visual cortex (area V1) and in motion sensitive area (MT/V5). Further contribution could be accounted for by dipoles that were in close proximity to fMRI activations in the the transverse parietal sulcus, ventral occipital areas VP and V4v and dorsal occipital areas V3A/V7. The present results showed that is possible decompose the steady-state VEP waveforms in a series of cortical components on the basis of their phase. Present results provide a detailed spatio-temporal profile of the cortical origins of the SSVEP, which should enhance its utility in both clinical and basic studies of visual-perceptual processing.

URL: www.webalice.it/fdirusso/FDR

10:30 *1208* **Spatial Localization with 3T GE BOLD: Dependence on Experiment Design and Resolution**

Cheryl A Olman[1] (cheryl@cmrr.umn.edu), Souheil Inati[2], David J Heeger[2]; [1]Departments of Psychology and Radiology, University of Minnesota, Minneapolis, MN, USA, [2]Department of Psychology and Center for Neural Science, New York University, New York, NY, USA

We compared two types of visual localizer to investigate the spatial accuracy of gradient echo BOLD fMRI at 3T. The "single-condition" localizer presented two annuli of flickering checkerboard (the target stimulus) against a mean gray background in block alternation (target for 8s, blank for 8s). The "differential" localizer comprised block alternation between the target stimulus and a checkerboard filling the complement of the visual field (i.e. everywhere except the target annuli). Each localizer was used to select a region of interest (ROI) at each of two spatial resolutions. Because a differential protocol minimizes blurring attributable to large pial and intracortical veins, we expected the differential localizer to identify a subset of the voxels selected by the single-condition localizer. However, at low-resolution (3mm isotropic voxels), a surprisingly large number of voxels selected by the differential localizer were not selected by the single condition localizer. *In fact, many voxels that responded positively to the stimulus in the differential protocol responded negatively to the stimulus in the single-condition protocol.* Estimating the hemodynamic impulse response function (HIRF) and mean-normalized variance of individual voxels demonstrated that the localization errors could be attributed to voxels near large veins. A much smaller percentage of the voxels in ROIs defined at high-resolution (1.2mm) exhibited these errors. These results reveal a distinct advantage to fMRI measurements at high spatial resolution, in spite of the lower signal-

to-noise ratio, above and beyond the expected improvement in spatial accuracy due to finer spatial sampling.

Acknowledgment: McKnight Foundation, Seaver Foundation

10:45 *1209* An Adaptive Method for Estimating Criterion Sensitivity (*d'*) Levels in Yes/No Tasks

Luis A Lesmes[1] (lu@salk.edu), Zhong-Lin Lu[2], Nina T Tran[2], Barbara A Dosher[3], Thomas D Albright[1,4]; [1]Vision Center Laboratory, Salk Institute for Biological Studies, [2]Laboratory of Brain Processes, University of Southern California, [3]Memory, Attention, and Performance Laboratory, University of California-Irvine, [4]Howard Hughes Medical Institute

Compared to those available for forced-choice tasks, there are few adaptive methods for estimating thresholds in *Yes/No* (*YN*) tasks. Even existing methods[1,2], aimed at estimating thresholds for specific *Yes* rates (e.g., 50%), are unreliable, due to contamination of *Yes* rate by response bias. We present a novel adaptive procedure (the "*quick YN*" or "*qYN*" method), to estimate thresholds at levels of criterion sensitivity (*d'*), rather than *Yes* rate. The method uses Bayesian estimation and a minimum entropy criterion[3,4,5] to place stimuli at signal intensities providing the most information about three parameters: (1) the observer's response bias,â; (2) the signal intensity, á, corresponding to *d'*=1; and (3) the steepness of the *d'* psychometric function, ã. Using simulations and a psychophysical experiment, we compared threshold estimates obtained in a *YN* task, using the *qYN* and the method of constant stimuli (*MCS*). Simulations showed that, for false-alarm (*FA*) rates from 10-50%, the *qYN* needed only 25 trials to provide accurate (bias <.5*dB*) and precise (*sd* < 2.5*dB*) estimates of *d'*=1. For *FA*=1%, *d'* estimates were biased by 2*dB*. For all *FA* rates, the number of *MCS* trials needed to match the *qYN*'s precision was roughly five-fold. Psychophysical results showed that *qYN* threshold estimates (*sd* < 2.5*dB*), deviated little from *MCS* estimates (<1*dB*). The *qYN* exhibits strong advantages over previous methods. Most notably, by measuring (and accounting for) response bias, the *qYN* estimates thresholds at criterion sensitivities with reduced data collection.

1. Green (1993)2. Kaernbach (1990)3. Cobo-Lewis (1996) 4. Kontsevich & Tyler (1999) 5. Lesmes et al (2005)

URL: lobes.usc.edu/qMethods

11:00 *1210* Hold it there and let's have a look: extracting shift-invariance templates and sub-template features from signal-clamped classification images

Bosco S. Tjan[1,2] (btjan@usc.edu), Anirvan S. Nandy[1]; [1]Department of Psychology, University of Southern California, [2]Neuroscience Graduate Program, University of Southern California

Invariance or constancy is a hallmark of visual processing. Linear techniques such as classification images and spike-triggered averaging are thought to be incapable of recovering the front-end template or receptive-field structure of a higher-order visual mechanism whose response may be invariant to the position, size, or orientation of a target. Using the max-pooling property of a typical uncertainty model, we show analytically, in simulations, and with human experiments (single-letter identification in fovea and periphery, with and without positional uncertainty) that the effect of intrinsic uncertainty (i.e. invariance) can be reduced or even eliminated by embedding a signal of sufficient strength in the masking noise of a classification-image experiment. We refer to this technique as "signal clamping". We argue against combining the classification images across stimulus-response categories as is typically done. We show that the signal-clamped classification images from the error trials contain a clear high-contrast image that is negatively correlated with the perceptual template associated with the presented signal; they also contain a low-contrast "haze" that is positively correlated with the superposition of all the templates associated with the erroneous response. In the case of positional uncertainty, we show that this "haze" provides an estimate of the spatial extent of the uncertainty. With the effect of intrinsic uncertainty significantly reduced by signal clamping, we further show that a covariance analysis can be applied to different regions of a classification image to reveal the elementary features that are the components of the perceptual template seen in the classification image.

Acknowledgment: Supported by: NIH/NEI R03-EY016391

11:15 *1211* Imaging Fast Intrinsic Optical Signals for Studies of Retinal Function

John S. George[1] (jsg@lanl.gov), Xin-cheng Yao[1]; [1]Biological and Quantum Physics, Los Alamos National Laboratory

Multi-electrode arrays extend traditional single-unit electrophysiology techniques, allowing simultaneous study of dozens of units; however, they sample a limited number of neurons on the retinal surface. Here we report imaging fast intrinsic optical responses evoked by light flashes in isolated frog retina, using a CCD camera operated at high frame rates (>100fps). The method holds for promise of high-resolution dynamic functional imaging of complete populations of cells in 3D. Optical recordings employed NIR illumination in transmitted, darkfield or cross-polarized configurations. Flashes or steps from a white LED stimulated a limited region of retina. Observed NIR response dynamics closely tracked the integral of electrophysiological activity. CCD image sequences disclose multiple response components with negative- and positive-going signals juxtaposed in a consistent spatial organization, initially limited to the region activated by the flash. Fractional responses exceeded 10% in some cases. Fast negative-going responses are correlated to a-wave of the retinal ERG and probably reflect the activation of photoreceptors. Positive-going responses are related to the b-wave, and appear to reflect the activation of ON (and OFF) bipolar cells and other postsynaptic neurons. We often observed a relatively enhanced bipolar response near the perimeter of the stimulated region as well as diffuse activation extending up to 100 microns into surrounding tissue. We observed differences in the polarity and time-course of NIR responses as a function of depth. Spatial and temporal structure in the image sequences indicates that we captured patterns of activation in extended populations of individual neurons in single passes.

Acknowledgment: Supported by the Artificial Retina Project, OBER, US DOE

Attention: Costs of Divided Attention and Inattention

10:00 - 11:45 am

Hyatt Ballroom South

Moderator: Brian Scholl

10:00 *1212* When Sustained Attention Impairs Contrast Sensitivity

Marisa Carrasco[1,2] (marisa.carrasco@nyu.edu), Sam Ling[1]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Background: The vast majority of behavioral and neurophysiological studies have shown that attention enhances stimulus representations. But can this enhancement be held indefinitely? Here we report that, over time, sustained (endogenous) attention can actually impair contrast sensitivity. We assessed the time course of attention's effects on contrast sensitivity. If attention boosts stimulus strength, the strengthened stimulus representation may result in stronger selective adaptation. **Methods:** Observers adapted to 4 vertical Gabors (4cpd, counter-phase flickering at 10 Hz, 4° eccentricity), which were presented for varying duration (50-8000ms). Before adapting, observers were shown either a Sustained or Neutral cue. These cues instructed observers either to focus their sustained attention towards one of the adaptor stimuli at an upcoming target location (Sustained), or to distribute attention to all four locations (Neutral). Following

a brief ISI (100 ms), observers performed a 2AFC orientation discrimination task on a tilted test Gabor (±2°) appearing at one of four iso-eccentric (4°) locations. Contrast thresholds for the test Gabor were measured using a staircase procedure for each adaptation duration and cue type. **Results:** For all observers, in the Neutral condition, contrast sensitivity diminished over time; this finding can be explained by contrast adaptation. More interestingly, our results show that sustained attention initially enhances contrast sensitivity (200-500 ms), but as adaptation duration increases, sustained attention leads to impaired contrast sensitivity compared to the neutral condition (>3000 ms). Given that attention boosts signal strength, we interpret these findings as a consequence of adaptation to an attentionally-enhanced stimulus.

10:15 *1213* Can we select two colors simultaneously?

Liqiang Huang[1] (lhuang@princeton.edu), Hal Pashler[2], Anne Treisman[1]; [1]Princeton University, [2]University of California, San Diego

Previous research on visual search has shown that searching for a target that could be in one of two colors can be very efficient so long as the target and distractor colors are linearly separable (Bauer, Jolicoeur & Cowan, 1996). Thus search for a <green or blue> target among red and yellow distractors is more efficient than to search for a <amber> target. However, in those studies the observer was never required to select two target colors from the display simultaneously. Here we employ an "attention to structure" task in which participants make a judgment about the shape of an area defined by one or two colors embedded among two other colors. We find that a visual structure comprised of <green and blue> items among red and yellow items is less readily perceived than a structure composed of <amber> items. This clearly shows that it is difficult to select two colors simultaneously even when they are linearly separable from all other colors present. "Attention to structure" tasks can uncover important aspects of visual attention that are not revealed in the visual search task.

10:30 *1214* Spatiotemporal cues for tracking objects through occlusion

Steven L. Franconeri[1] (steve@psych.ubc.ca), Zenon W. Pylyshyn[2], Brian J. Scholl[3]; [1]University of British Columbia, [2]Rutgers University, [3]Yale University

As we move about the world, and objects in the world move relative to us, objects constantly move in and out of view as they are occluded by other objects. How does the visual system maintain attention on objects of interest, given such disruptions? To explore the spatiotemporal cues used to link the pre- and post-occlusion views of objects, we asked observers to track a set of moving objects that frequently passed behind static vertical occluders, as we manipulated each object's exit position. Experiment 1 tested whether linking the two views relies on memory for the object's location. When objects exited occluders higher or lower than expected, tracking performance dropped, suggesting that linking the two object views relies on a location 'marker' at the site of disappearance. In Experiment 2, performance was better when objects exited closer to the initial entry location, rather than their expected extrapolated location, suggesting that the marker is not placed at the extrapolated position. In Experiment 3, tracking performance improved when objects reappeared from occluder centers, compared to at edges, again suggesting that the marker is placed close to the initial point of occlusion. Together, these results suggest that when an object is occluded, the occlusion location is a critical factor in linking pre- and post-occlusion views, but not the extrapolated exit point, or even rudimentary elements of scene structure like the edges of the occluder. This simple trick could underlie much of our perception of persisting objecthood when an object disappears from view.

Acknowledgment: SLF was supported by a Killam Postdoctoral Fellowship, ZWP by NIMH Grant 1R01-MH60924, and BJS by NSF #0132444

10:45 *1215* Is the ability to track multiple objects compromised by amblyopia?

Dennis M. Levi[1] (dlevi@berkeley.edu), Srimant P. Tripathy[2]; [1]School of Optometry, University of California, Berkeley, CA 94720-2020, [2]Dept. of Optometry, University of Bradford, Richmond Road, Bradford BD7 1DP, United Kingdom

Amblyopia results in a severe loss of positional information and in the ability to accurately enumerate objects (Sharma et al, 2000, Nat. Neurosci., 3, 496-501). In this study, we asked whether amblyopia also disrupts the ability to track a near-threshold change in trajectory of a single target amongst multiple targets. In the first experiment we examined the precision for detecting a deviation in the linear motion trajectory of a dot by measuring deviation thresholds as a function of the number of moving trajectories (T). As in normal observers, we found that in both eyes of amblyopes, threshold increases steeply as T increases from 1 to 4. Surprisingly, for T = 1 to 4, thresholds were essentially identical in both eyes of the amblyopes, and were similar to those of normal observers. To test whether the motion system is 'spared' in amblyopia, a second experiment measured the precision for detecting a deviation in the orientation of a static bilinear ?trajectory? by again measuring deviation thresholds (i.e., angle discrimination) as a function of the number of oriented line ?trajectories? (T). Relative to the non-amblyopic eye, amblyopes show a marked threshold elevation for a static target when T = 1. However, thresholds increased with T with the same slope as in the preferred eye, and that of the normal controls. We conclude that while amblyopia disrupts static angle discrimination, amblyopic dynamic deviation detection thresholds are normal; amblyopes are able to effectively monitor approximately one near-threshold trajectory (Tripathy & Barrett, 2004, J Vis., 4, 1020-1043).

Acknowledgment: Dennis Levi was supported by RO1EY01728 from the National Eye Institute

11:00 *1216* Hemifield Independence in Visual Crowding

Ramakrishna Chakravarthi[1] (chakrava@wjh.harvard.edu), Patrick Cavanagh[1]; [1]Vision Sciences Lab, Department of Psychology, Harvard University

We presented a set of three T's arranged in a line along a radius from fixation and subjects reported the orientation of the central T (eccentricity 7.5 degrees). This radial array was placed along one of the four obliques centered in each quadrant of the visual field. We determined the target-distracter separation at which the identification of target orientation was 85%. The average of this threshold distance for 7 subjects was 3.5 degrees. Keeping the target-distracter separation fixed at their individually determined value for each subject, we then presented two crowding arrays simultaneously in adjacent quadrants situated either both on the same side of the vertical meridian (unilateral presentation) or one on each side (bilateral presentation). When the two arrays were presented, subjects had to report only one of the targets indicated by a cue that followed the offset of the arrays. Adding the second array did not significantly affect performance when presented in opposite hemifields (80% mean accuracy vs. 85% with one array). However, when the two arrays were presented within one hemifield, performance dropped significantly (to 73%, $t(6) = 2.67$, $p<0.05$). This bilateral versus unilateral difference was not found for identification of uncrowded letters at the same eccentricity. A similar unilateral disadvantage has been reported for multiple tracking tasks when presented within the same hemifield (Alvarez and Cavanagh, 2005). Our results suggest that crowding might also be bound by hemifield limits on attentional resources.

11:15 *1217* Whole versus partial report: When attention does not blink

Mark R. Nieuwenstein[1] (nieuwe@mit.edu), Mary C. Potter[1]; [1]Massachusetts Institute of Technology

Many common tasks such as reading and visual search require the rapid updating of working memory with successive selections of visual inputs. This situation has been mimicked in the psychological laboratory using

partial report procedures that require observers to identify two targets (T1 and T2) embedded in a sequence of distractors. The striking outcome from these studies is that memory for T2 is often poor when T2 is presented within less than 500 ms of T1, an effect known as the attentional blink (AB). Previous work shows that the failure to recall T2 can be prevented by precuing the target, suggesting that the allocation of attention to T2 is delayed during the AB (Nieuwenstein, Chun, Van der Lubbe & Hooge, 2005). Here, we examined whether the cause of this delay lies in selecting or encoding of T1. We presented sequences of six letters and asked observers to report either as many letters as they could (whole report), or only two letters presented in a particular color (partial report). The results showed a substantial AB for T2 report in partial report, while report of the corresponding letter was relatively accurate in whole report. A similar effect was observed in a second experiment in which selection for partial report was based on letter-identity. These findings show that the delay in selecting targets presented during the AB is caused by selection, not encoding, of T1. Nieuwenstein, M.R., Chun, M.M., Van der Lubbe, R.H.J., & Hooge, I.T.C. (2005). JEP:HPP.

Acknowledgment: Grant MH47432 from the National Institute of Mental Health

11:30 *1218* Effects of Executive Functioning on Visual Search

Matthew S. Peterson[1] (mpeters2@gmu.edu), Melissa R. Beck[2], Jason H. Wong[1]; [1]George Mason University, [2]Naval Research Laboratory

Concurrent working memory tasks can degrade search efficiency when they are spatial in nature or require central executive processing (Woodman & Luck, 2004; Oh & Kim, 2004; Han & Kim, 2004). We investigated the role of executive functioning in visual search by tracking the eyes of subjects while they performed a concurrent auditory working memory task. The secondary auditory task required subjects to keep track of two tones: a sine and square wave with the same fundamental frequency presented monaurally. The tones occurred at pseudo-random intervals, and a staircase method was used to adjust the delay between the tones so that accuracy on the secondary tone task was around 80%. Response times and error rates for the search task were higher in the dual-task condition compared to the search-only condition, indicating that the secondary task interfered with visual search. The longer response times were not due to increased gaze durations, but rather to an increased number of gazes. In the dual-task condition, subjects were more likely to examine a target and then continue searching, suggesting that the secondary task caused subjects to suffer from inattentional blindness. However, an analysis of gaze durations indicates that this inattentional blindness is the result of an inability to inhibit queued shifts of attention. That is, occupying executive control caused shifts of attention to be executed before item processing was complete, which led to the increased number of gazes in the task. Executive control appears to be directly tied into this inhibition process.

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