Vision Sciences Society

8th Annual Meeting
May 9-14, 2008
Naples Grande Resort & Club
Naples, Florida

Program and Abstracts cover design by Emily Ward
T-shirt and tote bag design by Jeremy Wolfe

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Meeting Schedule

Friday, May 9

11:00 am - 8:30 pm	Registration Open	*Royal Palm Foyer*
1:00 – 3:00 pm	Symposia Session 1	*Royal Palm 4, Royal Palm 5, Royal Palm 6-8, and Orchid 1*
3:00 - 3:30 pm	Coffee & Beverages	*Royal Palm Foyer*
3:30 - 5:30 pm	Symposia Session 2	*Royal Palm 4, Royal Palm 5, Royal Palm 6-8, and Orchid 1*
5:30 – 7:30 pm	Opening Night Reception	*Vista Ballroom, Sunset Deck, Vista Deck*
5:30 – 8:30 pm	Evening Poster Session	*Vista Ballroom*

Saturday, May 10

7:30 am - 6:30 pm	Registration Open	*Royal Palm Foyer*
8:00 am - 8:30 pm	Coffee	*Royal Palm Foyer*
8:30 am – 12:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
8:30 am – 12:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8, Orchid Ballroom*
8:30 am – 6:30 pm	Exhibits Open	*Orchid Ballroom*
12:30 - 2:30 pm	Lunch Break	*Grab a lunch and head for the Beach! **
2:30 – 6:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
2:30 – 6:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8, Orchid Ballroom*
4:00 - 4:30 pm	Coffee & Beverages	*Royal Palm Foyer*
7:00 – 8:30 pm	Keynote and Awards Ceremony	*Royal Palm Ballroom 4-5*

Sunday, May 11

7:30 am – 6:30 pm	Registration Open	*Royal Palm Foyer*
8:00 am - 8:30 pm	Coffee	*Royal Palm Foyer*
8:30 am - 12:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
8:30 am – 12:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8, Orchid Ballroom*
8:30 am – 6:30 pm	Exhibits Open	*Orchid Ballroom*
12:30 - 2:30 pm	Lunch Break	*Grab a lunch and head for the Beach! **
2:30 – 6:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
2:30 – 6:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8, Orchid Ballroom*
4:00 – 4:30 pm	Coffee & Beverages	*Royal Palm Foyer*

Monday, May 12

7:30 am – 12:30 pm	Registration Open	*Royal Palm Foyer*
8:00 am - 8:30 pm	Coffee Service	*Royal Palm Foyer*
8:30 am - 12:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
8:30 am – 12:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8, Orchid Ballroom*
8:30 am – 12:30 pm	Exhibits Open	*Orchid Ballroom*
12:45 - 1:30 pm	Business Meeting	*Royal Palm Ballroom*
1:30 - 6:30 pm	Afternoon Break	*Grab a lunch and head for the Beach! **
6:30 – 8:30 pm	Demo Night BBQ	*Vista Ballroom, Sunset Deck, Vista Deck*
7:30 – 9:30 pm	Demo Night Demos	*Royal Foyer, Acacia Meeting Rooms*

** You can purchase a "grab-and-go" lunch in the Royal Palm Foyer or on the Sunset Deck*

Tuesday, May 13

7:30 am – 6:30 pm	Registration Open	*Royal Palm Foyer*
8:00 am - 8:30 pm	Coffee	*Royal Palm Foyer*
8:30 am - 12:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
8:30 am – 12:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8, Orchid Ballroom*
8:30 am – 6:30 pm	Exhibits Open	*Orchid Ballroom*
12:30 - 2:30 pm	Lunch Break	*Grab a lunch and head for the Beach! **
2:30 – 6:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
2:30 – 6:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8, Orchid Ballroom*
4:00 – 4:30 pm	Coffee & Beverages	*Royal Palm Foyer*
9:30 pm –1:30 am	Club Vision	*Vista Ballrooms*

Wednesday, May 14

7:30 am – 12:30 pm	Registration Open	*Royal Palm Foyer*
8:00 am - 8:30 pm	Coffee	*Royal Palm Foyer*
8:30 am - 12:30 pm	Poster Sessions	*Royal Palm 1-3, Royal Palm 6-8*
8:30 am – 12:15 pm	Talk Sessions	*Royal Palm Ballroom 4-5 and Vista Ballroom*
12:30 pm	Meeting Ends	

** You can purchase a "grab-and-go" lunch in the Royal Palm Foyer or on the Sunset Deck*

New Abstract Numbering System

A new abstract numbering system has been implemented for this year that assigns a unique 4 to 5 digit number to each abstract based on when and where it is to be presented. The fomat of the new abstract numbering is AB.CD where the digits before the period indicate WHEN the presentation is given, while the digits after the period indicate WHERE. (A is the day, B is the time period, C is the room and D is the presentation number)

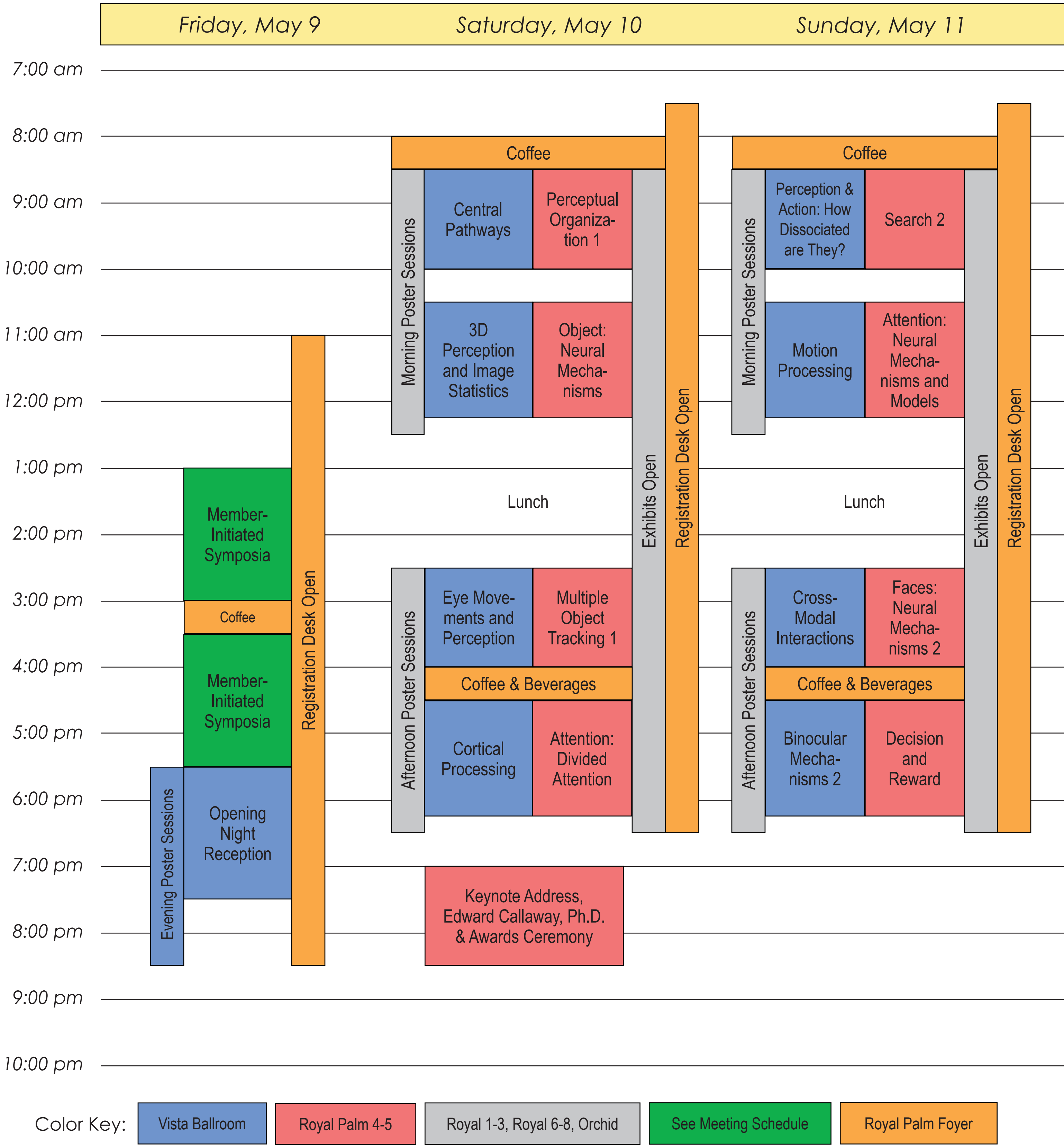
First Digit - Day (A)		**Second Digit - Time Period (B)**		**Third Digit - Room (C)**		**Fourth/Fifth Digits - Number (D)**	
1	Friday	1	Early AM talk session	1	Vista Ballroom	1, 2, 3...	For talks
2	Saturday	2	Late AM talk session	2	Royal Palm 4-5	01, 02, 03...	For posters
3	Sunday	3	AM poster session	3	Royal Palm 1-3		
4	Monday	4	Early PM talk session	4	Royal Palm 6-8		
5	Tuesday	5	Late PM talk session	5	Orchid Ballroom		
6	Wednesday	6	PM poster session				

Examples:

21.16 Saturday, early AM talk, in Vista Ballroom, 6th talk
36.513 Sunday, PM poster, in Orchid Ballroom, poster board 13
53.306 Tuesday, AM poster, in Royal Palm 1-3, poster board 6

Note: 2 digits after the period for talks, 3 digits after the period for posters. With a little learning, the hope is that the numbering system will be an efficient guide to finding each presentation.

Schedule-at-a-Glance



Friday, May 9

- Member-Initiated Symposia
- Coffee
- Member-Initiated Symposia
- Opening Night Reception
- Evening Poster Sessions
- Registration Desk Open

Saturday, May 10

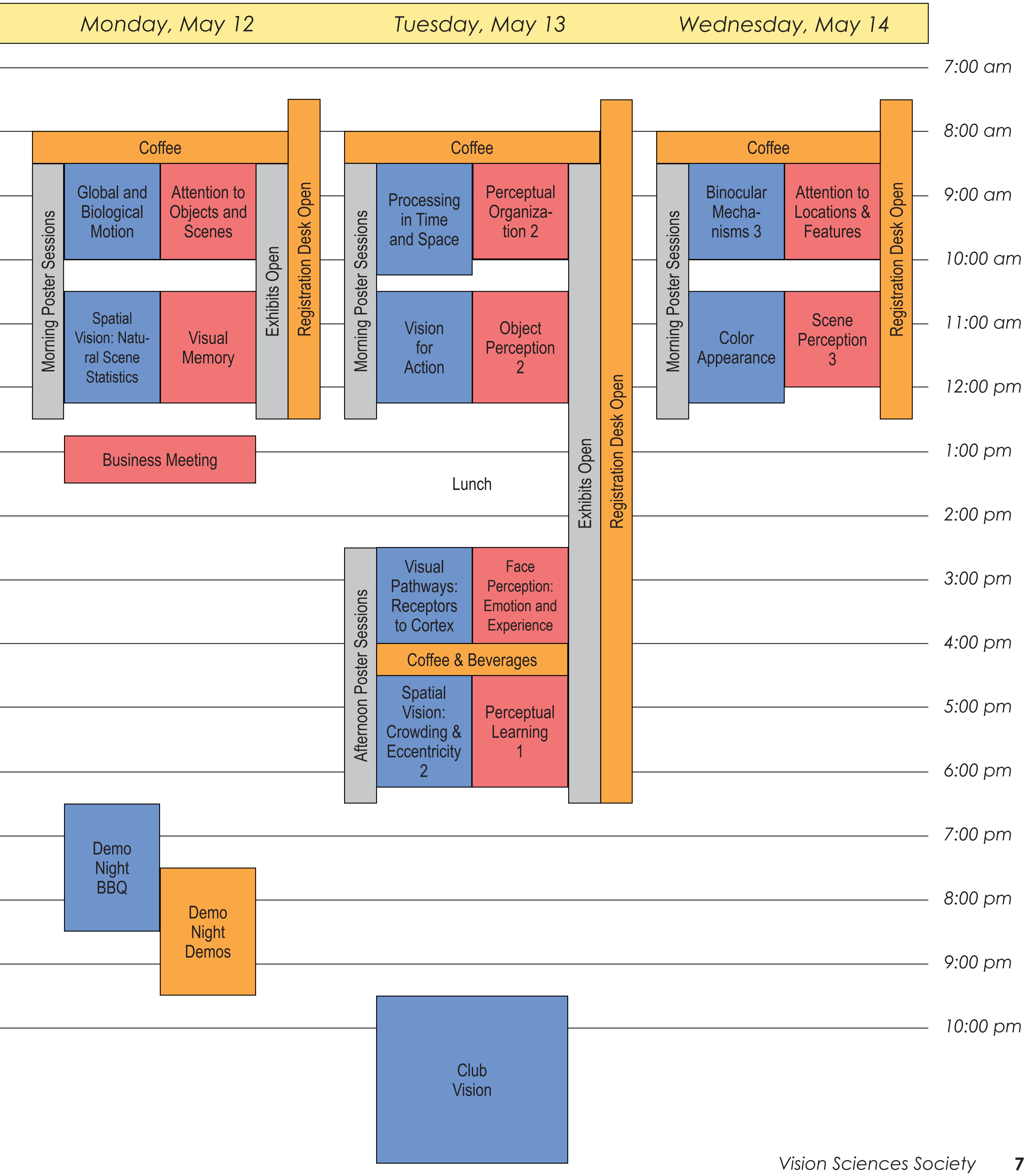
- Coffee
- Morning Poster Sessions
- Central Pathways
- Perceptual Organization 1
- 3D Perception and Image Statistics
- Object: Neural Mechanisms
- Lunch
- Afternoon Poster Sessions
- Eye Movements and Perception
- Multiple Object Tracking 1
- Coffee & Beverages
- Cortical Processing
- Attention: Divided Attention
- Keynote Address, Edward Callaway, Ph.D. & Awards Ceremony
- Exhibits Open
- Registration Desk Open

Sunday, May 11

- Coffee
- Morning Poster Sessions
- Perception & Action: How Dissociated are They?
- Search 2
- Motion Processing
- Attention: Neural Mechanisms and Models
- Lunch
- Afternoon Poster Sessions
- Cross-Modal Interactions
- Faces: Neural Mechanisms 2
- Coffee & Beverages
- Binocular Mechanisms 2
- Decision and Reward
- Exhibits Open
- Registration Desk Open

Color Key:

- 🟦 Vista Ballroom
- 🟥 Royal Palm 4-5
- ⬜ Royal 1-3, Royal 6-8, Orchid
- 🟩 See Meeting Schedule
- 🟧 Royal Palm Foyer



Monday, May 12

- Coffee
- Morning Poster Sessions
- Global and Biological Motion
- Attention to Objects and Scenes
- Spatial Vision: Natural Scene Statistics
- Visual Memory
- Exhibits Open
- Registration Desk Open
- Business Meeting
- Demo Night BBQ
- Demo Night Demos

Tuesday, May 13

- Coffee
- Morning Poster Sessions
- Processing in Time and Space
- Perceptual Organization 2
- Vision for Action
- Object Perception 2
- Lunch
- Afternoon Poster Sessions
- Visual Pathways: Receptors to Cortex
- Face Perception: Emotion and Experience
- Coffee & Beverages
- Spatial Vision: Crowding & Eccentricity 2
- Perceptual Learning 1
- Exhibits Open
- Registration Desk Open
- Club Vision

Wednesday, May 14

- Coffee
- Morning Poster Sessions
- Binocular Mechanisms 3
- Attention to Locations & Features
- Color Appearance
- Scene Perception 3
- Registration Desk Open

Poster Schedule

Friday Afternoon, May 9

Setup: 5:15 -5:30 pm
Session: 5:30 - 8:30 pm
Room: Vista Ballroom
- Attention: Selection over Time
- Motion: Integration, Flow, and Depth
- Object Perception: Neural Mechanisms
- Perception and Action: Hand Movements

Take down: 8:30 - 8:45 pm

Saturday Morning, May 10

Setup: 8:15 - 8:30 am
Session: 8:30 am - 12:30 pm
Room: Royal Palm Ballroom 1-3
- Binocular Mechanisms 1
- Eye Movements, Search and Attention
- Motion: Higher Mechanisms and Illusions

Room: Royal Palm Ballroom 6-8
- Attention: Selection and Modulation 1
- Faces: Inversion and Viewpoint Effects
- Multisensory Processing: Low Level

Room: Orchid Ballroom
- Faces: Learning and Expertise
- Faces: Lifespan Development
- Visual Working Memory 1

Take down: 12:30 - 12:45 pm

Saturday Afternoon, May 10

Setup: 2:15 - 2:30 pm
Session: 2:30 - 6:30 pm
Room: Royal Palm Ballroom 1-3
- Binocular Rivalry and Integration 1
- Faces: Other-race Effects
- Spatial Vision: Mechanisms 1

Room: Royal Palm Ballroom 6-8
- Lightness, Brightness and Luminance
- Perception and Action: Reaching and Grasping
- Search 1

Room: Orchid Ballroom
- Scene Perception 1
- Spatial Vision: Natural Images and Texture
- Temporal Processing and Dynamics

Take down: 6:30 - 6:45 pm

Sunday Morning, May 11

Setup: 8:15 - 8:30 am
Session: 8:30 am - 12:30 pm
Room: Royal Palm Ballroom 1-3
- Faces: Neural Mechanisms 1
- Perceptual Development across the Lifespan
- Spatial Vision: Crowding and Eccentricity 1

Room: Royal Palm Ballroom 6-8
- 3D Pictorial Cues
- Attention: Inattentional Blindness and Change Detection
- Perceptual Learning 2

Room: Orchid Ballroom
- Higher Cortical Processing
- Multiple Object Tracking 2
- Object Perception: Recognition and Categorization

Take down: 12:30 - 12:45 pm

Sunday Afternoon, May 11

Setup: 2:15 - 2:30 pm
Session: 2:30 - 6:30 pm
Room: Royal Palm Ballroom 1-3
- Attention: Object-based Selection
- Color Perception
- Perceptual Organization: Contours

Room: Royal Palm Ballroom 6-8
- Motion: Space and Speed
- Perception and Action: Goal Directed Movements
- Reading

Room: Orchid Ballroom
- Eye Movements
- Object Perception 1
- Smooth Pursuit and Perception

Take down: 6:30 - 6:45 pm

Monday Morning, May 12

Setup: 8:15 - 8:30 am
Session: 8:30 am - 12:30 pm
Room: Royal Palm Ballroom 1-3
- Faces: Emotion
- Perceptual Organization: 2D Shape
- Scene Perception 2

Room: Royal Palm Ballroom 6-8
- 3D Space Perception
- Attention: Crossmodal and Cognitive Effects
- Attention: Selection and Modulation 2

Room: Orchid Ballroom
- Binocular Rivalry and Integration 2
- Receptive Fields and Maps

Take down: 12:30 - 12:45 pm

Tuesday Morning, May 13

Setup: 8:15 - 8:30 am
Session: 8:30 am - 12:30 pm
Room: Royal Palm Ballroom 1-3
  3D Stereopsis and Motion
  Attention: Interactions with Memory
  Attention: Theoretical and Computational Models
Room: Royal Palm Ballroom 6-8
  Faces: Wholes, Part, Configurations and Features
  Motion: Biological Motion
Room: Orchid Ballroom
  Saccadic Eye Movements
  Spatial Vision: Mechanisms 2
Take down: 12:30 - 12:45 pm

Tuesday Afternoon, May 13

Setup: 2:15 - 2:30 pm
Session: 2:30 am - 6:30 pm
Room: Royal Palm Ballroom 1-3
  Attention: Costs of Divided Attention
  Attention: Neural Mechanisms
  Perceptual Organization: Grouping and Segmentation
Room: Royal Palm Ballroom 6-8
  Motion: Spatial Interactions and Aftereffects
  Perception and Action: New Issues
Room: Orchid Ballroom
  Multisensory Processing: High Level
  Search 3
Take down: 6:30 - 6:45 pm

Wednesday Morning, May 14

Setup: 8:15 - 8:30 am
Session: 8:30 am - 12:30 pm
Room: Royal Palm Ballroom 1-3
  Attention: Inhibition and Capture
  Perceptual Learning 3
Room: Royal Palm Ballroom 6-8
  Faces: Adaptation and Context
  Perception and Action: Locomotion and Navigation
  Visual Working Memory 2
Take down: 12:30 - 12:45 pm

Poster Information

The Friday evening poster session is located in the Vista Ballroom (Lobby level). All other poster sessions are held on the Ballroom level in Royal Ballroom 1-3, Royal Ballroom 6-8, and Orchid Ballroom.

Posters should be put up at the beginning of a session and taken down at the end. Authors are expected to be present at their posters during the entire "Author Presents" time, but may be there longer (see schedule below).

Please be courteous and take down your poster promptly at the end of the session, so that the board is empty when the next presenter arrives to put up his or her poster.

Push pins are available for your use and are located at the Meeting Registration Desk in the Royal Palm foyer.

Author Presents Schedule

Friday Evening Poster Session: 5:30 - 8:30 pm
  5:30 - 6:00 pm - All authors present
  6:00 - 7:00 pm - Even numbered posters authors present
  7:00 - 8:00 pm - Odd numbered posters authors present
  8:00 - 8:30 pm - All authors present
Morning Poster Sessions
Saturday - Wednesday: 8:30 am -12:30 pm
  8:30 - 9:00 am - All authors present
  9:30 - 10:30 am - Even numbered posters authors present
  10:30 - 11:30 am - Odd numbered posters authors present
  12:00 - 12:30 pm - All authors present
Afternoon Poster Sessions
Saturday - Tuesday: 2:30 - 6:30 pm
  2:30 - 3:00 pm - All authors present
  3:30 - 4:30 pm - Even numbered posters authors present
  4:30 - 5:30 pm - Odd numbered posters authors present
  6:00 - 6:30 pm - All authors present

Talk Schedule

Saturday, May 10

Time	Vista Ballroom	Royal Ballroom 4-5
8:30 - 10:00 am	Central Pathways	Perceptual Organization 1
10:30 am - 12:15 pm	3D Perception and Image Statistics	Object: Neural Mechanisms
2:30 - 4:00 pm	Eye Movements and Perception	Multiple Object Tracking 1
4:30 - 6:15 pm	Cortical Processing	Attention: Divided Attention

Sunday, May 11

Time	Vista Ballroom	Royal Ballroom 4-5
8:30 - 10:00 am	Perception and Action: How Dissociated Are They?	Search 2
10:30 am - 12:15 pm	Motion Processing	Attention: Neural Mechanisms and Models
2:30 - 4:00 pm	Cross-Modal Interactions	Faces: Neural Mechanisms 2
4:30 - 6:15 pm	Binocular Mechanisms 2	Decision and Reward

Monday, May 12

Time	Vista Ballroom	Royal Ballroom 4-5
8:30 - 10:00 am	Global and Biological Motion	Attention to Objects and Scenes
10:30 am - 12:15 pm	Spatial Vision: Natural Scene Statistics	Visual Memory

Tuesday, May 13

Time	Vista Ballroom	Royal Ballroom 4-5
8:30 - 10:00 am	Processing in Time and Space (8:30 - 10:15 am)	Perceptual Organization 2
10:30 am - 12:15 pm	Vision for Action	Object Perception 2
2:30 - 4:00 pm	Visual Pathways: Receptors to Cortex	Face Perception: Emotion and Experience
4:30 - 6:15 pm	Spatial Vision: Crowding and Eccentricity 2	Perceptual Learning 1

Wednesday, May 14

Time	Vista Ballroom	Royal Ballroom 4-5
8:30 - 10:00 am	Binocular Mechanisms 3	Attention to Locations and Features
10:30 am - 12:15 pm	Color Appearance	Scene Perception 3 (10:30 am - 12:00 pm)

Speaker Information

The meeting rooms are equipped with a data/video projector and a projection screen. Presentations can be made from your Mac or PC laptop. A technician will be present in each room to handle any technical problems that may arise.

Please arrive at the Ballroom no less than 30 minutes before the start of your session. Presenters are welcome to test their presentations between talk sessions. Please give priority to presenters whose talk is scheduled for the subsequent session.

Member-Initiated Symposia

Schedule Overview

Friday, May 9, 1:00 - 3:00 pm

S1: Perceptual expectations and the neural processing of complex images, *Royal Palm Ballroom 6-8*

S2: Cortical organization and dynamics for visual perception and beyond, *Royal Palm Ballroom 4*

S3: Crowding, *Royal Palm Ballroom 5*

S4: Visual Memory and the Brain, *Orchid Ballroom 1*

Friday, May 9, 3:30 - 5:30 pm

S5: Bayesian models applied to perceptual behavior, *Royal Palm Ballroom 4*

S6: Action for perception: functional significance of eye movements for vision, *Orchid Ballroom 1*

S7: The past, present, and future of the written word, *Royal Palm Ballroom 5*

S8: Surface material perception, *Royal Palm Ballroom 6-8*

S1: Perceptual expectations and the neural processing of complex images

Friday, May 9, 1:00 - 3:00 pm, Royal Palm Ballroom 6-8

Organizer: Bharathi Jagadeesh; University of Washington

Presenters: Moshe Bar, Bharathi Jagadeesh, Nicholas Furl, Valentina Daelli and Robert Shapley

Symposium Summary

The processing of complex images occurs within the context of prior expectations and of current knowledge about the world. A clue about an image, "think of an elephant", for example, can cause an otherwise nonsensical image to transform into a meaningful percept. The informative clue presumably activates the neural substrate of an expectation about the scene that allows the visual stimulus representation to be more readily interpreted. In this symposium we aim to discuss the neural mechanisms that underlie the use of clues and context to assist in the interpretation of ambiguous stimuli. The work of five laboratories, using imaging, single-unit recording, MEG, psychophysics, and network models of visual processes all show evidence of the impact of prior knowledge on the processing of visual stimuli.

In the work of Bar, we see evidence that a short latency neural response may be induced in higher level cortical areas by complex signals traveling through a fast visual pathway. This pathway may provide the neural mechanism that modifies the processing of visual stimuli as they stream through the brain. In the work of Jagadeesh, we see a potential effect of that modified processing: neural selectivity in inferotemporal cortex is sufficient to explain performance in a classification task with difficult to classify complex images, but only when the images are evaluated in a particular framed context: Is the image A or B (where A or B are photographs, for example a horse and a giraffe). In the work of Furl, human subjects were asked to classify individual exemplars of faces along a particular dimension (emotion), and had prior experience with the images in the form of an adapting stimulus. In this context, classification is shifted away from the adapting stimulus. Simultaneously recorded MEG activity shows evidence reentrant signal, induced by the prior experience of the prime, that could explain the shift in classification. In the work of Treves, we see examples of networks that reproduce the observed late convergence of neural activity onto the response to an image stored in memory, and that can simulate mechanisms possibly underlying predictive behavior. Finally, in the work of Shapley, we see that simple cells in layer 2/3 of V1 (a major input layer for intra-cortical connections) paradoxically show dynamic nonlinearities.

The presence of a dynamic nonlinearity in the responses of V1 simple cells indicates that first-order analyses often capture only a fraction of neuronal behavior, a consideration with wide ranging implications for the analysis in visual responses in more advanced cortical areas. Signals provided by expectation might influence processing throughout the visual system to bias the perception and neural processing of the visual stimulus in the context of that expectation.

The work to be described is of significant scientific merit and reflects recent work in the field; it is original, forcing re-examination of the traditional view of vision as a method of extracting information from the visual scene in the absence of contextual knowledge, a topic of broad interest to those studying visual perception.

Presentations

The proactive brain: using analogies and associations to generate predictions

Moshe Bar; Harvard Medical School

Rather than passively 'waiting' to be activated by sensations, it is proposed that the human brain is continuously busy generating predictions that approximate the relevant future. Building on previous work, this proposal posits that rudimentary information is extracted rapidly from the input to derive analogies linking that input with representations in memory.

The linked stored representations then activate the associations that are relevant in the specific context, which provides focused predictions. These predictions facilitate perception and cognition by pre-sensitizing relevant representations. Predictions regarding complex information, such as those required in social interactions, integrate multiple analogies. This cognitive neuroscience framework can help explain a variety of phenomena, ranging from recognition to first impressions, and from the brain's 'default mode' to a host of mental disorders.

Neural selectivity in inferotemporal cortex during active classification of photographic images

Bharathi Jagadeesh; University of Washington

Images in the real world are not classified or categorized in the absence of expectations about what we are likely to see. For example, giraffes are quite unlikely to appear in one's environment except in Africa. Thus, when an image is viewed, it is viewed within the context of possibilities about what is likely to appear. Classification occurs within limited expectations about what has been asked about the images. We have trained monkeys to answer questions about ambiguous images in a constrained context: is the image A or B, where A and B are pictures from the visual world, like a giraffe or a horse and recorded responses in inferotemporal cortex while the task is performed, and while the same images are merely viewed. When we record neural responses to these images, while the monkey is required to ask (and answer) a simple question, neural selectivity in IT is sufficient to explain behavior. When the monkey views the same stimuli, in the absence of this framing context, the neural responses are insufficiently selective to explain the separately collected behavior. These data suggest that when the monkey is asked a very specific and limited question about a complex image, IT cortex is selective in exactly the right way to perform the task well. We propose this match between the needs of the task, and the responses in IT results from predictions, generated in other brain areas, which enhance the relevant IT representations.

Experience-based coding in categorical face perception

Nicholas Furl; University College London

One fundamental question in vision science concerns how neural activity produces everyday perceptions. We explore the relationship between neural codes capturing deviations from experience and the perception of visual categories. An intriguing paradigm for studying the role of short-term experience in categorical perception is face adaptation aftereffects - where perception of ambiguous faces morphed between two category prototypes (e.g., two facial identities or expressions) depends on which category was experienced during a recent adaptation period. One might view this phenomenon as a perceptual bias towards novel categories - i.e., those mismatching recent experience. Using fMRI, we present evidence consistent with this viewpoint, where perception of nonadapted categories is associated with medial temporal activity, a region known to subserve novelty processing. This raises a possibility, consistent with models of face perception, that face categories are coded with reference to a representation of experience, such as a norm or top-down prediction. We investigated this idea using MEG by manipulating the deviation in emotional expression between the adapted and morph stimuli. We found signals coding for these deviations arising in the right superior temporal sulcus - a region known to contribute to observation of actions and, notably, face expressions. Moreover, adaptation in the right superior temporal sulcus was also predictive of the magnitude of behavioral aftereffects. The relatively late onset of these effects is suggestive of a role for backwards connections or top-down signaling. Overall, these data are consistent with the idea that face perception depends on a neural representation of the deviation of short-term experience.

Categorical perception may reveal cortical adaptive dynamics

Valentina Daelli, Athena Akrami, Nicola J van Rijsbergenand Alessandro Treves; SISSA

The perception of faces and of the social signals they display is an ecologically important process, which may shed light on generic mechanisms of cortically mediated plasticity. The possibility that facial expressions may be processed also along a sub-cortical pathway, leading to the amygdala, offers the potential to single out uniquely cortical contributions to adaptive perception. With this aim, we have studied adaptation aftereffects, psychophysically, using faces morphed between two expressions. These are perceptual changes induced by adaptation to a priming stimulus, which biases subjects to see the non-primed expression in the morphs. We find aftereffects even with primes presented for very short periods, or with faces low-pass filtered to favor sub-cortical processing, but full cortical aftereffects are much larger, suggesting a process involving conscious comparisons, perhaps mediated by cortical memory attractors, superimposed on a more automatic process, perhaps expressed also subcortically. In a modeling project, a simple network model storing discrete memories can in fact explain such short term plasticity effects in terms of neuronal firing rate adaptation, acting against the rigidity of the boundaries between long-term memory attractors. The very same model can be used, in the long-term memory domain, to account for the convergence of neuronal responses, observed by the Jagadeesh lab in monkey inferior temporal cortex.

Contrast-sign specificity built into the primary visual cortex, V1

Williams and Shapley; NYU

We (Wlliams & Shapley 2007) found that in different cell layers in the macaque primary visual cortex, V1, simple cells have qualitatively different responses to spatial patterns. In response to a stationary grating presented for 100ms at the optimal spatial phase (position), V1 neurons produce responses that rise quickly and then decay before stimulus offset. For many simple cells in layer 4, it was possible to use this decay and the assumption of linearity to predict the amplitude of the response to the offset of a stimulus of the opposite-to-optimal spatial phase. However, the linear prediction was not accurate for neurons in layer 2/3 of V1, the main cortico-cortical output from V1. Opposite-phase responses from simple cells in layer 2/3 were always near zero. Even when a layer 2/3 neuron's optimal-phase response was very transient, which would predict a large response to the offset of the opposite spatial phase, opposite-phase responses were small or zero. The suppression of opposite-phase responses could be an important building block in the visual perception of surfaces. Simple cells like those found in layer 4 respond to both contrast polarities of a given stimulus (both brighter and darker than background, or opposite spatial phases). But unlike layer 4 neurons, layer 2/3 simple cells code unambiguously for a single contrast polarity. With such polarity sensitivity, a neuron can represent "dark-left - bright-right" instead of just an unsigned boundary.

S2: Cortical organization and dynamics for visual perception and beyond

Friday, May 9, 1:00 - 3:00 pm, Royal Palm Ballroom 4

Organizer: Zoe Kourtzi; University of Birmingham

Presenters: Martin I. Sereno, Uri Hasson, Wim Vanduffel, Charles E. Connor, Geoffrey M. Boynton and Pieter R. Roelfsem

Symposium Summary

The symposium aims to showcase state-of-the-art work and methods for studying the cortical dynamics that mediate complex and adaptive behaviours.

Extensive work in anatomy, neurophysiology and brain imaging has approached this challenge by studying the topography and neural function of discrete cortical structures in the human and non-human primate brain. This approach has been very successful in generating a roadmap of the primate brain: identifying a large number of different cortical areas associated with different functions and cognitive abilities. However, understanding how the brain generates complex and adaptive behaviours entails extending beyond isolated cortical centres and investigating the spatio-temporal dynamics that underlie information processing within and across cortical networks.

Recent developments in multi-site neurophysiological recordings and stimulation combined with advances in brain imaging have provided powerful methods for studying cortical circuits and novel insights into cortical dynamics.

The symposium will bring together pioneers in the study of cortical circuits in the human and the monkey brain and combine evidence from interdisciplinary approaches: physiology, imaging, computational modelling.

First we will present brain imaging work that characterizes the common principles of spatial and temporal organization across and beyond the human visual cortex (Sereno, Hasson). Second, we will discuss studies that delineate the causal interactions within these cortical circuits combining fMRI and microstimulation (Vanduffel). Third, we will discuss neurophysiological evidence for the functional role of these spatiotemporal interactions in the integration of sensory information to global percepts for visual recognition and actions (Connor). Fourth, we will present brain imaging work showing that cortical circuits adapt to the task demands and the attentional state of the observer (Boynton). Finally, we will present computational approaches investigating how attention and learning shape interactions within cortical circuits for adaptive behaviour (Roelfsema).

Thus, the symposium will serve as a forum for discussing novel evidence on cortical organization and dynamics emerging from current human and animal research and a tutorial for interdisciplinary state-of-the-art methods for research in this field. As such, the symposium will target a broad audience of researchers and students in the vision sciences society interested in understanding the link between brain and behaviour.

Presentations

Finding the parts of the cortex

Martin I. Sereno; UCL and Birkbeck, London

Understanding brain dynamics requires knowing what its parts are. Human neuroimaging has attempted that using contrasts between high level cognitive tasks averaged across subjects in 3-D. Two problems are: (1) higher level tasks generate activity in multiple cortical areas, some of which adjoin each other, and (2) cross-subject 3-D averages must use blurring kernels close to the modal size of human cortical areas (1 cm) to overcome anatomical variation and variation in how subjects perform tasks. Even liberal statistical thresholds underestimate the area of cortex involved and activation borders only accidentally represent cortical area borders.

Another way to subdivide cortex is to find receptotopic (retinotopic, tonotopic, somatotopic) maps. Topological retinal maps were expected in V1 and early secondary visual areas based on non-human primate data. However, recent work in parietal, temporal, cingulate, and frontal cortex shows that these maps are present at higher levels, extending to the boundaries between modalities (e.g., VIP). This was not expected on the basis of work in animals because higher areas have larger receptive fields with a substantial degree of scatter. Independent manipulation of stimulus and attention shows that higher level maps are largely maps of attention. Three possible reasons why spatial maps might persist at high levels are: (1) intracortical connections are overwhelmingly local, (2) sensory space (retinal, frequency, skin position) is the most important feature for distinguishing events, and (3) cortical space remains a convenient way to allocate processing, even if it is not explicitly spatial.

A hierarchy of temporal receptive windows in human cortex

Uri Hasson, Eunice Yang, Ignacio Vallines, David Heeger, and Nava Rubin; New York University

Real-world events unfold at different time scales, and therefore cognitive and neuronal processes must likewise occur at different time scales. We present a novel procedure that identifies brain regions responsive to sensory information accumulated over different time scales. We measured fMRI activity while observers viewed silent films presented forward, backward, or piecewise-scrambled in time. In a first experiment, responses to backward presentations were time-reversed and correlated with those to forward presentations. In visual cortex, this yielded high correlation values, indicating responses were driven by stimulation over short time scales. In contrast, responses depended strongly on time-reversal in the Superior Temporal Sulcus (STS), Precuneus, posterior Lateral Sulcus (LS), Temporal Parietal Junction (TPJ) and Frontal Eye Field (FEF). These regions showed highly reproducible responses for repeated forward, but not backward presentations. In a second experiment, stimulus time scale was parametrically varied by shuffling the order of segments from the same films. The results show clear differences in temporal characteristics, with LS, TPJ and FEF responses depending on information accumulated over longer durations (~ 36 s) than STS and Precuneus (~12 s). We conclude that, similar to the known cortical hierarchy of spatial receptive fields, there is a hierarchy of progressively longer temporal receptive windows in the human brain.

Investigating causal functional interactions between brain regions by combining fMRI and intracortical electrical microstimulation in awake behaving monkeys

Wim Vanduffel; Massachusetts General Hospital and K.U. Leuven Medical School

Areas of the frontal and parietal cortex are thought to exert control over information flow in the visual cortex through feedback signals (Kastner and Ungerleider, 2000; Moore, 2003). Although a plethora of studies provided correlation data to support this hypothesis, corroborating causal evidence is virtually absent (but see e.g. Moore and Armstrong, 2003). Also, several models suggest that the frontal signals modulating incoming sensory activity are gated by bottom-up stimulation (van der Velde and de Kamps, 2001; Roelfsema, 2006). To test these models and examine the spatial organization of any observed modulations, we developed a combination of fMRI (Vanduffel et al. 2001) and chronic electrical microstimulation (EM) in awake, behaving monkeys. This approach allowed us to investigate the impact of increased frontal eye field (FEF) output, using biologically relevant currents, on visually-driven responses throughout occipito-temporal cortex.

Activity in higher-order visual areas, monosynaptically connected to the FEF, was strongly modulated in the absence of visual stimulation, shwoing that the combination of fMRI with EM holds great potential as in-vivo tractography tool (see also Tolias et al. 2005). Activity in early visual areas, however, could only be modulated in the presence of bottom-up stimulation, resulting in a topographically specific pattern of enhancement and suppression. This result suggests that bottom-up activation of recurrent connections is needed to enable top-down modulation in visual cortex. We furthermore uncovered a potentially new subdivision in many areas of the visual cortex, as the regions with strong visual responses are largely separate from regions influenced by feedback.

Spatiotemporal integration of object structure information

Charles E. Connor; John Hopkins University School of Medicine

Image representation in early visual cortex is extremely local. Object perception depends on spatial integration of this local information by neurons at later cortical stages processing larger image regions. We have studied the spatial and temporal characteristics of this integration process at multiple cortical stages in the macaque monkey. We have found that neurons in area V4 integrate across local changes in boundary orientation (a first-order derivative) to derive curvature (a second-order derivative). V4 neurons also integrate across position and binocular disparity to derive 3D orientation. At the next processing stage in posterior inferotemporal cortex (PIT), neurons integrate across spatially disjoint object boundary regions to derive more complex, larger-scale shape configurations. At still higher processing stages in central and anterior IT, neurons derive more complete boundary configurations with potential ecological relevance.

CIT/AIT neurons also integrate disparity and shading information to derive surface and volumetric elements of 3D object structure. These integration mechanisms are largely linear at early time points, producing ambiguous representations of object structure. Over the course of approximately 50 ms, presumably through recursive intracortical processing, nonlinear selectivity gradually emerges, producing more explicit signals for specific combinations of structural elements.

Feature-Based Attention in Human Visual Cortex

John Serences and Geoffrey M. Boynton; University of Washington, Department of Psychology

The spatial resolution of functional MRI makes it ideal for studying the effects of spatial attention on responses in the human visual cortex: with fMRI we can trace the enhancement of the BOLD signal in regions that are retinotopically associated with the spatial location of the attentional spotlight. Studying the effects of feature-based attention is more difficult because the columnar organization of visual features such as direction of motion and orientation are too small for traditional fMRI experiments. However, recent developments in pattern classification algorithms by Kamitani and Tong (2006) have allowed researchers to investigate these feature-based attentional effects by studying how the pattern of fMRI responses within a visual area is affected by changes in the physical and attended feature. I will present the results of two studies in which we have applied these methods to show that (1) in all early visual areas, feature-based attention for direction of motion spreads across to unattended locations of the visual field, and (2) only area MT+ (and possibly V3A) represent the perceived, rather than the physical direction of motion. These results provide evidence that the early stages of the visual system respond more than just to the bottom-up stimulus properties. Instead, the cortical circuitry adapts to the task demands and attentional state of the observer.

How attentional feedback guides learning of sensory representations

Aurel Wannig and Pieter R. Roelfsema; Netherlands Institute for Neuroscience

I will describe our new theory, AGREL (attention-gated reinforcement learning; Roelfsema & van Ooyen, 2005), which proposes a new role for feedback connections in learning. We aim to understand the neuronal plasticity that underlies learning in classification tasks and test the predictions of our theory using a multilayer neural network. Stimuli are presented to the lowest layer representing a sensory area of the cortex.

Activity is then propagated to the highest layer representing the motor cortex, which has to choose one out of a number of actions that correspond to the various stimulus categories. Neurons in the highest layer engage in a competition for action selection. A reward is delivered if this action is correct, and no reward is delivered in case of an error. On erroneous trials the correct action is not revealed to the network. The distinguishing feature of AGREL is that the neurons that win the competition in the motor cortex feed back to lower layers, just as is observed for attentional effects in neurophysiology. This attentional feedback signal gates synaptic plasticity at lower layers in the network so that only neurons receiving feedback change their synapses. i.e. the attentional feedback acts as a credit assignment signal. We show that the feedback signal makes reinforcement learning as powerful as previous non-biological learning schemes, such as error-backpropagation. Moreover, we demonstrate that AGREL changes the tuning of sensory neurons in just the same way as is observed in the visual cortex of monkeys that are trained in categorization tasks.

S3: Crowding

Friday, May 9, 1:00 - 3:00 pm, Royal Palm Ballroom 5

Organizer: Denis G. Pelli; New York University

Presenters: Patrick Cavanagh, Brad C. Motter, Yury Petrov, Joshua A. Solomon and Katharine A. Tillman

Symposium Summary

Crowding is a breakdown of object recognition. It happens when the visual system inappropriately integrates features over too large an area, coming up with an indecipherable jumble instead an object. An explosion of new experiments exploit crowding to study object recognition by breaking it. The five speakers will review past work, providing a tutorial introduction to crowding, and will describe the latest experiments seeking to define the limits of crowding and object recognition. The general question, including "integration", "binding", "segmentation", "grouping," "contour integration", and "selective attention", is a burning issue for most members of VSS.

Presentations

Crowding: When grouping goes wrong

Patrick Cavanagh; Harvard University and LPP, Université Paris Descartes

Early visual processes work busily to construct accurate representations of edges, colors and other features that appear within their receptive fields, dutifully posting their details across the retinotopic landscape of early cortices. Then the fat hand of attention makes a grab at a target and comes up with an indecipherable stew of everything in the region. Well, that's one model of crowding. There are others. Whatever the model of crowding, it is clear that the phenomenon provides a rare window onto the mid-level process of feature integration. I will present results on nonretinotopic crowding and anticrowding that broaden the range of phenomena we include in the category of crowding.

Correlations between visual search and crowding

Brad C. Motter; Veterans Affairs Medical Center and SUNY Upstate Medical University

Visual search through simple stimulus arrays can be described as a linear function of the angular separation between the target and surrounding items after scaling for cortical magnification. Maximum reading speeds as a function of eccentricity also appear to be bound by a cortical magnification factor. If crowding can explain these visual behaviors, what is the role of focal attention in these findings?

Locus of spatial attention determines inward-outward anisotropy in crowding

Yury Petrov; Northeastern University

I show that the locus of spatial attention strongly affects crowding, inducing inward-outward anisotropy in some conditions, removing or reversing it in others. It appears that under normal viewing conditions attention is mislocalized outward of the target, which may explain stronger crowding by an outward mask.

Context-induced acuity loss for tilt: If it is not crowding, what is it?

Joshua A. Solomon & Michael J. Morgan; Optometry Deptartment, City University, London

When other objects are nearby, it becomes more difficult to determine whether a particular object is tilted, for example, clockwise or anti-clockwise of vertical. "Crowding" is similar: when other letters are nearby, it becomes more difficult to determine the identity of a particular letter or whether it is, for example, upside down or mirror-reversed. There is one major difference between these two phenomena. The former occurs with big objects in the centre of the visual field; the latter does not. We call the former phenomenon "squishing." Two mechanisms have been proposed to explain it: lateral inhibition and stochastic re-calibration. Simple models based on lateral inhibition cannot explain why nearby objects do not impair contrast discrimination as well as tilt acuity, but a new comparison of acuities measured with the Method of Single Stimuli and 2-Alternative Forced-Choice do not support models based on stochastic re-calibration. Lateral inhibition deserves re-consideration. Network simulations suggest that many neurones capable of contrast discrimination have little to contribute towards tilt identification and vice versa.

The uncrowded window for object recognition

Katharine A. Tillman and Denis G. Pelli; Psychology and Neural Science, New York University

It has been known throughout history that we cannot see things that are too small. However, it is now emerging that vision is usually not limited by object size, but by spacing. The visual system recognizes an object by detecting and then combining its features. When objects are too close together, the visual system combines features from them all, producing a jumbled percept. This phenomenon is called crowding. Critical spacing is the smallest distance between objects that avoids crowding. We review the explosion of studies of crowding — in grating discrimination, letter and face recognition, visual search, and reading — to reveal a universal law, the Bouma law: Critical spacing is proportional to distance from fixation, depending only on where (not what) the object is. Observers can identify objects only in the uncrowded window within which object spacing exceeds critical spacing. The uncrowded window limits reading rate and explains why we can recognize a face only if we look directly at it. Visual demonstrations allow the audience to verify key experimental results.

S4: Visual Memory and the Brain

Friday, May 9, 1:00 - 3:00 pm, Orchid Ballroom 1

Organizer: Marian Berryhill; University of Pensylvania

Presenters: Lynn C. Robertson, Yaoda Xu, Yuhong Jiang; Neil Muggleton and Marian E. Berryhill

Symposium Summary

Focus:

Visual memory describes the relationship between perceptual processing and the storage and retrieval of the resulting neural representations. Visual memory occurs over a broad time rangeof scenes across eye movements - to years - in order to visually navigate to a previously visited location or to recognize an old friend. How does the brain encode, store, and retrieve theserepresentations? What neural mechanism limits the capacity and resolution of visual memory? Do the same neural areas participate in short-term and long-term visual memory? Do particular neural regions, such as the intraparietal sulcus, participate only in visual memory, or does it have a more generally role in attentionally demanding tasks such as binding and multi-object tracking? Are different brain areas critically involved in storing different visual materials, such as simple colors or complex scenes? These topics have only begun to be studied; the purpose of this symposium is to discuss the latest research and current problems facing our understanding of visualmemory. Investigators in this area of research employ a variety of techniques such as the lesion method (neuropsychology and TMS), neuroimaging (fMRI, ERP), and behavioral studies.

Timeliness:

The finding that the intraparietal sulcus may limit the capacity of visual short-term memory is an example of a topic that has been published in prominent journals, thereby fueling new studies andgenerating broad interest. Moreover, this general topic of the neural basis of visual memory relates to several other timely topics in the visual cognition literature including: neural areas involved inmulti-object tracking, attention, scene perception, navigation, and long-term memory.

Audience:

This symposium would be accessible to a broad VSS Audience as it includes both perceptual and cognitive processing. Furthermore, by including speakers who come from a variety of methodological backgrounds, including neuropsychology and neuroimaging. Both students and seasoned researchers will find it of interest. The audience will gain a better understanding of visualcognition and of current methodological techniques being used to understand brain-behavior relationships.

Presentations

Forms of visual representation in unattended space: neuropsychological evidence

Lynn C. Robertson, Thomas Van Vleet; UC Berkeley

Although there is a great deal of evidence that undetected information can affect subsequent performance (e.g., priming), the nature of the memory representation that produces this effect is not well understood. In a series of studies with patients who suffer from left sided neglect and/or extinction from right hemisphere damage, we show that feature displays prime a subsequent central target equally well whether the features were more or less likely to be detected. Conversely, conjunction displays prime more when they are more likely to be detected. These results will be discussed as they relate to visual storage of undetected stimuli and how memory representations differ with attention.

Dissociable parietal mechanisms supporting visual short-term memory for objects

Yaoda Xu; Yale University

In this talk, I will show that visual short-term memory (VSTM) storage is mediated by distinctive posterior brain mechanisms, such that VSTM capacity is determined both by a fixed number of objects and by object complexity. These findings not only advance our understanding of the neural mechanisms underlying VSTM, but also have interesting implications to theories on visual object perception.

Talk by Yuhong Jiang

Yuhong Jiang; University of Minnesota

Dr. Jiang will discuss behavioral and fMRI data on visual short-term memory, with an emphasis on synthesis of findings.

Migrating Memories: Remembering what comes next

Neil Muggleton and Vincent Walsh; University College London

Memory, along with attention, imagery, learning, getting grants and awareness is sometimes assumed to be a high level function. There is, however, an increasing “migration” of functions from higher to lower areas as we ask more diffiucult questions of the sensory cortex. For example, what were once considered “cognitive” contours with neural correlates in IT can be inferred from the responses of V1 or V2 neurons and visual imagery and visual awareness require V1. It is becoming increasingly clear that a similar migration of complexity is occuring in memory and we can now rightly speak about sensory memory in visual cortex. I will discuss experiments which explore the role of visual areas in short term memory and visual priming. Specifically I will discuss the effects of interfering with memory processes by applying TMS over visual area V5, the frontal eye fields and the parietal cortex.

When was I Where?

Marian E. Berryhill & Ingrid R. Olson; University of Pennsylvania, Temple University

The perceptual deficits following dorsal stream damage are well-known, i.e. hemispatial neglect, Balint’s syndrome. However, accumulating evidence suggests that these same cortical regions are involved in processing ‘when’ as well as ‘where’. In a series of studies examining unilateral and bilateral parietal patients we have observed visual, spatial working memory as well as autobiographical and constructive memory impairments. These data suggest that these patients have cognitive deficits that parallel their perceptual deficits. In this talk, we will discuss the effects of dorsal stream damage on visual perception as well as the effects on stored representations in short-term and long-term memory.

S5: Bayesian models applied to perceptual behavior

Friday, May 9, 3:30 - 5:30 pm, Royal Palm Ballroom 4

Organizer: Peter Battaglia; University of Minnesota

Presenters: Alan Yuille, David Knill, Paul Schrater, Tom Griffiths, Konrad Koerding and Peter Battaglia

Symposium Summary

This symposium will provide information and methodological tools for researchers who are interested in modeling perception as probabilistic inference, but are unfamiliar with the practice of such techniques. In the last 20 years, scientists characterizing perception as Bayesian inference have produced a number of robust models that explain observed perceptual behaviors and predict new, unobserved behaviors. Such successes are due to the formal, universal language of Bayesian models and the powerful hypothesis-evaluation tools they allow. Yet many researchers who attempt to build and test Bayesian models feel overwhelmed by the potentially steep learning curve and abandon their attempts after stumbling over unintuitive obstacles. It is important that those scientists who recognize the explanatory power of Bayesian methods and wish to implement the framework in their own research have the tools, and know-how to use them, at their disposal. This symposium will provide a gentle introduction to the most important elements of Bayesian models of perception, while avoiding the nuances and subtleties that are not critical. The symposium will be geared toward senior faculty and students alike, and will require no technical prerequisites to understand the major concepts, and only knowledge of basic probability theory and experimental statistics to apply the methods. Those comfortable with Bayesian modeling may find the symposium interesting, but the target audience will be the uninitiated.

The formalism of Bayesian models allows a principled description of the processes that allow organisms to recover scene properties from sensory measurements, thereby enabling a clear statement of experimental hypotheses and their connections with related theories. Many people believe Bayesian modeling is primarily for fitting unpleasant data using a prior: this is a misconception that will be dealt with! In previous attempts to correct such notions, most instruction about probabilistic models of perception falls into one of two categories: qualitative, abstract description, or quantitative, technical application. This symposium constitutes a hybrid of these categories by phrasing qualitative descriptions in quantitative formalism. Intuitive and familiar examples will be used so the connection between abstract and practical issues remains clear.

The goals of this symposium are two-fold: to present the most current and important ideas involving probabilistic perceptual models, and provide hands-on experience working with them. To accomplish these goals, our speakers will address topics such as the history and motivation for probabilistic models of perception, the relation between sensory uncertainty and probability-theoretic representations of variability, the brain’s assumptions about how the world causes sensory measurements, how to investigate the brain’s internal knowledge of probability, framing psychophysical tasks as perceptually-guided decisions, and hands-on modeling tutorials presented as Matlab scripts that will be made available for download beforehand so those with laptops can follow along. Each talk will link the conceptual material to the scientific interests of the audience by presenting primary research and suggesting perceptual problems that are ripe for the application of Bayesian methods.

Presentations

Modeling Vision as Bayesian Inference: Is it Worth the Effort?

Alan Yuille; University of Minnesota

The idea of perception as statistical inference grew out of work in the 1950s in the context of a general theory of auditory and visual signal detectability. Signal detection theory from the start used concepts and tools from Bayesian Statistical Decision theory that are with us today: 1) a generative model that specifies the probability of sensory data conditioned on signal states; 2) prior probabilities of those states; 3) the utility of decisions or actions as they depend on those states. By the 1990s, statistical inference models were being extended to an increasingly wider set of problems, including object and motion perception, perceptual organization, attention, reading, learning, and motor control. These applications have relied in part on the development of new concepts and computational methods to analyze and model more realistic visual tasks. I will provide an overview of current work, describing some of the success stories. I will try to identify future challenges for testing and modeling theories of visual behavior--research that will require learning, and computing probabilities on more complex, structured representations.

Bayesian modeling in the context of robust cue integration

David Knill; University of Rochester

Building Bayesian models of visual perception is becoming increasingly popular in our field. Those of us who make a living constructing and testing Bayesian models are often asked the question, “What good are models that can be fit to almost any behavioral data?” I will address this question in two ways: first by acknowledging the ways in which Bayesian modeling can be misused, and second by outlining how Bayesian modeling, when properly applied, can enhance our understanding of perceptual processing. I will use robust cue integration as an example to illustrate some ways in which Bayesian modeling helps organize our understanding of the factors that determine perceptual performance, makes predictions about performance, and generates new and interesting questions about perceptual processes. Robust cue integration characterizes the problem of how the brain integrates information from different sensory cues that have unnaturally large conflicts. To build a Bayesian model of cue integration, one must explicitly model the world processes that give rise to such conflicting cues. When combined with models of internal sensory noise, such models predict behaviors that are consistent with human performance. While we can "retro-fit" the models to the data, the real test of our models is whether they agree with what we know about sensory processing and the structure of the environment (though mismatches may invite questions ripe for future research). At their best, such models help explain how perceptual behavior relates to the computational structure of the problems observers face and the constraints imposed by sensory mechanisms.

Bayesian models for sequential decisions

Paul Schrater; University of Minnesota

Performing common perceptually-guided actions, like saccades and reaches, requires our brains to overcome uncertainty about the objects and geometry relevant to our actions (world state), potential consequences of our actions, and individual rewards attached to these consequences. A principled approach to such problems is termed "stochastic-optimal control", and uses Bayesian inference to simultaneously update beliefs about the world state, action consequences, and individual rewards. Rational agents seek rewards, and since rewards depend on the consequences of actions, and those consequences depend on the world state, updating beliefs about all three is necessary to acquire the most reward possible.

Consider the example of reaching to grasp your computer mouse while viewing your monitor. Some strategies and outcomes for guiding your reach include: 1.) keeping your eyes fixed, moving quickly, and probably missing the mouse, 2.) keeping your eyes fixed, moving slowly, and wasting time reaching, 3.) turning your head, staring at the mouse, wasting time moving your head, or 4.) quickly saccading toward the mouse, giving you enough positional information to make a fast reach without wasting much time. This example highlights the kind of balance perceptually-guided actions strike thousands of times a day: scheduling information-gathering and action-execution when there are costs (i.e. time, missing the target) attached. Using the language of stochastic-optimal control, tradeoffs like these can be formally characterized and explain otherwise opaque behavioral decisions. My presentation will introduce stochastic-optimal control theory, and show how applying the basic principles offer a powerful framework for describing and evaluating perceptually-guided action.

Exploring subjective probability distributions using Bayesian statistics

Tom Griffiths; University of California, Berkeley

Bayesian models of cognition and perception express the expectations of learners and observers in terms of subjective probability distributions - priors and likelihoods. This raises an interesting psychological question: if human inferences adhere to the principles of Bayesian statistics, how can we identify the subjective probability distributions that guide these inferences? I will discuss two methods for exploring subjective probability distributions. The first method is based on evaluating human judgments against distributions provided by the world. The second substitutes people for elements in randomized algorithms that are commonly used to generate samples from probability distributions in Bayesian statistics. I will show how these methods can be used to gather information about the priors and likelihoods that seem to characterize human judgments.

Causal inference in multisensory perception

Konrad Koerding; Northwestern University

Perceptual events derive their significance to an animal from their meaning about the world, that is from the information they carry about their causes. The brain should thus be able to efficiently infer the causes underlying our sensory events. Here we use multisensory cue combination to study causal inference in perception. We formulate an ideal-observer model that infers whether two sensory cues originate from the same location and that also estimates their location(s). This model accurately predicts the nonlinear integration of cues by human subjects in two auditory-visual localization tasks. The results show that indeed humans can efficiently infer the causal structure as well as the location of causes. By combining insights from the study of causal inference with the ideal-observer approach to sensory cue combination, we show that the capacity to infer causal structure is not limited to conscious, high-level cognition; it is also performed continually and effortlessly in perception.

How to: Applying a Bayesian model to a perceptual question

Peter Battaglia; University of Minnesota

Bayesian models provide a powerful language for describing and evaluating hypotheses about perceptual behaviors. When implemented properly they allow strong conclusions about the brain's perceptual solutions in determining what caused incoming sensory information. Unfortunately, constructing a Bayesian model may seem challenging and perhaps "not worth the trouble" to those who are not intimately familiar with the practice. Even with a clear Bayesian model, it is not always obvious how experimental data should be used to evaluate the model's parameters. This presentation will demystify the process by walking through the modeling and analysis using a simple, relevant example of a perceptual behavior.

First I will introduce a familiar perceptual problem and describe the choices involved in formalizing it as a Bayesian model. Next, I will explain how standard experimental data can be exploited to reveal model parameter values and how the results of multiple experiments may be unified to fully evaluate the model. The presentation will be structured as a tutorial that will use Matlab scripts to simulate the generation of sensory data, the brain's hypothetical inference procedure, and the quantitative analysis of this hypothesis. The scripts will be made available beforehand so the audience has the option of downloading and following along to enhance the hands-on theme. My goal is that interested audience members will be able to explore the scripts at a later time to familiarize themselves more thoroughly with a tractable modeling and analysis process.

S6: Action for perception: functional significance of eye movements for vision

Friday, May 9, 3:30 - 5:30 pm, Orchid 1

Organizers: Anna Montagnini[1] and Miriam Spering[2]; [1]Institut de Neurosciences Cognitives de la Méditerranée; [2]Justus-Liebig University Giessen, Germany

Presenters: Maria Concetta Morrone, Tirin Moore, Michele Rucci, Miriam Spering, Ziad Hafed and Wilson S. Geisler

Symposium Summary

When we view the world around us, our eyes are constantly in motion.

Different types of eye movements are used to bring the image of an object of interest onto the fovea, to keep it stable on this high-resolution area of the retina, or to avoid visual fading. Moment by moment, eye movements change the retinal input to the visual system of primates, thereby determining what we see. This critical role of eye movements is now widely acknowledged, and closely related to a research program termed "Active Vision" (Findlay & Gilchrist, 2003).

While eye movements improve vision, they might also come at a cost.

Voluntary eye movements can impair perception of objects, space and time, and affect attentional processing. When using eye movements as a sensitive tool to infer visual and cognitive processing, these constraints have to be taken into account.

The proposed symposium responds to an increasing interest in vision sciences to use eye movements. The aims of the symposium are (i) to review and discuss findings related to perceptual consequences of eye movements, (ii) to introduce new methodological approaches that take into account these consequences, and (iii) to encourage vision scientists to focus on the dynamic interplay between vision and oculomotor behavior.

The symposium spans a wide area of research on visuomotor interaction, and brings to the table junior and senior researchers from different disciplines, studying different types of eye movements and perceptual behaviors. All speakers are at the forefront of research in vision and brain sciences and have made significant contributions to the understanding of the questions at hand, using a variety of methodological approaches.

Concetta Morrone (Università Vita-Salute, Italy) reviews findings on the perisaccadic compression of space and time, and provides a Bayesian model for these perceptual phenomena. Tirin Moore (Stanford University, USA) discusses the neural mechanisms of perisaccadic changes in visual and attentional processing. Michele Rucci (Boston University, USA) argues for an increase in spatial sensitivity due to involuntary miniature eye movements during fixation, which are optimized for the statistics of natural scenes.

Miriam Spering (University of Giessen, Germany) focuses on the relationship between smooth pursuit eye movements and the ability to perceive and predict visual motion. Ziad Hafed (Salk Institute, USA) discusses the effect of eye movements on object perception, pointing out an intriguing role of oculomotor control for visual optimization. Wilson Geisler (University of Texas, USA) uses ideal-observer analysis to model the selection of fixation locations across a visual scene, demonstrating the high degree of efficiency in human visuomotor strategy.

The topic of this symposium is at the same time of general interest and of specific importance. It should attract at least three groups of VSS attendants – those interested in low-level visual perception, in motor behavior, and those using eye movements as a tool. We expect to attract both students, seeking an introduction to the topic, and faculty, looking for up-to date insights. It will be beneficial for VSS to include a symposium devoted to the dynamic and interactive link between visual perception and oculomotor behavior.

Presentations

Perception of space and time during saccades: a Bayesian explanation for perisaccadic distortions

Maria Concetta Morrone, Paola Binda & David Burr; Facoltà di Psicologia, Università Vita-Salute S Raffaele, Milano, Italy; Istituto Italiano di Tecnologia, Genova, Italy; Dipartimento di Psicologia, Università di Firenze, Italy

During a critical period around the time of saccades, briefly presented stimuli are grossly mislocalized in space and time and both relative distances and durations appear strongly compressed. We investigated whether the Bayesian hypothesis of optimal sensory fusion could account for some of the mislocalizations, taking advantage of the fact that auditory stimuli are unaffected by saccades. For spatial localization, vision usually dominates over audition during fixation (the "ventriloquist effect"); but during perisaccadic presentations, auditory localization becomes relatively more important, so the mislocalized visual stimulus is seen closer to its veridical position. Both the perceived position of the bimodal stimuli and the time-course of spatial localization were well-predicted by assuming optimal Bayesian-like combination of visual and auditory signals. For time localization, acoustic signals always dominate. However, this dominance does not affect the dynamics of saccadic mislocalization, suggesting that audio-visual capture occurs after saccadic remapping. Our model simulates the time-course data, assuming that position in external space is given by the sum of retinal position and a noisy eye-position signal, obtained by integrating the output of two neural populations, one centered at the current point of gaze, the other centered at the future point of gaze. Only later the output signal is fused with the auditory signal, demonstrating that some saccadic distortions take place very early in visual analysis.

This model not only accounts for the bizarre perceptual phenomena caused by saccades, but provides a novel vision-based account of peri-saccadic remapping of space.

Neural mechanisms and correlates of perisaccadic changes in visual perception

Tirin Moore; Stanford University School of Medicine

The changes in visual perception that accompany saccadic eye movements, including shifts of attention and saccadic suppression, are well documented in psychophysical studies. However, the neural basis of these changes is poorly understood. Recent evidence suggests that interactions of oculomotor mechanisms with visual cortical representations may provide a basis for modulations of visual signals and visual perception described during saccades. I will discuss some recent neurophysiological experiments that address the impact of oculomotor mechanisms, and of saccade preparation, on the filtering of visual signals within cortex. Results from these experiments relate directly to the observed enhancement and suppression of visual perception during saccades.

Fixational eye movements, natural image statistics, and fine spatial vision

Michele Rucci; Boston University

During visual fixation, small eye movements continually displace the stimulus on the retina. It is known that visual percepts tend to fade when retinal image motion is eliminated in the laboratory. However, it has long been debated whether, during natural viewing, fixational eye movements have other functions besides preventing the visual scene from fading. In this talk, I will summarize a theory for the existence of fixational eye movements, which links the physiological instability of visual fixation to the statistics of natural scenes. According to this theory, fixational eye movements contribute to the neural encoding of natural scenes by attenuating input redundancy and emphasizing the elements of the stimulus that cannot be predicted from the statistical properties of natural images. To test some of the predictions of this theory, we developed a new method of retinal image stabilization, which enables selective elimination of the motion of the retinal image during natural intersaccadic fixation. We show that fixational eye movements facilitate the discrimination of high spatial frequency patterns masked by low spatial frequency noise, as predicted by our theory.

These results suggest a contribution of fixational eye movements in the processing of spatial detail, a proposal originally speculated by Hering in 1899.

Motion perception and prediction during smooth pursuit eye movements

Miriam Spering, Alexander C. Schütz & Karl R. Gegenfurtner; Department of Psychology, Justus-Liebig University Giessen, Germany; Department of Psychology, New York University

Smooth pursuit eye movements are slow, voluntary movements of the eyes that serve to hold the retinal image of a moving object close to the fovea. Most research on the interaction of visual perception and oculomotor action has focused on the question what visual input drives the eye best, and what this tells us about visual processing for eye movement control. Here we take a different route and discuss findings on perceptual consequences of pursuit eye movements. Our recent research has particularly focused on the interaction between pursuit eye movements and motion sensitivity in different tasks and visual contexts. (i) We report findings from a situation that particularly requires the dissociation between retinal image motion due to eye movements and retinal object motion. A moving object has to be tracked across a dynamically changing moving visual context, and object motion has to be estimated. (ii) The ability to predict the trajectory of a briefly presented moving object is compared during pursuit and fixation for different target presentation durations. (iii) We compare the sensitivity to motion perturbations in the peripheral visual context during pursuit and fixation. Results imply that pursuit consequences are optimally adapted to contextual requirements.

Looking at visual objects

Ziad Hafed; Salk Institute

Much of our understanding about the brain mechanisms for controlling how and where we look derives from minimalist behavioral tasks relying on simple spots of light as the potential targets. However, visual targets in natural settings are rarely individual, point-like sources of light. Instead, they are typically larger visual objects that may or may not contain explicit features to look at. In this presentation, I will argue that the use of more complex, and arguably more "natural", visual stimuli than is commonly used in oculomotor research is important for learning the extent to which eye movements can serve visual perception. I will provide an example of this by describing a behavioral phenomenon in which the visual system consistently fails in interpreting a retinal stimulus as containing coherent objects when this stimulus is not accompanied by an ongoing eye movement. I will then shed light on an important node in the brain circuitry involved in the process of looking at visual objects. Specifically, I will show that the superior colliculus (SC), best known for its motor control of saccades, provides a neural "pointer" for the location of a visual object, independent of the object's individual features and distinct from the motor commands associated with this brain structure. Such a pointer allows the oculomotor system to precisely direct gaze, even in the face of large extended objects.

More importantly, because the SC also provides ascending signals to sensory areas, such a pointer may also be involved in modulating object-based attention and perception.

Mechanisms of fixation selection evaluated using ideal observer analysis

Wilson S. Geisler; University of Texas, Austin

The primate visual system combines a wide field of view with a high resolution fovea and uses saccadic eye movements to direct the fovea at potentially relevant locations in visual scenes. This is a sensible design for a visual system with limited neural resources. However, to be effective this design requires sophisticated task-dependent mechanisms for selecting fixation locations. I will argue that in studying the brain mechanisms that control saccadic eye movements in specific tasks, it can be very useful to consider how fixations would be selected by an ideal observer. Such an ideal-observer analysis provides: (i) insight into the information processing demands of the task, (ii) a benchmark against which to evaluate the actual eye movements of the organism, (iii) a starting point for formulating hypotheses about the underlying brain mechanisms, and (iv) a benchmark against which to evaluate the efficiency of hypothesized brain mechanisms. In making the case, I will describe recent examples from our lab concerning naturalistic visual-search tasks and scene-encoding tasks.

S7: The past, present, and future of the written word

Friday, May 9, 3:30 - 5:30 pm, Royal Palm Ballroom 5

Organizers: Frederic Gosselin[1] and Bosco S. Tjan[2]; [1]Université de Montréal, [2]University of Southern California

Presenters: Susana T.L. Chung, Dennis M. Levi, Denis G. Pelli, Gordon E. Legge, Mark A. Changiz and Marlene Behrmann

Symposium Summary

Gutenberg's invention has democratized the written word: It is estimated that an average English reader will be exposed to over 100 million printed words before the age of 25. The scientific investigation of reading pioneered by Cattell in the 19th century was largely focused on single word recognition through the study of its cognitive, linguistic, and other high-level determinants (e.g., lexical frequency). Accordingly, in most of the influential theories of reading, the front-end visual processing remains unspecified, except with the assumption that it provides the abstract letter identities. This approach to reading greatly underestimates the complexity and the critical role of vision. Text legibility is strongly determined by the ease with which letters can be identified (Pelli et al., 2003), but it appears that standard fonts (e.g., Arial, Times) may be suboptimal as visual stimuli. For instance, the discriminability of a letter from the remainder of the alphabet, as indexed by identification accuracy with brief presentations, is inversely correlated with letter frequency, such that the letters most frequently encountered in texts are among the least discriminable. There is also a significant mismatch between the diagnostic spatial frequency spectra of letters and the human contrast sensitivity function, such that a large proportion of stimulus information is of poor use for the visual system (Chung et al., 2002; Majaj et al., 2002; Poder, 2003; Solomon & Pelli, 1994). Is there room for improvement? Previous attempts to improve reading speed in individuals with low-vision by bandpassing word images in the mid to high spatial frequency range led to equivocal results (Fine & Peli, 1995). However, we have recently witnessed significant advances in our understanding of foveal and peripheral vision and the mechanisms for letter identification and reading. Can this novel knowledge be applied to the development of fonts optimized for normal and impaired visual systems (e.g., developmental, letter-by-letter, or deep dyslexia, macular degeneration, cataract, diabetic retinopathy)? This is the challenge that the organizers of this symposium are submitting to the participants. We hope that this will be the first step toward vision science leading the way to a second Gutenberg-like revolution: Instant speed reading for all!

Presentations

Enhancing letter recognition and word reading performance

Susana T.L. Chung; University of Houston

This talk will provide an overview of our efforts in enhancing letter recognition and word reading performance in the normal periphery and in patients with central vision loss.

Letter recognition, crowding and reading in amblyopia

Dennis M. Levi, Optometry, University of California, Berkeley, Denis G. Pelli, Department of Psychology, New York University and Shuang Song, Optometry, University of California, Berkeley

Crowding, not letter recognition acuity, limits reading in the amblyopic visual system.

Legibility

Denis G. Pelli; New York University

"Legibility" means different things to visual scientists and font designers, and font design affects the different kinds of legibility in different ways.

The eyes have it: Sensory factors limit reading speed

Gordon E. Legge; University of Minnesota

Sensory constraints influence reading speed for normally sighted young adults, children, senior citizens, people with low vision and blind Braille readers.

The structures of letters and symbols throughout human history are selected to match those found in objects in natural scenes

Mark A. Changizi; Rensselaer Polytechnic Institute

New research supports the hypothesis that human visual signs look like nature, because that is what we have evolved over millions of years to be good at seeing.

Cognitive and neural mechanisms of face and word processing: Common principles

Marlene Behrmann, Department of Psychology, Carnegie Mellon University and David Plaut, Department of Psychology, Carnegie Mellon University

Through joint empirical studies (with normal and brain-damaged individuals) and computational investigations, we will argue that face and word recognition are mediated by a highly distributed and interactive cortical network whose organization is strongly shaped and modified by experience rather than by discrete modules, each dedicated to specific, narrowly-defined function.

S8: Surface material perception

Friday, May 9, 3:30 - 5:30 pm, Royal Palm Ballroom 6-8

Organizer: Roland W Fleming; Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Presenters: Roland W. Fleming, Melvyn A. Goodale, Isamu Motoyoshi, Daniel Kersten, Laurence T. Maloney and Edward H. Adelson

Symposium Summary

When we look at an everyday object we gain information about its location and shape and also about the material it is made of. The apparent color of an orange signals whether it is ripe; its apparent gloss and mesoscale texture inform us whether it is fresh. All of these judgments are visual judgments about the physical chemistry of surfaces, their material properties. In the past few years, researchers have begun to study the visual assessment of surface material properties, notably gloss and mesoscale texture ("roughness"). Their research has been facilitated by advances in computer graphics, statistical methodology, and experimental methods and also by a growing realization that the visual system is best studied using stimuli that approximate the environment we live in. This symposium concerns recent research in material perception presented by six researchers in computer science, neuroscience and visual perception.

The successive mappings from surface property to retinal image to neural state to material judgments are evidently complex. Coming to understand how each step leads to the next is a fascinating series of challenges that crosses disciplines. An initial challenge is to work out how changes in surface material properties are mirrored in changes in retinal information, to identify the cues that could potentially signal a surface material property such as gloss or roughness.

A second challenge is to determine which cues are actually used by the visual system in assessing material properties. Of particular interest are recent claims that very simple image statistics contain considerable information relevant to assessing surface material properties. A third challenge concerns the neural encoding of surface properties and what we can learn from neuroimaging, a fourth, how variations in one surface material property affect perception of a second.

A final – and fundamental -- challenge is to work out how the organism learns to use visual estimates of material properties to guide everyday actions -- to decide which oranges to eat and which to avoid.

The symposium is likely to be of interest to a very wide range or researchers in computer vision, visual neuroscience and visual perception, especially perception of color. lightness and texture.

Presentations

Perception of materials that transmit light

Roland W. Fleming; Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Many materials that we commonly encounter, such as ice, marmalade and wax, transmit some proportion of incident light. Broadly, these can be separated into transparent and translucent materials. Transparent materials (e.g. gemstones, water) are dominated by specular reflection and refraction, leading to a characteristic glistening, pellucid appearance. Translucent materials (e.g. marble, cheese) exhibit sub-surface light scattering, in which light bleeds diffusely through the object creating a distinctive soft or glowing appearance. Importantly, both types of material are poorly approximated by Metelli's episcotister or other models of thin neutral density filters that have shaped our understanding of transparency to date. I will present various psychophysical and theoretical studies that we have performed using physically based computer simulations of light transport through solid transmissive objects. One important observations is that these materials do not exhibit many image features traditionally thought to be central to transparency perception (e.g. X-junctions). However, they compensate with a host of novel cues, which I will describe. I will discuss the perceptual scales of refractive index and translucency and report systematic failures of constancy across changes in illumination, 3D shape and context. I will discuss conditions under which various low-level image statistics succeed and fail to predict material appearance. I will also discuss the difficulties posed by transmissive materials for the estimation of 3D shape. Under many conditions, human vision appears to use simple image heuristics rather than correctly inverting the physics. I will show how this can be exploited to create illusions of material appearance.

How we see stuff: fMRI and behavioural studies of visual routes to the material properties of objects

Melvyn A. Goodale; The University of Western Ontario

Almost all studies of visual object recognition have focused on the geometric structure of objects rather than their material properties (as revealed by surface-based visual cues such as colour and texture). But recognizing the material from which an object is made can assist in its identification – and can also help specify the forces required to pick up that object. In two recent fMRI studies (Cant & Goodale, 2007; Cant et al., submitted), we demonstrated that the processing of object form engages more lateral regions of the ventral stream such as area LO whereas the processing of an object's surface properties engages more medial regions in the ventral stream, particularly areas in the lingual, fusiform, and parahippocampal cortex. These neuroimaging data are consistent with observations in neurological patients with visual form agnosia (who can still perceive colour and visual texture) and patients with cerebral achromatopsia (who can still perceive form). The former often have lesions in area LO and the latter in more medial ventral-stream areas. In a behavioural study with healthy observers (Cant et al., in press), we showed that participants were able to ignore form while making surface-property classifications, and to ignore surface properties while making form classifications – even though we could demonstrate mutual interference between different form cues. Taken together, these findings suggest that the perception of the material properties depends on medial occipito-temporal areas that are anatomically and functionally distinct from more lateral occipital areas involved in the perception of object shape.

Histogram skewness and glossiness perception

Isamu Motoyoshi; NTT Communication Science Laboratories

Humans can effortlessly judge the glossiness of natural surfaces with complex mesostructure. The visual system may utilize simple statistics of the image to achieve this ability (Motoyoshi, Sharan, Nishida & Adelson, 2007a; Motoyoshi, Nishizawa & Uchikawa, 2007b). We have shown that the perceived glossiness of various surfaces is highly correlated with the skewness (3rd-order moment) of the luminance histogram, and that this image property can be easily computed by the known early visual mechanisms. Our 'skewness aftereffect' demonstrated the existence of such skewness detectors and their link to the perceived glossiness. However, simple skewness detectors are not very sensitive to image spatial structures. They might not be able to distinguish a glossy surface from, say, a matte surface covered with white dusts while humans can do. These unsolved issues and questions will be discussed together with our latest psychophysical data. Our glossiness study suggests that the perception of material properties may be generally based on simple 'pictorial cues' in the 2D image, rather than on complex inverse optics computations. This hypothesis is supported by the finding that simple image manipulation techniques can dramatically alter the apparent surface qualities including translucency and metallicity (Motoyoshi, Nishida & Adelson, 2005).

Object lightness and shininess

Daniel Kersten; University of Minnesota

Under everyday viewing conditions, observers can determine material properties at a glance--such as whether an object has light or dark pigmentation, or whether it is shiny or matte. How do we do this? The first problem--lightness perception--has a long history in perception research, yet many puzzles remain, such as the nature of the neural mechanisms for representing and combining contextual information. The second--"shininess"--has a shorter history, and seems to pose even stiffer challenges to our understanding of how vision arrives at determinations of material properties. I will describe results from two approaches to these two problems. For the first problem, I will describe neuroimaging results showing that cortical MR activity in retinotopic areas, including V1, is correlated with context-dependent lightness variations, even when local luminance remains constant. Further, responses to these lightness variations, measured with a dynamic version of the Craik-O'Brien illusion, are resistant to a distracting attentional task. For the second problem, I will describe an analysis of natural constraints that determine human perception of shininess given surface curvature, and given object motion. One set of demonstrations show that apparent shininess is a function of how statistical patterns of natural illumination interact with surface curvature. A second set of demonstrations illustrates how the visual system is sensitive to the way that specularities slide across a surface.

Multiple surface material properties, multiple visual cues

Laurence T. Maloney; New York University

Previous research on visual perception of surface material has typically focused on single material properties and single visual cues, with no consideration of possible interactions. I'll first describe recent work in which we examined how multiple visual cues contribute to visual perception of a single material property, the roughness of 3D rendered surfaces, viewed binocularly. We found that the visual system made substantial use of visual cues that were in fact useless in estimating roughness under the conditions of our experiments. I'll discuss what the existence of pseudo-cues implies about surface material perception. In a separate experiment, we used a conjoint measurement design to determine how observers represent perceived 3D texture ("bumpiness") and specularity ("glossiness") and modeled how each of these two surface material properties affects perception of the other. Observers made judgments of "bumpiness" and "glossiness" of surfaces that varied in both surface texture and specularity. We found that a simple additive model captures visual perception of texture and specularity and their interactions. We quantify how changes in each surface material property affect judgments of the other. Conjoint measurement is potentially a powerful tool for analyzing surface material perception in realistic environments.

What is material perception good for?

Edward H. Adelson; MIT

What are the essential ways in which vision helps us interface with the physical world? What is the special role of material perception? One way to approach this question is: 1. Marry a vision scientist. 2. Have children with her. 3. Take videos of your children interacting with the world. 4. Study these videos, taking note of the essential tasks children must master. 5. Make your colleagues watch these videos. For some tasks (e.g., learning the alphabet or recognizing giraffes) material perception is relatively unimportant, but for others (e.g., eating, walking, getting dressed, playing outside, taking a bath) it is critical. The mastery of materials -- the way they look, feel, and respond to manipulation -- is one of the main tasks of childhood. Why, then, is so little known about material perception, as compared to, say, object recognition? One of the issues seems to be that material perception is embedded in procedural knowledge (knowing how to do), whereas object recognition is embedded in declarative knowledge (knowing how to describe). This suggests that material perception should be approached from multiple modalities including vision, touch, and motor control. It suggests that the brain might contain mechanisms devoted to the joint visual/haptic analysis of stiffness, slipperiness, roughness, and the like. In pursuit of this program, we have recently been showing our home videos to colleagues in other fields.

Friday Sessions

Friday, May 9, 5:30 - 8:30 pm
Poster Session, Vista Ballroom

Attention: Selection over Time
Motion: Integration, Flow, and Depth
Object Perception: Neural Mechanisms
Perception and Action: Hand Movements

Attention: Selection over Time

16.101 The contingent negative variation (CNV) event-related potential (ERP) predicts the attentional blink

Kimron Shapiro[1] (k.shapiro@bangor.ac.uk), Elwyn Martin[1], Isabel Arend[1], Stephen Johnston[1], Christoph Klein[1]; [1]School of Psychology, Bangor University, Wales UK

Recently a number of investigators (e.g., Arend et al. 2006; Olivers & Nieuwenhuis, 2005, 2006) have reported the beneficial effects of an "unfocused" attentional mode in the temporal allocation of attention while selecting two targets in the attentional blink (AB) paradigm. An 'overinvestment' hypothesis to account for this benefit has been considered, suggesting that the AB is in fact produced by an 'over-allocation' of attention to the T1 task. To investigate the mechanism underlying the beneficial effect of this unfocused attentional mode the present investigators recorded ERPs while participants took part in a study designed after Arend et al. to attenuate the AB. Separate participants (N = 12) took part in two conditions. In the 'motion' condition, a flowfield of moving dots appeared behind the fixation point two seconds prior to the onset of the RSVP stream and remained for the duration of the trial. This condition was designed to remove attention from the locus of the RSVP stream. In the control 'static' condition an identical number of non-moving dots were placed on the screen in the same locations as in the motion condition. Whereas the 'static' condition showed a normal AB, the 'motion' condition revealed a significantly attenuated AB as was found in Arend et al. (2006). No difference was found for T1 accuracy across conditions. ERPs from a 64-channel (BrainProducts UK) system revealed a slow negative potential shift, similar to the contingent negative variation (CNV), which developed between fixation and RSVP onset. This CNV exhibited a topographical maximum at parietal sites, was larger over the right as compared to the left hemisphere, and importantly was significantly larger before no AB as compared to AB trials in the "motion" group only. These results are discussed in terms of the over-investment hypothesis.

Acknowledgement: The Wellcome Trust (Project Grant 071944) to K. Shapiro

16.102 The "working" component of working memory predicts AB magnitude

Mary MacLean[1] (mm07fi@brocku.ca), Kirk Stokes[1], Carleen Gicante[1], Karen Arnell[1]; [1]Brock University

In rapid serial visual presentation (RSVP) second target (T2) accuracy decreases with temporal proximity to the first target (T1). This phenomenon is known as the attentional blink (AB). Colzato et al. (2007) used an individual differences approach to examine whether individual AB magnitude was predicted by working memory (WM) operation span, using the Operation Word Span paradigm (OSPAN), and general cognitive ability, measured with Raven's Standard Progressive Matrices (SPM). They found that OSPAN score inversely correlated with AB magnitude even with Raven's SPM partialled out. However, it is not clear from this study whether active "working" memory ability would predict AB magnitude better than a less dynamic measure of short-term memory capacity. Using a continuum of WM measures that reflect varying degrees of the active "working" process could better define the source of the relationship. The digit-forward task is a simple rote memory task that reflects static STM capacity, requiring individuals to repeat a string of digits in order of presentation. The digit-backward task requires an increasing degree of the active "working" component by having individuals repeat the string of digits in the opposite order of presentation. Our study used these measures plus a reliable measure of individual visual memory capacity (k) in addition to the OSPAN; as well as Raven's SPM and a reading comprehension task to look at as predictors of individual AB magnitude. Dramatically, the OSPAN still inversely correlates with AB magnitude with Raven's SPM, reading comprehension, and digit- forward and backward partialled out. This is strong support that a "working", executive component of WM predicts temporal limitations of selective attention beyond static STM capacity and general cognitive ability.

16.103 That's My Name, Don't Wear it Out: Attentional Blink and the Cocktail Party Effect

Gillian Dale[1] (gillian.dale@brocku.ca), Ryan Young[1], Karen Arnell[1]; [1]Brock University

When individuals are asked to identify two targets in an RSVP task, accuracy on the second target (T2) is reduced if presented shortly after the first target (T1) — an attentional blink (AB). Previous research has shown that sexual words can increase the magnitude of the AB when presented as T1, set off an AB as a distractor, and can overcome the AB when presented as T2. When an individual's name is presented, it too can set off an AB as a distractor, and overcome the AB when presented as T2, but one study has shown that the AB is not affected when a person's name is presented as T1 (Shapiro et al., 1997). As sexual words and personal names are especially salient stimuli, it is surprising that own names do not create a larger AB when presented as T1. To examine this, we used an AB task where we presented own names, other names, or nouns as T1, and neutral colour names as T2. The AB was significantly increased for own names as compared to other names and nouns, but only for the first 15 presentations of the name. For each participant there is only one own name, yet sets of over 20 sexual words have been used in previous studies. Therefore, sexual words may be able to show effects over 20 times more trials than own names. Indeed, when we examined the impact of own names presented as T1 to a single sexual word presented as T1, the AB magnitude and the number of trials before the effects disappeared were comparable. We conclude that own names are salient stimuli and increase the AB when presented as T1, but that this effect rapidly disappears due to the fact that only one stimulus can be used in the own name condition.

Acknowledgement: NSERC and CFI/OIT

16.104 When do additional distractors reduce and increase the attentional blink?

Jun Kawahara[1] (jun.kawahara@aist.go.jp); [1]National Institute of Advanced Industrial Science and Technology

When two targets are embedded in a rapid serial visual presentation stream of distractors, perception of the second target is impaired when the inter-target lag is relatively short (less than 500 ms). Stimuli concurrently presented with the stream can affect this phenomenon, which is called attentional blink (AB). Previous studies have yielded conflicting results concerning the direction of the effect of added distractors on the AB: some studies (e.g., Kawahara, 2003; Visser et al., 2004) report an increased AB, while others (e.g., Choo and Kim, 2006) report a decreased AB. The present study explored the boundary conditions of the exaggeration/reduction effects of distractors on the AB and investigated possible underlying mechanisms by manipulating the spatial configuration, timing, and type of distractors. Specifically, Experiments 1-3 manipulated the spatial uncertainty and spatial switching between the targets independently and found that location uncertainty of at least one of the targets was a critical factor in explaining the apparent inconsistency between the studies of Visser et al. (2004) and Choo and Kim (2006). The results of Experiments 4-6 indicated that the magnitude of the AB deficit increased, regardless of the type of distractors, when spatial uncertainty of the target locations was involved. Interestingly, the reduction effect occurred when task-irrelevant distractors were presented, but the effect depended on the similarity between the distractors and targets: if the irrelevant items were too similar or too dissimilar, the reduction effect did not occur. Moreover, the reduction effect occurred only when the second target was presented at subthreshold level. These results suggest the possible contribution of stochastic resonance or the centre-surround attentional mechanism in producing the effects of distractors on the AB deficit.

16.105 **Shrinking and Shifting: Two alternative task-dependent modes of attentional control**

Lisa N. Jefferies[1] (ljefferi@gmail.com), Vincent Di Lollo[2]; [1]University of British Columbia, [2]Simon Fraser University

There is substantial evidence both for a broad focus of attention that shrinks/expands (e.g.,Eriksen & St.James,1986) and for a narrow focus that shifts from one location to another (Weichselgartner & Sperling,1987). We hypothesized that either mode of attentional control (shrink/expand vs. shift) can be implemented, depending on task demands. We used the attentional blink (in which perception of the second of two targets is impaired at short inter-target lags) and Lag-1 sparing (spared perception of the second target when it is presented directly after the first) to test this hypothesis. In the present work, two concurrent streams of random-dot-pattern distractors were presented one on either side of fixation. Lag-1 sparing is known to occur to targets (letters) in different streams only if the second target falls within the attentional focus. Thus, the magnitude of Lag-1 sparing provides an index of the spatial extent of attention. One group of participants knew which stream would contain the first target, encouraging a narrow focus that is shifted between the two streams. For a second group, the targets appeared in either stream unpredictably, encouraging a broad focus of attention encompassing both streams. To manipulate the time available for changing the extent/location of the focus of attention, we varied the stimulus-onset-asynchrony between successive items in the stream. If participants did not know which stream would contain the first target, there was a gradual, linear change from Lag-1 sparing to Lag-1 deficit with increasing SOA, indicating a broad focus of attention that shrank to the location of the first target. If participants knew which stream would contain the first target, Lag-1 deficit changed to Lag-1 sparing, indicating a narrow focus of attention shifted from the first-target stream to the opposite stream. These results also speak to the relative time course of shrinking/expanding and shifting the focus of attention.

Acknowledgement: Grants to LNJ and VDL from the Natural Sciences and Engineering Research Council of Canada

16.106 **Delay of selective attention during the attentional blink**

Deborah Hanus[1] (dhanus@mit.edu), Edward Vul[1], Nancy Kanwisher[1]; [1]Brain and Cognitive Sciences, MIT

The attentional blink refers to the inability to report the second of two targets in an RSVP stream when they are separated by 200-500 msec. Recent evidence shows that this failure results from three dissociable changes to the properties of temporal selective attention. During the attentional blink, selection is suppressed (items are selected less effectively, resulting in greater levels of random guessing) and delayed (the items that are selected tend to be later in the RSVP stream relative to the cue) (Vul, Nieuwenstein, Kanwisher, in press). Here we assess the properties of the delay in selection and evaluate how the delay contributes to the attentional blink. First, by pre-cueing, we manipulate the delay of selective attention and show that neither delay nor suppression alone is sufficient to account for the failure to report the second target; thus both play a role in the usual attentional blink. Second, we explore the persistence of the delay effect over much longer T1-T2 SOAs and show that the effect remains strong at lags of 1400 msec and appears to subside with a time-constant of roughly 500 msec. Third, we manipulate RSVP rate and measure delay as a function of serial position and delay as a function of time – we find that across RSVP rates, delay at a fixed SOA is constant as a function of time and variable as a function of serial position, indicating that the "delay" of selection is a delay in time.

16.107 **Individual Differences in Distractor Priming During the Attentional Blink: Distractor Inhibition Gives Rise to Awareness**

Paul Dux[1,2,3] (paul.dux@vanderbilt.edu), René Marois[1,2,3]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center, Vanderbilt University, [3]Center for Integrative and Cognitive Neurosciences, Vanderbilt University

The attentional blink (AB) refers to subject's impaired ability to detect the second of two targets (T2) in a rapid serial visual presentation (RSVP) stream of distractors if it appears within 200-600 ms of the first target (T1). As is the case with many cognitive tasks, there are large individual differences in AB magnitude. Here we show that a key determinant of this variability is the extent to which subjects are able to inhibit distractors in the RSVP stream. Distractor inhibition was assessed by measuring the extent to which T2 was primed from a distractor presented within the AB. We found that while subjects with small ABs displayed negative priming (i.e. worse performance on T2 when it was preceded by a distractor stimulus that shared its identity), subjects with greater AB magnitude instead displayed positive priming (T2 performance improved by the presence of a preceding distractor stimulus with the same identity). These findings demonstrate that distractor inhibition plays a vital role in the conscious perception of stimuli distributed across time and have strong implications for theories of the AB.

Acknowledgement: NIMH grant R01MH70776 to R.M

16.108 **Object processing in the absence of attention**

Irina Harris[1] (irina@psych.usyd.edu.au), Claire Benito[1], Paul Dux[2]; [1]School of Psychology, University of Sydney, Australia, [2]Department of Psychology, Vanderbilt University

We investigated how ignored objects are processed, by examining priming from a distractor under rapid serial visual presentation (RSVP) conditions. Subjects performed a dual-target RSVP task in which they were required to report two red target objects embedded within streams of black object distractors. Target 1 was an upright object, while Target 2 and the distractors appeared in different orientations. On a proportion of trials, one of the distractors (priming distractor) in the stream had the same identity as Target 2 and was presented either in the same orientation or rotated by 90°. In Experiment 1, the priming distractor occurred prior to Target 1 (serial position T1-2), and resulted in Target 2 accuracy being enhanced when the priming distractor had a different orientation to Target 2, but not when it had the same orientation. These results indicate that orientation-invariant information extracted from an ignored distractor can prime a later target. However, this priming effect appeared to be moderated by attentional suppression of distractors, leading to a loss of priming when the priming distractor was identical to Target 2 (same identity and orientation). To test this, in a second experiment, we examined the influence of the priming distractor when it was presented within the attentional blink, where distractor suppression is impaired (Dux & Harris, 2007). When the priming distractor was presented at Lag 2 and Target 2 appeared at Lag 4, there was equal positive priming for the second target regardless of the orientation of the priming distractor. The findings suggest that object identity and orientation are at least partially independent and that attention plays an important role in the representation of object orientation.

Acknowledgement: Funded by ARC grant DP0557590

16.109 **Noise Overlay on the RSVP stream reduces the AB**

Fook Chua[1] (fkchua@nus.edu.sg); [1]Psychology, National University of Singapore

In the typical single-stream RSVP task, two target letters (T1 and T2) are embedded among other letter distractors, with each item presented for 100 ms and then replaced by the next item. Identification of T2 is poor if it lags the first (T1) by 200-500 ms. This phenomenon, the attentional blink (AB), has been attributed to processing demands of T1. In this set of experiments, we overlay the letter stream with a 8x8 noise matrix, which was irrelevant to the task. Observers were instructed to ignore it. In Experiment 1, 3 conditions were compared: (a) canonical (no noise matrix); (b) static noise matrix; and (c) changing noise matrix. There was no difference between (a) and (b), which performance was worse than (c). When the noise matrix changed as the letters changed, performance was enhanced. In the following experiments, we show that the critical loci were the frame following the targets (i.e., the T1+1 and the T2+1 frames). In Experiment 2, the focus was the frame succeeding T2 (i.e., T2+1 frame). When the noise matrices of the T2 and the T2+1 frames were identical, performance was worse. In Experiments 3 and 4, the noise matrix of the T1+1 frame was manipulated. The results showed that when the noise matrix of the T1+1 frame was different from the preceding T1 frame, performance improved. We argue that the AB is caused by a failure in rapid disengagement from the T1 stimulus. Visual cues that inform the system that the T1 episode is over facilitates disengagement and thus modulates the blink. The changing noise matrix signals the visual system that a new frame has appeared, goading the attentional system to disengage from the previous temporal locus.

Acknowledgement: NUS Grant R-581-000-042-112

16.110 **Inter-trial switches in perceptual load modulate semantic processing during the attentional blink**

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Classic studies in the attentional blink (AB) literature indicate that despite the severe impairment in identification of the second of two briefly presented targets (T1 and T2), semantic information about T2 survives the AB. However, recent work has demonstrated that semantic processing is attenuated when i) the T1 task is perceptually demanding (Giesbrecht, et al., 2007) and ii) when there is a task-switch between T1 and T2 (Vachon, et al, 2007). In the present experiments, we examined whether a switch in attentional-set between trials affects semantic processing during the AB. In two experiments, participants identified two masked targets presented in rapid succession. In both experiments, the T1 task was to identify the direction of a central arrow while perceptual load was manipulated by the direction of irrelevant flankers (i.e., low load, >> > >>; high load, >> <>>). In Experiment 1, the T2 task was to discriminate the gender of a name that was either the participant's name or a different name. In Experiment 2, the context-sensitive N400 event-related potential evoked by T2 was measured while participants indicated the relationship of a T2 word to a context word presented at the start of the trial. Trials were analyzed as a function of whether T1-load on consecutive trials was the same (repeat trials) or different (switch trials). Experiment 1 indicated that there was a significant AB for both name conditions on switch trials, but only an AB for someone else's name on repeat trials. Experiment 2 found that the magnitude of the N400 during the AB was suppressed on switch trials relative to repeat trials. The finding that semantic processing during the AB is influenced by switching attentional-set between trials is consistent with the notion that the locus of selection is flexible and determined by task demands.

URL: http://www.psych.ucsb.edu/labs/giesbrecht/

16.111 **Rapid reconfiguration reduces the attentional blink**

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Visual attention has been conceived of as a dynamic system that configures and maintains visual input filters for specific features, objects and/or locations depending on goals and the current task demands. Temporarily losing control of this input system has been proposed as a cause of the performance impairment known as the attentional blink (AB). According to this proposal (Di Lollo, Kawahara, Ghorashi, & Enns, 2005), when the visual system is faced with identifying two masked targets presented in a rapid sequence, accurate selection and processing of the first target (T1) induces a momentary loss of control over the maintenance of input filters. This loss of control results in the impaired selection and processing of the second target (T2). The purpose of the present work was to test whether cued reconfiguration of attentional sets can be used to reduce the AB. In these dual-task experiments, T1 was not only one of the critical targets, but it also served as a cue that was either an accurate predictor of the category of T2 or it was not predictive of the category of T2. The results indicated that the severity of the AB was reduced when T1 predicted the category of T2 relative to when T1 did not accurately predict T2. These results suggest that the dynamic process of establishing and maintaining attentional sets can be rapidly reconfigured to reduce the performance decrements typically observed during the attentional blink.

16.112 **ERP Evidence for Temporary Loss of Control During the Attentional Blink**

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The attentional blink (AB) occurs when paying attention to one target (T1) results in impaired identification of a second target (T2) occurring 300-600 ms later. According to limited capacity accounts, T1 depletes the limited resources necessary for memory consolidation, allowing the T2 visual representation to decay and be overwritten. This explanation has recently been challenged by the "Temporary Loss of Control" theory (TLC) which proposes that processing of T1 temporarily interferes with the maintenance of information that defines T2 (e.g., "look for red digits"). Distractors that follow T1 can reset the filter settings exogenously, causing the filter setting for T2 to be lost. Consequently, T2 is not selected and fails to reach working memory. The current research was designed to provide a direct measure of perceptual control settings in order to determine whether maintenance of these settings is indeed interrupted by detection of targets. We examined two ERP components (occipital selection negativity and frontal selection positivity) that index the discrimination and selective processing of particular features (e.g., the color red). Experiment 1 required participants to identify both a digit (T1) and an odd colored letter (T2) among a stream of letter distractors. The amplitude of both selection components was suppressed for a short time following detection of T1. To determine if this pattern of findings was caused by the need to switch target categories between T1 and T2, a second experiment was conducted with digits serving as both targets. Once again, both selection components were suppressed following detection of T1. Taken together, these findings support the TLC theory in showing that maintaining a set for T2 is disrupted for a short period following detection of T1.

16.113 **Evidence for rapid extraction of average size in RSVP displays of circles**

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To reduce redundant information, the visual system may create statistical representations of sets, discarding information about individual items. Ariely (2001) found that observers could not reliably determine whether a test circle appeared in a set of circles presented immediately beforehand, but could determine whether it corresponded to the mean size of the set. Here we investigate whether the average size of a set of circles presented in a rapid sequence is statistically represented. In Experiment 1, an RSVP display of circles was followed by a test circle, and observers determined whether the test circle was the mean or a member of the set. Observers could determine average size, but could not identify individual circles. Furthermore, the test circle was erroneously identified as the mean with increasing frequency as the difference in size between the target and mean decreased. To determine whether performing the mean identification task depleted central attentional resources needed to perform concurrent processing, in Experiment 2 observers were presented either with a stream of circles (and identified the mean) followed by a stream of shapes, or with a single circle within a stream of shapes (and identified the size of the circle). The target shape followed the circle(s) at one of five lags. Shape identification was better at short lags following the mean task compared to the single circle task. Further, shape identification was lag-dependent following the single circle task (an attentional blink; Raymond, Shapiro, & Arnell, 1992), but unaffected by lag following the mean judgment task. This suggests that identifying a single circle, but not judging the mean of the set, depleted central attentional resources necessary to perform the subsequent shape task. We conclude that rapid averaging over sequentially presented displays is accomplished by an efficient, possibly unavoidable process, that does not require central attentional resources.

16.114 **Can race enhance perceptual awareness? Evidence from the attentional blink paradigm**

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When two visual targets are presented in a rapid serial visual presentation sequence, people typically demonstrate a brief impairment in subjective awareness for the second visual target, a phenomenon known as the 'attentional blink.' Here we investigated the influence of race as a salient visual cue to modulate this temporary perceptual impairment for faces when shown in a rapid visual presentation sequence. In this experiment, Black and White participants viewed a rapid serial visual stream of distractor images and intact Black and White target faces, which were presented sequentially at varying degrees of temporal lag. When the second visual target was a face of a different race, Black and White participants demonstrated an attenuation of the attentional blink. This finding demonstrates that race can enhance subjective awareness and highlights the importance of race in shaping the initial perceptual experience of faces.

16.115 **Does the prolonged attentional blink to emotional stimuli affect driving performance?**

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The attentional blink is a temporary delay in responding to a second stimulus in a stream after attending to the first. Recent investigations suggest the duration of the attentional blink is longer after viewing pictures with a negative emotional valence (Most, Chen, & Widders, 2005) though this effect has never been demonstrated in a day-to-day task. This study investigated whether this extended attentional blink would have an impact on driving performance. Participants were tested in a DriveSafety DS-600c driving simulator (a full car body surrounded by six viewing screens that immersed drivers in a 300 degree wrap-around virtual driving environment). They were required to drive down a virtual highway, following a lead vehicle. During the 75 minute drive they were exposed to high and low arousal pictures from the International Affective Picture System (IAPS: Lang, Bradley, & Cuthbert, 2001), pictures that had either a positive or negative emotional valence. In most cases, participants would simply be required to indicate whether the picture was positive or negative while lane keeping performance was assessed. However, occasionally the lead-vehicle would brake unexpectedly, forcing the participant to brake. Braking response times after positive and negative pictures were compared to those in a baseline (no picture) control condition. Results have practical implications as they relate to the enhanced collision risk that may occur as the result of upsetting images displayed on billboards or on in-vehicle entertainment devices (e.g., onboard DVD players).

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Motion: Integration, Flow, and Depth

16.116 **Similar Processing for Detection and Position Discrimination of Expanding, Contracting and Rotating Motion Flow Patterns in Random Dot Kinematograms, Shown by Adaptation and TMS**

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Accurately localizing the centre of an expanding, contracting or rotating motion pattern is a key element of optic flow processing, necessary for example for deriving heading from optic flow. We have previously shown that, unlike the detection of an optic flow pattern, centre-of-motion localization depends on a very small region near this centre (Harvey and Braddick, 2006 Perception 35S, 238). Together with studies showing normal localization in a stroke patient with direction discrimination deficits (Beardsley and Vaina, 2005 Journal of Computational Neuroscience 18 55) and retinotopic activation of V3A depending on the positions of centres of radial motion (Koyama et al, 2005 Current Biology 15 2027-2032), this suggests that centre localization and flow pattern detection may depend on distinct cortical systems. Here we show, however, that adaptation to radial or rotating flow patterns affects coherence thresholds for detection and centre-of-flow position discrimination similarly, and at a global processing level. For both pattern detection and position discrimination, adaptation to the tested pattern or to a flow pattern moving in the opposite direction (e.g. contracting adaptation for an expanding test pattern) increases test coherence thresholds. In both tasks, however, adaptation to expansion does not significantly impair processing of contraction in most subjects. In neither task did adaptation to a rotating pattern affect performance on a radial test pattern, or vice versa. Furthermore, repetitive TMS stimulation of hMT+ affects both tasks, while TMS over V3A and nearby areas affects neither. These results suggest that the position of motion patterns is encoded in the global motion processing areas of hMT+. Furthermore, we show that when detection and position discrimination tasks are equated for difficulty, pattern detection can be achieved after a briefer exposure than position discrimination, suggesting that accurate position information requires longer temporal integration than detection of a flow pattern.

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16.117 **Coherence dependence of high-density visual evoked potentials to global form and motion displays**

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Coherence thresholds for global form and motion can be used to assess function of the extra-striate ventral and dorsal pathways respectively. Psychophysical thresholds are similar in adults, but show differential development, and motion thresholds are raised in a variety of developmental disorders.

Thresholds can also be estimated by measuring the amplitude of visual evoked potentials (VEPs) as a function of coherence, and extrapolating to zero amplitude. With a single occipital channel, VEP form and motion thresholds are similar, but motion amplitudes are about half those for form coherence (Braddick et al, VSS 2006). Here, we extend this approach to high-density (128 channel) VEPs to address three questions: (a) are the single-channel amplitude differences a result of non-optimal electrode location for form and/or motion? (b) are form and motion VEP thresholds the same when each is measured at its optimal location? (c) do any scalp locations show a non-linear response to coherence, as found in some brain regions with fMRI?

The form stimulus had dots arranged in short concentric arcs giving a static global circular pattern. The motion stimulus dots moved along similar arcs, producing global rotation. Coherence of each pattern type varied from 0% - 100% in separate recording blocks. These patterns alternated at 2 Hz with randomly-arranged dot trajectories with no global structure.

Both form and motion elicited significant posteriorly-located VEPs, showing significant linear regression with coherence. Amplitudes of the peak responses to form and motion were similar, but the locations differed; the motion peak was close to the midline, the form peak more lateral. Form and motion VEP thresholds derived from these peaks were similar to each other, but significantly greater than the psychophysical thresholds. Finally, we found no evidence of systematic 2nd- or 3rd-order non-linearities at any scalp location.

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16.118 **Common first- and second-order motion processing at high temporal frequencies**

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At high temporal frequencies, early compressive nonlinearities within the visual system introduce artifacts enabling luminance (i.e. first-order) sensitive mechanisms to process contrast-modulated (i.e. second-order) stimuli. However, it is generally accepted that the impact of such artifacts can be canceled by adding a luminance grating. Furthermore, the fact that CM stimuli can be perceived even when compensating for such artifact is generally considered as evidence of two distinct motion processing pathways. The target of the present study was to investigate whether LM and CM processing at high temporal frequencies are common or distinct by trying to dissociate them using a noise masking paradigm. The CM stimuli were constructed so that the signal and carrier spatial frequencies importantly differed (0.5 cpd and 7-to-9 cpd, respectively). Using a direction discrimination task, contrast thresholds to LM (0.5 and 8 cpd) and CM (0.5 cpd) drifting (8 Hz) gratings were measured in dynamic noise filtered at either low (0.25-to-1 cpd) or high (4-to-16 cpd) spatial frequencies. For CM processing, early compressive nonlinearities were measured and compensated for by adding a LM grating. At the noise contrasts tested, the processing of 0.5 cpd LM gratings was more affected by low than high spatial frequency noise and the processing of 8 cpd LM gratings was more affected by high than low spatial frequency noise. This predictable double dissociation shows that the processing of 0.5 and 8 cpd LM gratings is, at least partially, distinct. CM processing was affected by similar proportions as luminance processing at 0.5 cpd. In other words, we failed to dissociate LM and CM processing (both at 0.5 cpd) suggesting that they are common. We propose a model within which non-uniform early nonlinearities across the visual field would cause non-uniform artifacts explaining CM processing at high temporal frequencies without inferring distinct processing.

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16.119 The Perceived Motion Direction of Fast-Moving Type-II Plaids

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A plaid motion stimulus consists of two superimposed sinewave gratings moving in independent directions. Every plaid has a rigid interpretation as a translating single frame. Sometimes plaids components are perceived to move transparently in different directions, sometimes in the direction of the vector sum of the component direction-speed vectors, sometimes in the rigid direction. Whereas the vector sum direction always lies between the two component directions, in Type-II plaids, the rigid direction lies outside, making Type-II plaids useful for discriminating theories. We varied component-contrasts of Type-II plaids to produce different contrast ratios and used high temporal frequencies (e.g., 10 and 20 Hz) to exclude third-order motion ("feature tracking"). Explanations of previous plaid experiments have concentrated on "rigid" versus "vector sum" directions. With our plaids, 1 cycle/deg gratings within a circular Gaussian window, we find something quite different. At sufficiently high temporal frequencies, perceived plaid motion direction is entirely determined by the contrast ratio of the components. Whenever the contrast of the higher-contrast grating exceeds the lower by more than about 4:1, perceived direction is the direction of the higher-contrast component. For intermediate contrast ratios, all intermediate directions are systematically observed. For contrasts of the higher-contrast component ranging from 4 to 32%, the perceived plaid direction depends entirely on the components' contrast ratio, independent of overall contrast. However, when component temporal frequencies decrease towards the range of third-order motion, the direction of plaids with equal and near-equal-contrast components deviates increasingly towards the rigid direction, especially at higher overall contrasts. Conclusions: When only the first-order motion system is stimulated, perceived plaid direction is determined by the relative strengths of the components, strength increasing monotonically with grating contrast. Slower third-order motion processing influences perceived plaid motion towards the rigid direction. The vector sum direction is irrelevant.

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16.120 Motion integration fields are dynamically elongated in the direction of motion

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In order to solve the aperture problem, and to reduce noise, motion estimates are integrated over space. Nishida et al (2006, Journal of Vision, 6(6):1084) showed that arrays of randomly oriented 1D motion elements appear to move coherently in a single direction if the speeds are consistent with a specific 2D motion. It is generally assumed that motion integration fields are radially symmetric. If so then coherence should be unaffected by rotating the global configuration of the motion elements with the distribution of local velocities held constant. To test this we compared the apparent speeds of arrays of Gabor and Plaid elements (1 or 2 superimposed sine gratings modulated by Gaussian windows). Subjects were shown arrays of Plaids drifting in one direction followed by spatially identical arrays of randomly oriented Gabors drifting in the same global direction and were asked to judge which was moving faster. The 50% point on the psychometric function was used as a measure of the perceived speed of the Gabors. At high densities the two stimuli were comparable, but the relative perceived speed of the Gabors fell as the number of patches decreased. The reduction in perceived speed can be interpreted as resulting from a loss of coherence accompanied by a shift from an intersection of constraints calculation towards a vector average speed estimate. We also found that Gabors arranged in a line appeared to move slower than when arranged randomly. We then compared global motion parallel or orthogonal to the in line spatial layout. Global motion appeared slower when orthogonal, rather than parallel, to the line. This indicates that the integration zone underlying the global motion computation must be dynamically elongated in the direction of motion. This asymmetry is reminiscent of the 'association fields' of contour and motion integration.

16.121 Spatial scale invariance of the amblyopic global motion deficit

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It has been demonstrated that amblyopic observers are impaired in the processing of global motion [Simmers, AJ, Ledgeway, T, Hess, RF, and McGraw, PV, Deficits to global motion processing in human amblyopia. Vision Res, 2003. 43(6): p. 729-38]. Whilst the contrast sensitivity deficit in amblyopia shows a clear dependence on spatial scale, being greater at finer scales, the spatial scale dependence of the global motion deficit is not yet known. We used global motion stimuli composed of isotropic log Gabors, each adjusted for their detectability, to determine the spatial scale of the amblyopic global motion deficit. The deficit relative to normal eyes was constant across spatial scale. The relative deficit between the amblyopic and fellow eyes did, however, show a dependence on velocity. Using elements that are a constant factor above the thresholds of the normal and amblyopic eyes, for different spatial scales, ensures that the spatial scale dependence that we measure for global motion reflects the properties of a deficit whose site is likely is likely to be beyond V1.

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16.122 The perception of path curvature: Effects of projected velocity and projected size

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Previous research (Todd, 1984) has shown that observers can judge 3-D surface curvature from the motion of texture elements in a 2-D projection. Our recent research (VSS, 2007) found that observers are sensitive to available velocity information when judging the trajectory of an object moving along a straight path in a 3-D scene. The present study examines the degree to which the projected velocity function and the projected size change function can be used to judge the sign of curvature of the motion trajectory of an object moving towards the observer. The displays simulated a ball moving towards the observer above the ground against a realistic scene background. The simulated motion path was either curved upward or downward relative to a level path, with one of two curvature magnitudes in each direction. The projected path was identical in all conditions. In one condition, the curvature of the simulated path was indicated by both the projected size change function and the projected velocity function. In a second condition, the curvature was indicated only by the size change function, with the velocity function corresponding to a level path. In the third condition, the velocity function indicated the curvature, with the size change function indicating a level path. Observers were able to judge the direction of curvature (upward or downward) from the velocity change function alone, but not from the size change function alone. This indicates that variations in projected velocity indicating path curvature are more important than variations in projected size in determining perceived curvature in a 3-D scene.

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16.123 Motion detection sensitivity enhanced by induced motion

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Visual perception of motion depends on motion detection threshold, and motion with slower velocity than threshold is not perceived. Visual motion information is thought to pass through three stages: local motion processing, spatial contrast of motion, and integration of motion directions. However, it is not clear in which stage motion detection threshold is determined physiologically. The purpose of our study is to test whether motion detection threshold is affected by induced motion (Dunker, 1929), in which a central stimulus, even if it is stationary, appears to move in the opposite direction to the motion in the surround. Since this phenomenon is arguably related to the stage of spatial contrast of motion, induced motion should affect detection threshold if it is determined after the spatial contrast. Thus, we compared the detection thresholds for motions with and without integration with induced motion. We presented a central Gabor patch moving leftward or rightward together with a grating moving upward or downward within a surrounding annulus. The surround moved in one of nine speeds, stayed stationary, or was left blank. When the surround moved (e.g., upward), the central Gabor patch was induced to move perceptually in the opposite direction (e.g., downward), and if it was physically moving (e.g., rightward), the illusory direction and physical direction were integrated (e.g., appeared to move down-right). We determined the motion detection threshold of the Gabor patch for each condition by two-alternative forced-response task of directional judgment (left vs. right). The result showed that, at a certain range of surround motion speeds, the threshold for motion integrated with induced motion (perceptually moving diagonally) was lower than the threshold for motion not integrated with induced motion (i.e., conditions of stationary or blank surround). Our result indicates that motion detection threshold is physiologically determined at a stage after integration of motion direction.

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16.124 **Motion Grouping/Segmentation Via Velocity Gradients**

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Introduction: Plants and animals bear extended limbs whose velocities vary smoothly with distance from the trunk or torso. Conversely, local velocity measurements change abruptly between occluding and occluded objects. This suggests velocity gradients may be useful for perceptual grouping/segmentation. Here we test perceptual grouping/segmentation as a function of velocity gradient magnitude.

Methods: Stimuli were obliquely oriented velocity gradients (either +45° or -45°) over dense random noise patterns with velocities either collinear or orthogonal to the gradient. Subjects indicated gradient orientation in a 2AFC task over multiple gradient magnitudes. Velocity endpoints (2 and 3 cycles/sec) and spatial frequency (2 cpd) were held fixed while gradient center location and gradient sign varied over trials.

Results: Performance for gradient-orientation identification peaks for steep velocity gradients and falls off smoothly for shallower gradients. Furthermore, performance is best when motion and gradient directions are orthogonal and worst when they are collinear.

Conclusions: A gradient's maximum and minimum velocity endpoints provide unambiguous orientation identification information, however, observers' performance varies significantly depending on whether the gradient between velocity endpoints is steep or shallow. This suggests that the visual system links similar local velocity estimates and segregates differing estimates, which subsequently makes the gradient endpoints difficult to distinguish in the shallow gradient case and easier to distinguish in the steep gradient case. While steep gradients generally facilitate perceptual segregation, motion directions orthogonal to the velocity gradient direction maximize this percept.

16.125 **Visual motion interaction between central and peripheral visual fields for the manual following response**

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When a sudden large field visual motion is presented during arm reaching, a quick and involuntary manual response occurs in the direction of visual motion. A unique feature of this manual following response (MFR), distinctive from the ocular following response and possibly from conscious visual motion perception, is high sensitivity to visual motion presented in the far periphery. We recently demonstrated that the MFR amplitude increased progressively with stimulus size (up to 50 deg in diameter) when the stimulus area was filled with the low spatial frequency sinusoidal grating (Gomi et al. 2007 Society for Neurosci.). To evaluate how the central and peripheral visual fields contribute to, and interact in, the MFR generation, we here presented sudden sinusoidal grating motions with different spatial frequencies (0.02, 0.05, 0.2, 0.8 cpd, 10Hz) in one of or combination of the three eccentric visual fields (center, near-periphery, far-periphery) during arm reaching movements. When the stimulus was shown only in the far- or near-periphery, the strong MFR was generated especially by the spatial frequency of 0.05 cpd, suggesting a significant influence of the peripheral visual field on the MFR. More interestingly, when more than two visual fields were stimulated simultaneously, the MFR amplitudes were not simply accumulated. The MFR amplitude was sometimes even smaller than that evoked only one of the visual fields when the adjacent visual fields were simultaneously stimulated. When the center and far-periphery were simultaneously stimulated, on the other hand, the MFR appeared to be greater than the MFR in each of the single visual field conditions. These results suggest that strong suppression interactions exist between the adjacent visual fields in generating MFR, possibly contributed by the spatial integration process of visual motion between the striate and extrastriate cortices.

16.126 **Stability of SSVEP Responses to Optic Flow**

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Adults have distinct patterns of neural activation in response to specific patterns of optic flow. The stability of the VEP response has not been investigated, but is crucial for understanding changes across time such as those that occur during development. Two adult participants (1 female) participated in 4 VEP data sessions across a period of several weeks. During each session, the participants observed random dot patterns of optic flow consisting of translational motion, rotational motion, and expansion/contraction. The displays reversed direction at 1 Hz. EEG was measured with a standard 5-channel electrode array over positions PO7, O1, OZ, O2, and PO8. The EEG waveform was analyzed by amplitude at harmonics 1F1-5F1 of the fundamental frequency. Stability was assessed by Spearman-Brown correlations of phase-locked amplitude across sessions and a Spearman rho test of the rank-ordered harmonic amplitudes. Consistent with previous research, translational displays evoked the highest phase-averaged amplitudes at 2F1 and 4F1. Midline (O1, Oz, O2) channels showed the highest between-session stability for the translation condition in both participants. For one participant, these same channels showed high stability for the expansion display, but only modest stability for rotation. The other participant showed higher stability for rotation than expansion. The results suggest that there is moderate stability in ssVEPs to some patterns of optic flow, that there are individual differences in the stability of the response depending on display type, and that lateral channels show less stable responses overall.

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16.127 **Linear sub-space modeling responses to transparent motions comprised of radial dot flows**

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Motion contrast describes a systematic pattern of error in apparent motion direction that occurs when two independently-moving groups of elements are transparently superimposed (Marshak and Sekuler, 1979). Dyre, Richman, and Fournier (2000) found a similar motion contrast effect on the localization of the foci of expansion in transparently superimposed diverging optical flow. Observers perceived a single coherent flow with an FOE between the actual FOEs for angular separations between the FOEs of less than 8° (attraction error), and two transparent flows with FOEs repulsed away from the actual FOEs (repulsion error) for greater angular separations. Similarly, Duffy and Wurtz (1993) showed that planar motion shifts the apparent location of the FOE of a diverging flow in the direction of planar motion. Here we examined the responses of linear sub-space heading models (Heeger & Jepson, 1992; Lappe & Rauchecker, 1995) to optical flow exhibiting non-rigid motion transparency to determine whether these models can account for these effects. Results show that the Heeger & Jepson (1992) model accurately predicts attraction errors, but is incapable of recognizing multiple radial flows. The 2-layer (emulating MT and MSTd) linear sub-space model described by Lappe & Rauschecker (1995) accurately predicts attraction errors and is capable of recognizing multiple flows, but does not predict repulsion errors, although it has accurately modeled the Duffy and Wurtz illusion (Lappe & Duffy, 1998). Lappe and Duffy theorize the illusion is an emergent property of the MST layer population response. We speculate that when two radial flows are presented symmetrically about the center of the field of view at angular separations less than 16° any bias in population response is nulled by an opposing bias. Current research is investigating whether a competitive layer of directional tuned MT neurons might explain the Dyre et al. (2000) results.

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URL: http://www.webpages.uidaho.edu/~bdyre/vss2008b.htm

16.128 Neural circuits underlying the perception of 3D motion

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Although extensive research investigates the encoding of both two-dimensional motion and binocular disparity, relatively little is known about how the human visual system combines these cues to infer three-dimensional motion. 3D-motion stimuli produce two different signals on the two retinae. Percepts of 3D-motion may depend on velocity-based cues (velocity difference of the two retinal motions), or on the corresponding disparity-based cues (change of binocular disparity over time).

We performed a series of human fMRI experiments (3T BOLD 2-shot spiral fMRI, (2.2 mm)3 voxels, 3 s TR) to isolate these velocity and disparity signals in the visual system, and to link them to percepts of 3D-motion. Subjects viewed displays via a mirror stereoscope, and performed a task to control attention.

We selectively studied the disparity-based cue with random dot dynamic stereograms that did not contain systematic retinal velocity signals, and studied the velocity-based cue by parametrically varying the proportion of anticorrelated dots (which have opposite contrast in the two eyes). We also parametrically varied the orientation of the dot element motions from horizontal (yielding strong 3D-motion percepts) to vertical (no percepts of 3D-motion).

We observed strong responses in human MT+ during the presentation of motion through depth. This contrasts with observations of motion opponency in this area, given that 3D-motion displays include oppositely-moving dots in corresponding parts of the visual field. Much like the percepts, MT+ responses were invariant to anticorrelation level for 3D-motion displays, but decreased with anticorrelation for laterally-moving control stimuli.

However, MT+ responses were invariant to orientation, suggesting that net activity in this region does not straightforwardly track the strength of 3D-motion percepts. Instead, we noted an area in the posterior parietal lobe that appeared selectively responsive to stimuli that yielded a percept of 3D-motion. These results suggest that the processing of realistic 3D-motion requires more than MT+.

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URL: http://web.austin.utexas.edu/rokers/demo/vss08

16.129 Failure of Decomposition of Translation and Expansion/Rotation in Optic-flow Perception

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The natural optic flow is typically complex, containing components from both ego-and object-motion in the world. Some theoretical studies proposed that the brain might decompose the optic flow locally into fundamental components, such as translation, rotation, and expansion (Koenderink, 1976; Yuille and Grzywacz, 1998). Recent psychophysical results seem to support these theoretical frameworks for rotation and expansion (Barraza and Grzywacz, 2005). In this study, we extended the psychophysical probes, using random-dot fields that expand/rotate while translating simultaneously. If such fields were viewed instantaneously, the resultant flow field would be another perfect expansion/rotation with its center shifted to the new point of singularity. Thus, one instantaneous frame of the velocity field is insufficient for one to decompose the flow field correctly into its radial/rotary and translational components. However, if one views the optic flow over an extended period, correct decomposition is possible in principle because the motion of the singularity over time could disambiguate the translation. In this investigation, we tested psychophysically whether human subjects can perform the correct decomposition over time. Subjects were requested to perform 2AFC tasks to compare the location of the perceived center to a reference. The perceived center of the combined field was obtained from 50% threshold. Our results show that humans cannot correctly decompose the flow field into its components even with prolonged stimulus presentation. Rather, humans perceive the shifted center of each instantaneous velocity field and perceive a concatenation of these centers to give a sensation of translation. Surprisingly, even adding boundaries to the moving field, which should have thus disambiguated the translation, did not correct the misperception of the center. We conclude that, contrary to the theoretical frameworks mentioned above, humans cannot decompose translation and rotation/expansion from the combined field in the case of random dots.

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16.130 When Are Trajectories for Motion-in-depth Stimuli Perceived Accurately?

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Recent studies have argued that trajectories of motion-in-depth stimuli are perceived quite inaccurately (e.g. Harris & Drga 2005). The perceptual errors could have been caused by the absence of appropriate changes in image size (looming), the absence of appropriate changes in focus cues (blur and accommodation), and the use of an estimation procedure that is subject to the response-mapping problem. To better understand the causes of these reported errors, we manipulated the availability of disparity, looming, and focus cues, and used a response measure that should not be subject to the mapping problem. Observers viewed stimuli that moved in elliptical paths in depth and judged whether the path was too compressed or stretched to be circular. Real world motion of a LED served as a condition in which all trajectory cues were consistent. In a second condition, an equivalent stimulus was shown on a computer display; in this case focus cues specified a frontoparallel path while other cues were veridical. In a third condition, the computer-displayed stimulus had constant angular size; in this case, looming and focus cues specified a frontoparallel path. With the real moving LED, responses indicated very accurate percepts with binocular viewing and reasonably accurate percepts with monocular viewing. With the computer-displayed target with appropriate looming, responses with binocular and monocular viewing were somewhat less accurate than for the corresponding real motion. With fixed angular size, responses with binocular viewing were less accurate than the other binocular conditions and responses with monocular viewing were very inaccurate. As cues to depth were removed observers perceived circular paths as increasingly compressed in depth. Thus, the visual system uses many cues to estimate 3D trajectories, so accurate percepts occur only when all cues specify the same path.

16.131 Superior perception of circular/radial than translational motion cannot be explained by generic priors

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A fundamental question in motion perception is how the visual system integrates local motion information over space to form a coherent global percept. We examined whether different motion flows affect spatial integration in motion perception, and whether a Bayesian model that includes generic but not specific priors is able to account for human performance.

We adopted the stimulus developed by Nishida et al. (2006) to compare human performance for three types of motion flow: translational, circular and radial motion. Each stimulus consisted of 728 Gabor elements (drifting sine-wave gratings windowed by stationary Gaussians) in a 12°circular window. The orientations of the Gabors were randomly assigned and their drift velocities were determined by a specified global motion flow pattern. The motions of signal Gabor elements were consistent with global motion, but the motions of noise Gabor elements were randomized. Motion sensitivity was measured by the coherence threshold: the proportion of signal elements that yielded a performance level of 75% correct in a discrimination task of determining the global motion direction. We found worse performance for perceiving translation than circular/radial motion (coherence threshold: translation 44%, circular 34%, radial 28%). Such superior performance in circular/radial motion was also replicated in a detection task.

We implemented a Bayesian model incorporating a generic prior preferring slow and spatially smooth motion. This model predicts slightly worse discrimination performance for circular/radial motion than for translation (coherence threshold: translation 35%, circular 38%, radial 39%), which is the opposite from human performance. Similarly, the model predicts the opposite trend from humans in the detection task. The failure of the model with generic priors suggests a specific prior for circular/radial motion is involved at the computational level. The apparent need to postulate special mechanisms is consistent with physiological evidence that MST neurons are selective to circular/radial motion.

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16.132 Effects of Focal Brain Lesions on Perception of Different Motion Types

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Functional neuroimaging studies in humans and neuropsychological case studies provide evidence for a variety of extrastriate cortical areas involved in visual motion perception. Multiple mechanisms underlying processing of different motion types have been proposed, however, support for cortical specialization has remained controversial so far. We therefore studied motion perception in 23 patients with focal lesions to various cortical areas due to ischemic stroke or hemorrhage. We considered luminance- (first order) and contrast-defined (second-order) motion in gratings, as well as translational motion, heading from radial flow, and biological motion in random dot kinematograms. Stimuli were presented with different signal-to-noise ratios. We measured detection thresholds for the contra- and ipsilesional visual hemifields and compared patients' performance with data from an age-matched healthy control sample (N=124). Elevated thresholds and significant threshold asymmetries between both visual hemifields were defined as deficits. We found specific deficits in 10 patients, whereas 7 patients showed impaired perception of multiple motion types. Lesions for all patients were mapped onto a template brain scan. Functional areas were explored by lesion density plots and subtraction analysis to compare lesions of patients with and without specific deficit. Results emphasized a dissociation between basic motion processing and processing of complex motion. Anatomical analysis confirmed critical occipito-temporo-parietal areas for perception of translational motion and moreover specific functional areas for first- and second-order motion perception in parieto-frontal and occipto-temporal regions, respectively. In contrast, heading from radial flow perception proved to be remarkably robust to most lesions. We exclusively identified the frontal eye fields as a critical structure. Biological motion perception relied on distinct pathways involving temporal, parietal, and frontal areas. Although precise functional roles of identified areas cannot be determined conclusively, results clearly indicate regional specialization for motion types of different complexity. We propose a network for motion processing involving widely distributed cortical areas.

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Object Perception: Neural Mechanisms

16.133 Visual Denoising of Object Images Along the Ventral Pathway

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We are remarkably accurate at recognizing objects in "noisy" viewing conditions, such as those involving dim illumination, partial occlusion, or conditions of rain or snow. To accomplish this task, the visual system must somehow extract the coherent visual structure embedded in noisy images to achieve a more noise-invariant representation of object form. We investigated the neural basis of this denoising process by scanning subjects as they viewed line drawings of faces, houses, chairs, and shoes, in the presence of varying levels of pixel-based noise (0, 50% or 75% noise). Pattern classification decoding techniques were used to infer the categories of the viewed objects from fMRI activity patterns, allowing us to determine how well individual areas along the visual hierarchy could distinguish object categories at different noise levels. Although all visual areas could discriminate the object category of noise-free images with well above chance accuracy (55-65% correct, chance 25%), high levels of noise severely disrupted the performance of early visual areas (V1-V3). In contrast, higher visual areas showed greater robustness to visual noise, with lateral occipital and ventral object-selective regions demonstrating almost complete noise invariance. For all visual areas, classifiers trained on cortical responses to either noisy or noise-free images were equally accurate at identifying the category of noisy test images. This implies that while on average noisy and noise-free images of the same object category produced similar patterns of activation, the patterns evoked by noisy images of different categories were less well separated than those produced by noise-free images. In summary, the results suggest that invariance to visual noise emerges gradually along the cortical hierarchy, with a fully "denoised" image representation found in higher object-sensitive areas of the visual system. This form of noise invariance may reflect the operation of long-range contour integration mechanisms in higher visual areas.

16.134 The release from adaptation in LOC from viewing a sequence of two different objects: An effect of shape or semantics?

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Changing object category from a cup to a violin produces a large release from adaptation in LOC compared to when the same images are repeated (Grill-Spector et al., 2001). This release from adaptation with a change in object class could be interpreted as a semantic effect (Simons et al., 2003). However, a class change is not only a change in semantics, it is also a change in shape. In the present experiment, subjects viewed a sequence of two object images, S1 and S2, under one of four conditions: a) the two stimuli were identical, b) the stimuli were identical but mirror reversed, c) S1 and S2 were different exemplars from the same basic-level class, (e.g., two different breeds of dogs in different poses), or d) S1 and S2 were from different, but closely related, basic-level classes, (e.g., a cat in a similar pose to a dog shown at S1). S2 was always translated with respect to S1. The subject's task was to respond with one key if the shapes were identical (ignoring the reversal in condition b) and another key if the shapes were different (conditions c and d). The shape similarity of S1 and S2 in conditions c and d were equated using the Gabor-jet model (Lades et al, 1993), which simulates the multi-scale, multi-orientation filtering of the visual field that is characteristic of early visual areas. Within LOC, BOLD responses for conditions b, c, and d, were substantially equivalent, and all higher than that of condition a, suggesting sensitivity to shape rather than class. In frontal and parietal areas, greater BOLD responses were evident for the reflected and different-exemplar conditions--the more difficult conditions (as assessed by RTs and error rates) for their respective responses --suggesting that activity in these areas may be reflecting task difficulty.

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16.135 Explicit relation coding in the Lateral Occipital Complex

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Despite widespread incorporation in theoretical accounts of visual cognition and the apparent ease of humans to employ prepositions (e.g., "above") or to reason about spatial relations, no neural evidence has ever been reported for structural descriptions (SDs), which make explicit a distinction between the shape of the entities in a scene and the relations between those entities. A number of current theoretical accounts dispense with the distinction all together, assuming that when object A is above object B different features will be defined than when object B is above object A and that explicit relations are only defined at a later stage. Subjects viewed a sequence of two briefly-presented frames, each composed of a pair of separated objects and had to judge whether one of the objects had changed. Switching the relative positions of the objects resulted in a greater release from fMRI-adaptation in the posterior fusiform, an area critical for object recognition, than when the objects were translated to the same extent, indicating explicit representation of relations. Control conditions ruled out explanations that posit global or inter-object features by observing that the greater relational release was maintained even when the objects were embedded in different contexts (gratings varying in scale and orientation) that changed with translation but not with the relational switch. Attentional shifts, eye movements, and foveal overrepresentation were ruled out as possible accounts by showing that the greater release from adaptation was independent of whether the same object was or was not closer to fixation and by showing that the greater release from adaptation was maintained at presentation times as short as 50ms.

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16.136 Can value learning modulate low-level visual object recognition? An ERP study

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Experience of interacting with visual objects allows us to acquire neural codes that predict both the value of interacting with them (i.e., in terms of reward or punishment) and the likelihood of obtaining that outcome. Acquisition and storage of these expected value (EV) codes involves prefrontal and limbic system circuits that have ample opportunity to interface with visual object processing networks. Here we ask whether object recognition is modulated by previously acquired EV codes; would prior experience with reward or punishment facilitate object recognition. To test this, we used face stimuli with learned values and measured both behavioral recognition and the N170 ERP component. The N170 is widely seen as an automatically elicited, face-specific response reflecting pre-categorical structural encoding. Modulating the N170 by presenting stimuli with different EVs would indicate an influence of value learning at a relatively early stage of processing. We first had participants engage in a simple choice task in which they gained or lost money. Through this experience, they acquired specific (and quantified) EVs for 12 different face stimuli (O'Brien & Raymond, VSS 2007). We then measured recognition (old/new judgement) for these and novel faces when briefly presented. ERPs were simultaneously recorded from 64 scalp electrodes. Recognition was significantly higher and faster for faces associated with high positive (gain) EV than for similarly exposed faces with low positive, negative (loss), or zero EV. Preliminary results indicate that the N170 amplitude during recognition may also depend on EV, demonstrating a top-down influence on 'early' face processing and explaining conflicting data on N170 modulation by face identity, familiarity, and top-down information such as emotional context.

16.137 Invariant decoding of object categories from V1 and LOC across different colors, sizes and speeds

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Categorical representations of objects in visual cortex have been intensively investigated using fMRI in humans. However it remains unclear to which degree specific brain regions encode objects invariant of their defining features. We approached the problem using 3D rendering of objects rotating along a randomly changing axis. Support vector machine (SVM) based pattern classification algorithms were used in combination with a spherical searchlight technique to decode objects from fMRI signals. We investigated to which extent changes of size, color and rotation speed of objects affected the accuracy with which they could be decoded. The degree of generalization of classifiers across different conditions was further assessed by training the classifier on one scale or rotation speed and testing it on the other. As expected object selectivity in temporal cortex showed much higher generalization than in retinotopic cortex. We also predicted that decoding of rotating images across different trajectories would be possible only in LOC but not in V1 where the time-average pattern should be identical for all objects and thus should not provide any discriminative information. Interestingly, contrary to this expectation, decoding accuracy for objects in V1 was above chance for all speeds except for a static control condition where decoding was attempted across multiple static 3D renderings, suggesting that static rather than dynamic images provide the best way to distinguish V1 and LOC. In summary, our results support the notion that object representations in temporal cortex can be decoded independently of their precise spatial representation in retinotopic regions.

16.138 Location-Invariant Object Information in Foveal Retinotopic Cortex

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According to standard theories of object perception, information in early stages of the visual hierarchy is tied to stimulus location, with more abstract 'position-invariant' representations of object shape achieved only at later stages. Here we present a new phenomenon that challenges this standard view: the pattern of fMRI response in foveal retinotopic cortex contains position-invariant information about objects presented outside the fovea. Subjects fixated centrally while viewing three categories of novel objects. In each trial, two objects were presented simultaneously in diagonally opposite peripheral retinal locations. These two objects were always from the same object category, and subjects were asked whether the two objects were identical or subtly different exemplars of that category. We then used multivariate pattern analysis methods to ask whether information about object category was present in the pattern of response across voxels in each of several cortical regions of interest (ROIs). Same-category correlations were higher than different-category correlations in the LOC, a region with a well-established role in shape representation. Astonishingly, however, correlations in the foveal region of retinotopic cortex were also higher for same-category than different-category pairs. This object information in foveal retinotopic cortex is behaviorally relevant: i) it is present during a discrimination task on objects presented in the periphery, but not a color discrimination task performed on the same stimuli, and ii) stronger information in foveal cortex is correlated across subjects with higher task performance. These findings suggest that position-invariant object information is fed back from higher areas to foveal retinotopic cortex, improving performance. Control experiments ruled out differential eye movements across object categories, activation from the fixation cross itself, or spillover activation from peripheral retinotopic cortex or from LOC. Instead, our data strongly suggest that position-invariant object information from higher cortical areas is fed back to foveal retinotopic cortex, improving task performance.

16.139 Dynamic objects are more than the sum of their views: Behavioural and neural signatures of depth rotation in object recognition

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Motion plays an important role in object recognition at both the behavioural and neural levels. For example, studies have shown that observers extrapolate to unfamiliar views of objects rotating in depth when the motion is smooth and predictable. Using a combined psychophysics and fMRI study, we tested whether the smoothness of rotation affected performance and neural responses. Sixteen observers performed a same-different discrimination task in a 3T scanner at the Max Planck Institute. They were presented with a probe-test stimulus sequence, and judged whether both depicted the same or different objects. In blocks of trials, the probe stimulus was either a static image of an object, a smooth animation of a rotating object, or a scrambled animation of an object in which the frames of a smooth animation were randomized. Importantly, both motion blocks presented the same set of views. Within a block, the test stimulus was an image which depicted the object from unfamiliar views that preceded (pre condition) or continued the observed rotation trajectory (post condition). The blocks were optimized to counterbalance for history effects. Observers responded more quickly in the post than pre condition with smooth animations but responded equally fast for these conditions in scrambled and static blocks. Whole-brain group analyses showed that parietal regions were more active in smooth than scrambled blocks, frontal regions were more active for smooth than static blocks, and medial temporal regions were more active in both motion blocks relative to static blocks. These regions are known to process dynamic stimuli. Preliminary analyses of the time courses within these regions show different patterns of activation between pre and post conditions across the different blocks. Overall, the results highlight the importance of smooth motion, and suggest that a rotating object is more than the sum of its views.

16.140 Integral versus Separable Perceptual Dimensional Pairs are Reflected in Conjoint versus Independent Neural Populations

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Some visual properties of objects are apprehended separately, whereas other dimensions are perceived as a composite; these have been termed separable and integral dimensions. We hypothesize that integral perceptual dimensions are represented by populations of neurons that represent the dimensions conjointly, while separable dimensions are represented by independent neural populations. To test this idea, we used a continuous carry-over fMRI design (GK Aguirre, 2007) to measure the recovery from neural adaptation associated with stimulus changes along a single perceptual dimension or combined across two dimensions. Stimulus changes along both perceptual dimensions should produce a recovery from adaptation that is the additive sum of the recovery for each axis in the case of separate representation, but which is sub-additive in the case of conjoint representation.

In our first experiment, we presented a continuous stream of shapes that varied along two radial frequency component (RFC) dimensions which are characterized as behaviorally integral. Significant adaptation that was proportional to the perceptual similarity of the stimuli was observed in right, ventral LOC and in area V3A bilaterally (all $p<0.05$). We then tested if shape changes along both perceptual dimensions resulted in a recovery from adaptation that was less than the sum of the recovery to changes along each axis in isolation. The significant sub-additivity observed ($p<0.05$) indicates that neural populations within these regions represent the two, behaviorally integral, perceptual dimensions conjointly. In ongoing experiments, we are studying stimuli that vary along the dimensions of color and a single RFC component. These two dimensions are behaviorally separable. Preliminary data has identified recovery from adaptation for changes in shape and color in ventral area V2, with additive recovery from adaptation for stimulus changes that combine shape and color. If further replicated, these results indicate independent representation of shape and color information by neurons within V2v.

16.141 **Dissociate binding processing and object representation – a study combining EEG and fMRI**

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Integrating discrete features into coherent object representation is an essential ability of the human brain. However, the basic relationship between the binding processing and the object representation is still not clarified -- Are they the same or different processes? Are they supported by the same or different neural mechanisms? We combined Electroencephalogram (EEG) and functional magnetic resonance imaging (fMRI) approaches, attempting to dissociate the binding processing and the object representation by modulating the support ratio (SR) of Kanizsa-type illusory counters (IC, which is a classical example of visual feature binding). The hypothesis is that: as the SR increases, less binding (interpolation of the discrete edges of an IC) is needed while the perception of an object (IC) becomes stronger. Such dissociated results were observed in the occipital EEG results. The induced gamma activity occurring at about 100~150 ms decreased with SR, while the ERP component N1 occurring at about 170 ms increased with SR. The fMRI results further showed that the lateral occipital cortex (LOC) activation increased with SR. We thus show dissociable binding and object processes, which are associated with the induced gamma activity and the N1 respectively. This finding also provides the evidence for different roles of the induced and evoked activities in cognitive functions. The fMRI results further confirm the role of the LOC in object representation with a parametric design. A tentative indication of the present results may be that, the binding processing and the object representation occur at the same brain regions but involve different neurons.

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16.142 **Inter-area correlations in the human ventral visual pathway reflect feature integration**

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The neural representation of an object is constructed hierarchically. Elementary features are detected in early visual cortex and are progressively integrated throughout higher levels of processing. This hierarchical computation should be reflected in interactions between lower and higher visual areas. Furthermore, disrupting feature integration should reduce these neural interactions. We used letter crowding to disrupt feature integration, testing whether crowding affects the interactions between visual cortical areas. We used fMRI to measure neural activity in multiple visual areas while observers viewed closely-spaced letters (8° eccentricity, presented at 1 Hz for blocks of 15-21 s, separated by 15-21 s blocks of no stimulation). Adjacent letters were displayed in alternation in the uncrowded condition and simultaneously in the crowded condition. We performed a control psychophysics experiment to confirm that letter identification was impaired by crowding under these stimulus conditions. However, during the fMRI experiment, observers performed a demanding contrast discrimination task at fixation to ensure that attention was diverted from the letter stimuli. In each observer, we defined sub-regions in retinotopic visual areas that corresponded to the letter locations, and the visual word-form area (VWFA) in inferotemporal cortex. For each area, we removed the mean response using orthogonal projection, and then computed pairwise correlations between the residuals for both conditions. We found that crowding reduced correlations between several pairs of visual areas. This effect was particularly strong between retinotopic visual areas (V1, V2, V4) and VWFA. This effect was eliminated in a control experiment using Gabor patches, which are elementary features that do require feature integration. Crowding reduces correlations between early visual areas and higher visual areas, presumably by disrupting feature integration. We conclude that interactions between early feature-selective areas and higher object-selective areas reflect the feature integration process.

16.143 **Implicit coding of location, scale and configural information in feedforward hierarchical models of the visual cortex**

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Feedforward hierarchical models of the visual cortex constitute a popular class of models of object recognition. In these models, position and scale invariant recognition is achieved via selective pooling mechanisms, resulting in units at the top of the hierarchy having large receptive fields that signal the presence of specific image features within their receptive fields, irrespective of scale and location. Hence, it is often assumed that such models are incompatible with data that suggest a representation for configurations between objects or parts. Here, we consider a specific implementation of this class of models (Serre et al, 2005) and show that location, scale and configural information is implicitly encoded by a small population of IT units.

First we show that model IT units agree quantitatively with the coarse location and scale information read out from neurons in macaque IT cortex (Hung et al, 2005). Next, we consider the finding by Biederman et al (VSS 2007) that changes in configuration are reflected both behaviorally and in the BOLD signal measured from adaptation experiments. Model results are qualitatively similar to theirs: for stimuli consisting of two objects, stimuli that differ in location (objects shifted together) evoke similar responses, while stimuli that differ in configuration (object locations swapped) evoke dissimilar responses. Finally, the model replicates psychophysical findings by Hayworth et al. (VSS 2007), further demonstrating sensitivity to configuration. Line drawings of objects were split into complementary pairs A and B by assigning every other vertex to A, and complementary vertices to B. Scrambled versions A' and B' were then generated. Both human subjects and the model rated A as more similar to B than to A'.

Altogether, our results suggest that implicit location, scale and configural information exists in feedforward hierarchical models based on a large dictionary of shape-components with various levels of invariance.

16.144 **Does perceived shape underlie the category selectivity in human occipitotemporal cortex for faces, body parts, and buildings?**

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Studies using functional magnetic resonance imaging (fMRI) have revealed cortical regions with strong selectivity for the category objects belong to, especially for faces, buildings, and headless bodies or body parts. We investigated the role of perceived shape for this neural selectivity for highly familiar object categories. We scanned nine human volunteers while they viewed images from six conditions, with two sub-categories from each of the aforementioned categories: old african faces, non-african baby faces, rural buildings, skyscrapers, hands, and headless torsos. Twenty other volunteers rated pairs of images in terms of perceived shape. Analyses of the pattern of selectivity in ventral visual cortex with multivariate techniques revealed a fine-grained organization of ventral visual cortex that extended beyond the typical three object categories. More specifically, we have found small differences in the activation pattern for old faces versus baby faces, and very clear differences between hands and torsos. Several aspects of this fine-grained organization were not consistent with a role of perceived shape. The clearest dissociation was that the activation pattern of torsos was somewhere in the middle between faces and hands while the perceived shape of torsos was more similar to the skyscrapers than to the faces and the hands. As a consequence, a semantic distinction between “living/body-related” and “non-living/artefact” is very clear in the brain but not in ratings of perceived shape. These results contrast with findings that object selectivity for unfamiliar, artificial objects reflects differences in perceived shape (Op de Beeck et al., 2007, Society for Neuroscience meeting). In conclusion, we have found a detailed and multi-level category selectivity for familiar, meaningful objects that is not fully explained by differences in perceived shape.

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16.145 **Reliability of object- and face-selective activations measured with high-resolution fMRI**

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Ongoing debate focuses on the functional properties of human object- and face-selective visual cortex. Recent reports disagree about whether high-resolution (approximately 1mm3 voxels) and standard-resolution (approximately 27mm3 voxels) fMRI reveal qualitatively different patterns of activation in these regions. Here, we investigated face- and object-selective fMRI activations at high-resolution to establish their reproducibility and dependence on a variety of scanning parameters. Five subjects participated in four scanning sessions in which we acquired fMRI data at high resolution (1.5mm isotropic voxels, 3 Tesla, bilateral prescription). Each subject participated in four sessions over several weeks using each of two radio-frequency coils: a single-channel surface coil, or an 8-channel surface coil array and each of two T2*-weighted acquisitions: either slice or slab excitation. During scanning, subjects viewed six image types: grayscale front-view faces; grayscale face profiles; grayscale abstract sculptures; two-tone face silhouettes; two-tone abstract shapes; and scrambled images. We examined the reliability of object- and face-selective activations across sessions within large anatomically defined regions including the posterior fusiform gyrus and lateral occipital cortex. Our results reveal robust, reproducible patterns of response within subjects across sessions for contrasts of object vs. scrambled images in lateral occipital cortex (R= 0.22±0.11, p<10-3) and face vs. object images in fusiform (R= 0.47±0.06, p<10-8). We also found reliable profiles of the mean time course (R= 0.74±0.17, p<10-13) and its stimulus selectivity (R= 0.81±0.18, p<10-13) across functionally defined regions of interest including object- and face-selective patches in lateral occipital cortex and fusiform gyrus. Additional analyses revealed differences in the volume of activation associated with different scanning parameters. However, these differences varied by the region and contrast of interest. In summary, our results demonstrate that standard methods for determining object- and face-selective activations are robust and reproducible across sessions using high-resolution fMRI.

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16.146 **BOLD signal response functions for object and face processing in noise**

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Tjan, Lestou, and Kourtzi (2006, J Neurophysiol) postulated that the log-log slope of signal response function (BOLD signal amplitude vs. signal-to-noise ratio (SNR) of the stimulus) is related to the intrinsic uncertainty or feature invariance of a visual area, and therefore indicates the ordering of the information processing in the cortex. Here, we examined the generality of this conjecture using two classes of stimuli, tested separately: common objects and faces. In the scanner, subjects decided which of the two noisy sample images matched the category (for objects) or gender (for faces) of the target image. For each scan, four levels of image SNR were tested in a rapid event-related design. The mean luminance and RMS contrast of the images were kept constant. To measure the log-log slope of signal response functions across the cortical surface without using predefined regions of interest (ROIs), we defined, for each voxel, a “floating” ROI of 15 mm in diameter on the cortical surface, from which we determined the hemodynamic response functions (HRF) for each stimulus SNR using deconvolution. We then estimated the peak amplitudes of the HRFs and computed the log-log slope of the signal response function. We found that for both objects and faces, the log-log slope of the signal response function increased orderly from low- to high-level visual areas, consistent with Tjan et al. We also found that “islands” of slope maxima developed in the anterior regions of the visual cortex, where slopes were high. The locations, but not the values, of the maxima were consistent across both faces and objects, with some corresponding to well-known regions: LO, pFs, and FFA. Assuming the conjecture of Tjan et al, these islands would represent different branches of the visual processing hierarchy.

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Perception and Action: Hand Movements

16.147 **Integration of object-centered and viewer-centered visual information in an open-loop pointing task**

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Investigations on the relative contribution of object-centered (allocentric) and viewer-centered (egocentric) visual information to motor behaviour often have focused on determining which of these sources of information predominate, and under which circumstances. In contrast, multi-sensory integration studies have shown that information from different sensory modalities is combined based on reliability estimates for each modality. We sought to determine if a similar process is applied to egocentric and allocentric visual information in an open-loop pointing task. METHOD: Head-restrained, gaze-fixated subjects were presented briefly with a peripheral visual stimulus consisting of a to-be-remembered yellow dot surrounded by an array of four vibrating blue dots (allocentric stimulus) situated at the vertices of an invisible square. During a delay period subjects made controlled eye movements. After a brief reappearance of the allocentric stimulus without the to-be-remembered yellow dot, subjects made a pointing response to indicate the remembered location of the yellow dot. In order to tease apart the contribution of egocentric and allocentric cues, the allocentric stimulus was shifted randomly by three degrees from presentation to test, thus introducing cue-conflict. The vibration amplitude of the allocentric stimulus and the eye movement amplitude were varied randomly between two fixed levels each from trial to trial in order to control the reliability of allocentric and egocentric information, respectively. PREDICTION: Based on multisensory integration findings, we predicted that lower vibration and higher eye movement amplitude would bias pointing results towards a position consistent with the shifted allocentric stimulus, while larger vibration and smaller saccade amplitudes would have the opposite effect. RESULTS: For small eye movement conditions mean pointing responses were biased as expected according the vibration amplitude of the allocentric stimulus. However, mean pointing responses were halfway between the two locations and indistinguishable from one another for both vibration amplitude conditions when eye movement amplitude was large.

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16.148 **Visual feedback control of pointing movements in depth**

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Purpose: Previous work has shown that humans continuously use visual feedback about the position and movement of the hand to control goal-directed hand movements online. In these studies, visual error signals were predominantly in the image plane and thus were available in an observer’s retinal image. We investigated how humans use visual feedback about finger depth provided by binocular disparities alone to control pointing movements. Methods: In a calibrated, virtual reality environment, subjects were asked to move their fingers from a starting point on the right hand side of the virtual space to point to and touch a target ball that appeared at a random position on the left-hand side of the virtual display 30 cm away from the starting position. A fixed platform was co-aligned with the starting position, while a target ball positioned on a robot arm was co-aligned with the visual target on each trial. Visual feedback of the unseen finger, whose position was recorded at 120Hz using an Optotrak system, was provided in real time by a rendered finger. On 1/3 of the trials, the position of the virtual fingertip was perturbed 1cm either along the line of sight in depth or in the image plane behind a virtual occluder positioned 1/3 of the way between start and target. Results: All subjects corrected for the in-depth perturbations as well as the in-the-image-plane ones. Mean corrections were 50% of the size of the perturbations in both directions, but corrections for perturbations in depth were slower than corrections for perturbations in the image plane (167 vs. 117 ms reaction times). Conclusions: Based on the large decrease in stereo acuity, it is likely that an optimal estimator integrating uncertain visual feedback over time can account for the apparent difference in delays.

16.149 **Effects of Experience and Amount of Visual Feedback when Pointing to Visible and Remembered Targets**

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Most studies involving pointing to present and remembered targets tend to report situations when both the limb and target are present (closed loop-target present), or when both the limb and target are occluded (open loop-target absent). This neglects conditions where only 1 of the above 2 variables is available. There may exist differences between these 2 variables so that unique information for a particular visual condition is utilized while pointing to targets in space. To address this, we asked young (N=10, mean age=22.9 years) right-handed participants to point to targets in a virtual aiming task. Six movements were performed to each of six targets while manipulating whether participants had vision of their pointing limb, the target, or both. In target-absent trials, the time between target occlusion and movement initiation were changed to examine mental target representation. To do so, there were 2 delay times: 0 and 2 seconds. To investigate the effect of experience, performance was also compared before and after a practice period. Half of the participants received open loop feedback first; the other half received closed loop feedback initially. Results indicate open loop aiming tasks are more dependent on the delay periods between target occlusion and movement onset. Only block effects (that is, before or after practice) affected closed loop results. This suggests the use of a time sensitive (<2 seconds) stored visual representation of the environment available only when vision of the limb is absent. Implications of initial visual condition exposure and kinematic and accuracy differences between open and closed loop aiming conditions with the target present or absent will be discussed.

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16.150 **Non-lateralized impairments in anti- but not pro-pointing in patients with hemispatial neglect**

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It has been widely shown that hemispatial neglect manifests itself in a rightward perceptual bias, but whether this bias extends to goal-directed movements remains a matter of debate. Here we analysed the ability of 10 patients with hemispatial neglect to perform pro- and anti-pointing movements in response to left and rightwardly presented targets. A group of 10 age-matched healthy controls and 10 patients with right-hemisphere lesions but no neglect served as controls. In the pro-pointing condition, subjects were asked to point directly to the target, whereas in the anti-pointing condition they had to move in the opposite direction of the target (i.e. if a target was illuminated on the right subjects had to point to the equivalent target position on the left and vice-versa). In the pro-pointing condition, no impairments specific to patients with hemispatial neglect where found. However for anti-pointing, neglect specific deficits emerged: neglect patients showed greater directional errors (i.e. anti-pointing movements in the wrong direction) and were also severely disrupted in the end-point accuracy of their movements, in particular when anti-pointing rightwards in response to leftwardly presented targets. We relate these findings to the presence of impairments in movements that require specific location mapping and cannot be performed on-line.

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16.151 **Attention for action? Examining the link between attention and visuomotor control deficits in a patient with optic ataxia**

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Lesions to the superior parietal lobe (SPL), including the intraparietal sulcus (IPS) , commonly lead to optic ataxia (OA) – a disorder in which patients have difficulty reaching to objects under visual guidance. These visuomotor impairments are usually restricted to peripheral vision and spare central vision. Importantly, the classic definition of 'pure' OA suggests that these visuomotor impairments occur independently from any perceptual or attentional deficits (which, if present, were thought to be related to Balint-Holmes syndrome). However, more recent work from our group suggests that some patients with OA have difficulty orienting and reorienting attention towards their ataxic visual field. Thus, an important question is whether these attentional deficits might be related to the well known problems in visuomotor control evident in these patients. That is, these patients may be inaccurate when reaching towards peripheral targets because they are not able to adequately attend to peripheral locations. To investigate this question we had control participants (N=5) and CF, a patient with OA in his left visual field, perform tasks that required them to either detect, or reach towards, a target presented in either central, or peripheral vision. CF was impaired in both the detection and the reaching tasks compared to controls. Specifically, CF was much slower to detect the presence of targets in his ataxic (left) visual field, and he was very inaccurate when reaching towards those same targets. Interestingly, although CF was obviously impaired relative to controls in both tasks, there was no correlation between his attentional and his visuomotor impairments. Since the motor response in each task was carried out using the same effector (right, ipsilesional hand) it suggests that although SPL/IPS lesions may impair both attention and visuomotor control, these deficits may arise from damage to independent mechanisms.

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16.152 **Improved blindsight near the hand is associated with increased fMRI activation in the superior parietal-occipital cortex**

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Recently we reported the case of MB, a young man showing improved residual visual processing in his blind (upper left) field when he placed his ipsilateral hand near the target object. We argued that placing the hand near the target allowed the target to fall within the receptive field of visual-tactile bimodal cells linked to the hand, and that their recruitment bolstered visual processing. Here we use fMRI to examine this possibility further. If visual processing is improved in the hand-near condition because bimodal cells are recruited, then we may observe that brain areas thought to contain populations of bimodal cells may be more active when the hand is near, rather than far from, the target. We asked MB to either reach or grasp for targets presented briefly either in his good upper-right visual field or his blind upper-left visual field under two conditions. In the hand-near condition, his hand was placed next to the target location, and in the hand-far condition, his hand rested away from the target location. We found that when targets were presented in his blind field, the right superior parieto-occipital (SPOC) area was more active in the hand-near condition than in the hand-far condition. Previous studies have also found that SPOC is sensitive to the proximity of the target to the body, as it shows greater activation for targets within reach than beyond reach. Furthermore, previous single-cell recordings in monkeys and imaging studies in humans show that the region around the parietal-occipital sulcus is multimodal; it responds both to visual and tactile information. Therefore, SPOC appears to be recruited more robustly when a hand is near a visual target, and its recruitment may help explain the hand-near improvements we observed for MB's blind grip-size scaling.

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16.153 **Neural model for the visual recognition of hand actions**

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The visual recognition of goal-directed movements is crucial for the learning of actions, and possibly for the understanding of the intentions and goals of others. The discovery of mirror neurons has stimulated a vast amount of research investigating possible links between action perception and action execution (Rizzolatti & Craighero, 2004). However, it remains largely unknown what is the extent of this putative visuo-motor interaction during visual perception of actions and which relevant computational functions are accomplished by purely visual processing.

Here, we present a neurophysiologically inspired model for the recognition of hand movements demonstrating that a substantial degree of performance can be accomplished by the analysis of spatio-temporal visual features. The model integrates a hierarchical neural architecture for extracting relevant form and motion features with simple recurrent neural circuits for the realization of temporal sequence selectivity. Optimized features are learned using a trace learning rule eliminating features which are not contributing to correct classification results (Serre et al., 2007). As novel computational function, the model implements a plausible mechanism that combines the spatial information about goal object and its affordance and the specific posture, position and orientation of the effector. The model is evaluated on video sequences of monkey and human grasping actions.

We demonstrate that well-established physiologically plausible mechanisms account for important aspects of visual action recognition. Specifically, instead of explicit 3D representations of objects and the action the proposed model realizes predictions over time based on learned pattern sequences arising in the visual input. Our results complement those of existing models (Oztop et al., 2006) and motivate a more detailed analysis of the complementary contributions of visual pattern analysis and motor representations on the visual recognition of imitable actions.

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16.154 **Intermittent feedback model of goal directed forearm movement**

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There have been two approaches to model human movement based on the assumption that the movement is a result of minimizing the duration of the total movement with the constraint that the movement has to end within a target. In one approach, the duration of submovements were optimized (e.g., Mayer et al., 1988). In the other, the entire trajectory of a single movement, characterized by the relation between position and time was optimized (e.g., Harris & Wolpert, 1998). Both approaches can successfully explain the speed-accuracy tradeoff, but neither is complete. The former does not specify the properties of the movement trajectory, whereas the latter either does not include feedback, or the feedback is continuous. As a result, the movement does not consist of discrete submovements.

We propose a new model, which combines aspects of these two approaches. Specifically, we assume that a movement consists of two submovements and a single feedback, and the trajectory of each submovement is being optimized. Each submovement is generated using a fourth order system with signal dependent noise (Harris and Wolpert, 1998). The transition from the first to the second submovement as well as the profile of each submovement are being optimized so that the total movement time is minimal and the variance at the landing position is less than some criterion. For simplicity, the jerk at the transition is assumed to be zero.

The simulation results show that the optimal transition occurs at the early stage of the movement showing a sharp peak of the acceleration profile. The sharp peak of the acceleration profile, which has never been reported before, is consistent with our preliminary psychophysical data. The simulation results also show bell-shaped positional variance curve in accordance with psychophysical data.

16.155 **The use of visual information during a visual saccade for the control of a goal-directed upper limb movement**

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There is reduced visual sensitivity during visual saccades (i.e., saccadic suppression: see Bedell, 2001; Irwin, 2002; Michels, 2004) yet small target displacements presented during a saccade lead to limb trajectory corrections without perception of the target jump (Goodale et al. 1986). As such, it could be hypothesized that visual information is unconsciously gathered during the saccade to update the limb trajectory. We designed a study to test this hypothesis by manipulating visual feedback during saccades to a single- and double-step target presentation for a manual aiming task. The experimental task involved single-step trials to a 16° and 23° target (i.e., 10 cm and 15 cm, respectively) and the target was displaced further at peak eye velocity by 2.2° each on 50% of the trials. Eye movements were monitored using EOG and limb movements were captured using an OptoTrak Certus, both sampling at 400 Hz. Liquid crystal goggles were used to manipulate vision only during the primary visual saccade in real-time using five (5) conditions: full vision (FV), vision during high (V_High) or low eye velocity (V_Low), and vision early (V_Early) or late (V_Late) in the saccade. As expected, there was a main effect for Target Step (single, double) on limb movement endpoint, aiming movement time, and aiming movement symmetry. However, this was true across all vision conditions indicating that amendments to the limb trajectory following an unperceived target jump do not appear to be based on information gathered during the primary visual saccade. Interestingly, both the FV and V_Low conditions led to higher maximum limb velocity than in the other experimental conditions (V_High, V_Early, V_Late). As such, some visual information is gathered for manual aiming planning processes during low saccadic velocity.

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16.156 **Movement intention versus motor preparation in the orientation of visuo-spatial attention: The case of tool use**

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Previous research has shown that the preparation of both eye and hand movements orients visuo-spatial attention towards the position aimed for by that movement.

The definition of the “aimed-for” position is currently under debate. Indeed, movement preparation could orient attention toward the goal of the movement (i.e. the sensory coordinates as defined by movement intention) or towards the position defined by the motor coordinates of the movement itself. These two positions (movement goal versus motor endpoint) are habitually closely aligned but must be dissociated to investigate which one guides attention. We examined hand movement preparation and dissociated the goal of the movement from the movement endpoint by tool use.

Participants had to point towards a visual target with the tip of a hand-held tool. The movement goal corresponded to the position aimed for with the tip of the tool, and the motor coordinates corresponded to the position towards which the hand moved to place the tool correctly on the visual target.

Visual discrimination performance was tested at both positions with a feature discrimination task.

The results shed new light on the debate regarding the role of movement intention and motor computation in the orientation of visuo-spatial attention during movement preparation.

16.157 **Motion Interference Effects while Performing and Viewing Actions with Hand-Held Objects**

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Through instruction from others and direct experience with the goal-directed manipulation, people establish typical patterns of tool use. In this study, participants performed horizontal or vertical motions in one of two tool-holding conditions: empty hands or holding tools. Tools were selected that are more typically moved either horizontally or vertically. In both tool-holding conditions, participants were required to make movements in time with videos of another person moving along the same or the orthogonal axis. Videotaped actions contained tool and empty hand motions. We measured the interference on motions produced (as in Kilner, Paulignan, & Blakemore, 2003) to determine to what extent hand and tool motions elicit covert imitation from participants making motions in the same or different tool-holding condition and with the same or different tool type. Our results first indicate that variance in individual observed motions affects variance produced motions. Additionally, the relationship between the orientation of the longer axis of a hand or object one is moving and the orientation of the longer axis of an observed hand or object seems to affect interference. Finally, our results suggest that prior combinations of a tool-holding/tool-type conditions may affect interference in subsequent condition combinations.

16.158 It's all a matter of mass: Both the eye and hand know it

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Recent findings suggest that oculomotor action can – partially – modulate perceptual bias in manual responses (e.g., Binsted et al 1999a: Exp Brain Res); others however posit the manual and saccadic systems operate independently (e.g., Thompson & Westwood 2007: Neurosci Letters). Common to these and other eye-hand derived accounts of perception-action dichotomies in vision is the reliance on Müller-Lyer (ML) figures: a stimulus that coincidentally generates an asymmetric center of mass (CoM). However, CoM has been shown to attract attention within a visual scene (Zhou et al 2006: Neuroreport), such attentional bias can both generate and reverse illusory effects (Coren & Porac 1983: Perception). The purpose of this study was to examine the degree to which CoM, can bias ocular and manual movements, independently and in the absence of illusory percept. Participants (n=27) were asked to point, saccade, or make a 'normal eye-hand response' to a visual target. Targets consisted of a central lobe with a directional tail roughly corresponding to the letters p, q, d, b; center of mass was moved to each quadrant of the target. Participants were asked to point as 'quickly and accurately as possible' to the center of the central 'lobe' of the target. Vision of the target and hand was available throughout all pointing trials. In all conditions (i.e. saccade; point; eye-hand coordinated), responses were consistently biased throughout the response trajectory consistent with the CoM shift. Thus, despite the mixed observations of ML effects on manual and ocular movements (Bruno et al, 2007; Neur Biobeh Rev; Binsted & Elliott 1999b; Hum Mov Sci), ML findings may simply reflect presence/absence of biases due to CoM and not bare any direct contribution to extant debates regarding the discrete nature of perceptual and motor visual processes.

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16.159 Why does intermanual transfer occur?

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After adapting to altered visual feedback of an unseen hand while reaching to visual targets, many studies have shown that the opposite hand also benefits when reaching with the same altered feedback, suggesting intermanual transfer. It is unclear why intermanual transfer occurs. Does transfer occur because the brain is learning new cursor mechanics, which are constant for each hand? If so, then we predict that bimanual transfer should occur when subjects learn to reach with a cursor representing their hand and not an image of their hand. Subjects reached to one of 10 radial targets with an unseen hand. One group of subjects reached with a rotated cursor representing their unseen right hand. Another group of subjects saw a rotated view of their right hand while they performed the same task: these movements were captured using a camera, and displayed in real time on a vertical screen. ThThhTe motion of the cursor or the image of the hand was rotated either 45° or 105° CCW in the learning condition, where subjects reached for 200 trials with their right hand. Each learning session was followed by a test condition where subjects reached to the same targets under the same viewing condition but with the left, untrained hand for 30 trials. Reaching with the left hand in the cursor condition was significantly less deviated for the first 10 trials of testing compared to the first 10 trials of learning for the 45° rotation ($p = .001$) and the 105° rotation ($p = .001$), suggesting intermanual transfer when the cursor was seen. The rotated hand view condition showed no significant transfer for either rotation ($p > .05$). Our results suggest that intermanual transfer may occur because an internal model of the cursor, rather than the arm motor system, is learned.

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16.160 Bimanual coupling in left and right space: which hand is yoked to which?

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Several studies have demonstrated that, when reaching toward targets at the same time, functional asymmetries in both reaction time and movement duration are substantially reduced (i.e. Kelso et al., 1983). To investigate which hand is coupled to which (i.e. which hand is 'in charge') we combined the well known performance deficits seen when a hand reaches into contralateral space (i.e. Carey et al., 1998), in a bimanual context. Right handed participants performed 1 and 2 handed reaches to the left or right sides of space, meaning in the bimanual conditions, a contralateral reach was yoked to an ipsilateral reach. It was predicted that the yoking between a contralateral reaching left hand would be to able to utilise some of the ipsilateral reaching right hand's properties to improve performance relative to an equivalent unimanual movement. Results suggest however that the 'bimanual cost' of reaching with 2 hand proved too strong, and a pattern of right hand ipsilateral 'compromises', to maintain coupling was seen. Therefore, in a second experiment participants performed reaches of differing amplitudes, such that a contralateral reach could be combined with a shorter ipsilateral reach – the combination most likely to show an improvement on a unimanual equivalent. When the 'bimanual cost' was accounted for, the left hand was improved at input level (i.e. reaction time), and the right hand was improved at output level (i.e. movement duration) relative to equivalent ipsilateral reaches. The results are discussed in relation to strategic attentional biases to overcome the increased difficulties posed to the central nervous system by reaching with 2 hands concurrently.

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URL: www.abdn.ac.uk/~psy452/dept

16.161 Hand-eye correlation: Sensorimotor learning of movement/color pairs

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People can learn sensorimotor contingencies between hand movements and color perception (Richters & Eskew, 2007) which produce changes in subsequent color judgments that are dependent on the hand movements. These experiments include a pre-test, a learning phase, and a post-test. In the learning phase, we correlated leftward hand movements (using a joystick) and presentation of a high-contrast red spot, and rightward hand movements and a green spot. In each learning trial, observers heard five color names (e.g., "red", "red", "green", "red", "green"), and then produced that sequence of colors on the screen by moving the joystick to the appropriate sides. We found that 45 minutes of learning trials produced a shift in color judgments in the post-test : observers compared near-threshold colors of the spots, which varied around white, by judging if the second spot was "redder" or "greener" than the first spot (cf. Bompass & O'Regan, 2006). However, this effect could be linguistic rather than sensory -- a pairing between hand-movements and the words "red" and "green," which influenced the color judgments later. The present study substituted the words "left" and "right" for the color name words used previously in the learning phase. This linguistic change had no effect on the results, showing that the change in color judgments is not just a shift in color naming. Instead, the effect is caused by learning a new sensorimotor contingency between a color percept and a hand movement, and then compensating for that contingency. We also examine detection thresholds from red and green spots, paired with leftward and rightward hand movements, to see if the effect can be obtained at threshold and to test whether the effect is best characterized as a shift in criterion or sensitivity. Both explanations will be discussed along with related experiments.

16.162 The impact of expertise on the processing of 2D and 3D images: the case of minimal invasive surgery

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2D and 3D images do not contain the same information and thus do not lead to the same performance. Literature reports better performance with 3D images because they contain more visual cues, especially in order to accurately and efficiently guide the action. Although 3D images lead to a better performance than 2D view in reaching and grasping tasks, the effect of subject expertise on this difference has never been investigated. In order to answer this question in a natural and meaningful setting, we compared the performance of 12 novices (medical students) with the performance of 12 laparoscopic surgeons and 4 robotic surgeons, using a new robotic system that allows 2D and 3D view. After a familiarisation phase, all subjects performed 4 tasks of increasing complexity into 3 conditions (classical laparoscopy (2D view) and robotic system in 2D and 3D). Our results showed a trivial effect of expertise (surgeons generally performed better than novices). Moreover, novices performance was very sensitive to the 2D-3D difference (they performed better in 3D than in 2D) while the performance of laparoscopic surgeons was similar in 2D and 3D view. Robotic surgeons, used to manipulating robotic system in 3D, obtained same performance as laparoscopic surgeons in 2D view and significantly better performance in 3D. In conclusion, our study showed expertise had an effect on sensitivity to the 2D-3D difference: novice subjects were strongly sensitive to this difference, laparoscopic surgeons accurately compensated the loss of depth perception in 2D view and obtained similar performance in 2D and 3D, and robotic surgeons achieved to improve their performance in 3D. All these results were also emphasized by a questionnaire about their subjective impression about their performance (satisfaction, self-confidence and difficulty).

Acknowledgement: Grants from FNRS

Saturday Sessions

Saturday, May 10, 8:30 - 10:00 am
Talk Session, Vista Ballroom

Central Pathways

Moderator: Ruxandra Sireteanu

8:30 am

21.11 The visual field maps in the human MT+ complex

Kaoru Amano[1] (amano@brain.k.u-tokyo.ac.jp), Brian Wandell[1], Serge Dumoulin[1]; [1]Department of Psychology, Stanford University

Purpose: Human motion-selective cortex (hMT+) is typically localized based on a functional selectivity to moving stimuli. This functional definition spans several visual field maps. Conventional retinotopic mapping techniques using rings and wedges identified one visual field map thought to be the homolog of MT (Huk et al, 2002); but mapping has not provided a clear characterization of neighboring regions. We applied the population receptive field (pRF) model-based method (Dumoulin and Wandell, 2008) to reveal visual field maps and estimate pRF size within the hMT+ region. Methods: Magnetic resonance images were acquired with a 3 T General Electric Signa scanner and an eight-channel coil (Nova Medical, Wilmington, MA) centered over the subject's occipital pole (voxel size 1.5mm isotropic). In addition to novel bar stimuli, we modified the conventional wedge and ring stimuli by inserted blank periods. These stimuli are more adept to reconstruct visual field maps with larger receptive fields like hMT+. Stimulus radius was 10 deg. Results: We found at least two visual field maps in hMT+, which we refer to as temporal occipital 1 (TO-1) and 2 (TO-2). This conservative nomenclature acknowledges uncertainties in the human-monkey homologies. TO-1 borders LO-2 and TO-2 is anterior to TO-1. The TO-1 polar angle map extends from the lower to the upper vertical meridian and reverses at TO-2. The maps share a foveal representation that is distinct from that of V1/V2/V3/LO-1/LO-2. TO-1/2 represent the contralateral hemifield. The pRF size of TO-2 (σ = 5-12 deg) is significantly larger than that of TO-1 (σ = 4-8 deg) over the measured eccentricity range (1-6 deg). Discussion: The two visual field maps match the general retinotopic and functional dissociation proposed by Huk et al. (2002) and Dukelow et al. (2001). The two maps probably correspond to macaque MT and MST (Rosa and Tweedale, 2006).

8:45 am

21.12 Functional brain imaging of the 'Rotating Snakes' illusion

Ichiro Kuriki[1] (ikuriki@riec.tohoku.ac.jp), Hiroshi Ashida[2], Ikuya Murakami[3], Akiyoshi Kitaoka[4]; [1]Research Institute of Electrical Communicaiton, Tohoku University, Japan, [2]Graduate School of Letters, Kyoto University, Japan, [3]Department of Life Sciences, University of Tokyo, Japan, [4]Department of Psychology, Ritsumeikan University, Japan

The 'Rotating Snakes' (abbreviated as 'snake') figure (Kitaoka, 2003) is one of the static figures that induce perception of smooth illusory motion. Previous studies have suggested that cortical motion sensors are actually involved, but there has been no direct evidence for humans. Here we investigated whether this illusion activates motion sensitive areas in the human visual cortex by using functional magnetic- resonance-imaging (fMRI) technique. We compared the blood- oxygenation- level- dependent (BOLD) signals for 'snake' and control stimuli. The 'snake' stimulus consisted of an array of micropatterns, each having four colored blobs (black - blue - white - yellow; perceived direction is in this order). Circular repetition of this micropattern in the same color order yields illusory motion of slow rotation. The control stimulus was made by reversing the color order of adjacent micropattern in this circular array. No motion was perceived in this control stimulus. The stimulus sequence was designed as the repetition of 15 s of either 'snake' or 'control' stimulus and 15 s of uniform gray screen. We used a 1.5 T MRI scanner to obtain functional images (TR=3000 ms, voxel size of 3 mm x 3 mm x 3 mm, 120 scans/run). Separate fMRI runs were conducted for spontaneous- (SEM), guided- (GEM), and no- eye- movement (NEM) conditions. A stimulus for attentional control was constantly presented at the fixation point in GEM and NEM conditions. Significant differences in BOLD signals between 'snake' and 'control' were found under SEM and GEM conditions in human MT/MST complex (hMT+), but not under NEM condition. SEM condition exhibited the largest difference. Under no conditions did we find a significant difference in the primary visual cortex. Our results show activation of hMT+ underlying the 'Rotating Snakes' illusion and also support a significant role of eye movements in this illusion.

Acknowledgement: Supported by the program of Grant-in-Aid for Scientific Research (A) #18203036 to AK by MEXT, Japan.

URL: http://www.ritsumei.ac.jp/~akitaoka/index-e.html

9:00 am

21.13 Human brain regions that are responsive to optic flow only when the flow is consistent with egomotion

Andrew T Smith[1] (a.t.smith@rhul.ac.uk), Matthew B Wall[1]; [1]Dept. Psychology and CUBIC, Royal Holloway, University of London, UK

Primate visual cortical area MST is responsive to optic flow and can encode direction of heading but it may not directly signal motion of the body through space (egomotion). We identify two areas of the human brain that represent visual cues to egomotion more directly than does MST. Sensitivity to whether a flow pattern could have been caused by egomotion was tested with fMRI. Responses to a standard random-dot flow pattern were compared with responses to a 3x3 array of nine identical flow patches. Optic flow generated by egomotion can only have one centre of motion (expansion for forward motion). Consequently, the nine flow patches may drive neurons tuned to flow components such as expansion, but the overall stimulus is inconsistent with egomotion. Visual areas were defined in separate retinotopic mapping experiments. Areas V1-V4 and MT all responded about equally to both types of flow stimulus. MST also responded well to multiple patches but showed a modest preference for a single, egomotion-compatible patch. Putative area VIP in the anterior portion of the intraparietal sulcus showed much stronger selectivity, the response to a single flow stimulus being about twice that to the array. More striking still was the result in a new visual area, which we refer to as CSv (cingulate sulcus visual area). Here, a strong response was obtained with a single flow patch but the region was almost completely unresponsive to multiple patches. This requirement for egomotion-compatible stimulation may explain why CSv has not commonly been identified as a visual area. Various control experiments for dot motion parameters, size of motion patch and presence of motion boundaries all yielded similar results. We suggest that MST is merely an intermediate processing stage for visual cues to egomotion and that such cues are more comprehensively encoded by VIP and CSv.

Acknowledgement: Supported by The Wellcome Trust

9:15 am

21.14 Types and Tokens in the Ventral Visual Pathway: The neural representation of multiple visual objects

Won Mok Shim[1] (wshim@mit.edu), Yuhong V Jiang[2], Nancy Kanwisher[1]; [1]Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]Psychology, University of Minnesota

Extensive research over the last decade has characterized the neural response to objects in the ventral visual pathway in humans. However, in most of this work, single objects are presented in isolation, a situation rarely if ever found in real-world scenes. Here we explored the neural representation of displays containing multiple objects by asking whether responses in the ventral visual pathway are sensitive to i) the number of identical copies ("tokens") of an object in a given display, and ii) the number of different kinds ("types") of objects. We measured the fMRI responses in LOC, FFA, and PPA while subjects performed a dimming-detection task at fovea while one or four faces, scenes, or objects were presented in the periphery. All ventral ROIs showed sensitivity to copy/token information, as mean response in each ROI to four identical copies of the same item, one in each quadrant (the four-same condition) was nearly twice as high as the response to a single item in one quadrant (the single-object condition). The token sensitivity does not merely reflect the existence of separate pools of neurons that respond to each quadrant, as activation in the single-object condition was not significantly lower than the four-different condition, where different objects from the same superordinate category were presented, one in each quadrant. The ROIs also showed sensitivity to kind/types information because they responded much more strongly in the four-same condition than the four-different conditions. Similar patterns of response were observed in retinotopic visual areas whose receptive fields were confined to a single visual quadrant although the difference among conditions was smaller. These results may reflect two distinct phenomena, a gain in representation strength from multiple tokens and a competition in representation from multiple types.

Acknowledgement: NIH 071788, ARO 46926-LS, and NSF 0345525

9:30 am

21.15 Collicular vision guides non-conscious behavior

Marco Tamietto[1,2] (tamietto@psych.unito.it), Franco Cauda[1,3], Luca Latini Corazzini[1], Silvia Savazzi[4], Carlo Marzi[4], Rainer Goebel[5], Lawrence Weiskrantz[6], Beatrice de Gelder[2,7]; [1]Department of Psychology, University of Torino, Italy, [2]Cognitive and affective neuroscience lab, Tilburg University, The Netherlands, [3]Koelliker Hospital, Torino, Italy, [4]Department of Neurological and Vision Sciences, University of Verona, Italy, [5]University of Maastricht, The Netherlands, [6]University of Oxford, UK, [7]Martinos Center for Biomedical Imaging, MGH-HMS, MA

Following destruction of the primary visual cortex (V1) phenomenal blindness ensues. There is however a multiplicity of parallel pathways, many of older evolutionary origin, that by-pass V1 and project to other targets in the brain. In a conjoint behavioral/fMRI study we provide conclusive demonstration that in the absence of V1 the superior colliculus (SC) is essential to translate visual signals that cannot be consciously perceived into motor outputs. We show that a stimulus in the blind field of a patient with unilateral V1 lesion, although not consciously seen, influences his responses to consciously perceived stimuli in the intact field and is accompanied by activation in the SC. However, when the stimulus is colored purple, and is hence rendered invisible to the SC, it no longer influences visuo-motor responses, and the activation in the SC drops significantly.

09:45

21.16 Graphical illustration and functional neuroimaging of visual hallucinations during prolonged blindfolding: A comparison to visual imagery

Ruxandra Sireteanu[1,2,3] (sireteanu@mpih-frankfurt.mpg.de), Viola Oertel[4,5], Harald Mohr[1,2,4], Corinna Haenschel[1,4,5], David Linden[6], Konrad Maurer[5], Wolf Singer[1,4], Marietta Schwarz[7]; [1]Department of Neurophysiology, Max-Planck-Institute for Brain Research, Frankfurt, [2]Department of Biological Psychology, Institute for Psychology, Johann Wolfgang Goethe University, Frankfurt, [3]Department of Biomedical Engineering, College of Engineering, Boston University, [4]Brain Imaging Centre, Johann Wolfgang Goethe University, Frankfurt, [5]Neurophysiology and Neuroimaging Laboratory, Department of Psychiatry, Johann Wolfgang Goethe University, Frankfurt, [6]Department of Psychology, University of Bangor, United Kingdom

Purpose: To compare the subjective experience and the brain activity associated with visual hallucinations produced by prolonged blindfolding with the activity associated with mental imagery of the same patterns. Methods: The subject was a 37-year-old healthy female who developed visual hallucinations during three weeks of complete visual deprivation. We acquired fMRI data with a Siemens 3T Magnetom Allegra towards the end of the deprivation period, to assess hallucination-related activity, and again after recovery from blindfolding, to measure imagery-related activity. Subjective descriptions and graphical illustrations were provided by the subject after blindfolding was completed. Results: During blindfolding, the subject experienced vivid visual hallucinations, consisting of flashes of light and coloured, moving patterns. The hallucinated images become gradually less vivid and lost their colour intensity, but gained in structural complexity during the three weeks of blindfolding. Neural activity related to hallucinations was found in occipital visual, posterior parietal and several prefrontal regions (the left medial frontal gyrus, the bilateral inferior frontal gyri and the bilateral middle frontal gyri). In contrast, mental imagery of the same percepts led to activation in prefrontal, but not in posterior parietal and occipital regions. Conclusions: These results suggest that deprivation-induced hallucinations result from increased excitability of early visual areas, while mentally-induced imagery involves active read-out under the volitional control of prefrontal structures. This agrees with the subject's report that visual hallucinations were more vivid than mental imagery.

Saturday, May 10, 8:30 - 10:00 am
Talk Session, Royal Palm Ballroom 4-5

Perceptual Organization 1

Moderator: Pascal Mamassian

8:30 am

21.21 Patch Pair Statistics for Leaf Segmentation

Almon Ing[1,2] (ing.dave@gmail.com), Wilson Geisler[1,2]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Psychology Department, University of Texas at Austin

The human visual system is remarkable for its ability to segment objects in natural scenes. To study the problem of leaf segmentation and related natural tasks, we created a database of hand-segmented leaves in foliage-rich images calibrated to the human L, M, and S cones. Here we consider a simple patch classification task where the goal is to determine whether a pair of image patches is contained within a leaf's surface or whether the pair lies across a leaf's boundary. First, we measured the probability distributions of color differences and color-contrast differences between patches randomly selected from the database. These distributions are neatly described using a whitened three-dimensional (l,α,β) color space, where $l \approx \log L + \log M + \log S$, $\alpha \approx \log L + \log M - 2\log S$, and $\beta \approx \log L - \log M$ (e.g., Ruderman et al., 1998, JOSA-A 15:8). Next, we derived a near-optimal classifier based on these distributions. We find that the classifier's accuracy is largely determined by the color differences between patches and not by the color-contrast differences. Based on the color differences alone, the classifier performs at 79% correct for nearby patches and falls to 67% at greater distances (chance = 50%). Finally, we measured human performance in the patch classification task without, and then with, feedback. Without feedback, the human subjects paralleled (but were slightly below) the performance of the near-optimal classifier when they categorized unaltered natural image patches ("full"), uniform image patches ("texture removed"), and image patches where the average color differences were removed but texture remained ("color removed"). With feedback, substantial performance improvements were observed for the color removed conditions (especially when patches were close together), but not for the others. A subjective examination of trials where the near-optimal classifier disagreed with humans suggests that humans may use the following texture cues: good/bad continuation of a shadow or surface marking, shading gradients, and fine texture similarity.

Acknowledgement: Supported by NIH grants EY11747 and EY02688

8:45 am

21.22 **Binding the pieces: Efficacies of grouping cues**

Yuri Ostrovsky[1] (yostr@mit.edu), Anya Leonova[1], Pawan Sinha[1]; [1]Brain and Cognitive Sciences, MIT

When a newborn baby sees the booming, buzzing confusion of the visual world, how does it begin to piece together the parts that make up contours, objects, and background? The Gestaltists have identified many of the cues to which the adult visual system is sensitive, but it is not known which of these cues are innately specified and which are learned through visual experience. Infant work has identified common motion as an important grouping cue early in development. Our own work in Project Prakash (Nature, 2006, 441, 271-272) has shown that late-onset vision patients, almost immediately after sight recovery, are able to make use of motion, but not other grouping cues (such as continuation, junction parsing, and color) to parse visual imagery. Building upon these results, here we explore the process by which learning heuristics might be acquired, and, specifically, the role of motion in this process.

We conducted computational analyses to examine the relative efficacies of motion and color cues for learning grouping heuristics. Working with natural visual sequences, we find that common motion cues, as compared to common color or luminance cues, are more effective for learning at least one important Gestalt heuristic – grouping via contour continuation. Motion-mediated learning, we find, can proceed with fewer training samples and is effective over larger spatial distances. We infer that motion cues, more than others, might embody reliable statistical properties in the natural world. To complement this computational result, we are conducting empirical studies with normal adults to examine whether the privileged status of motion as a grouping mechanism is evident in the mature visual system. By pitting motion cues against other binding cues in behavioral grouping tasks, we are able to titrate the contribution of different cues and arrange them in a tentative hierarchy based on their grouping efficacy.

Acknowledgement: The John Merck Foundation

9:00 am

21.23 **Perceptual organization across spatial scales in natural images: Seeing more high spatial frequency than meet the eyes**

Aude Oliva[1] (oliva@mit.edu), Timothy F. Brady[1]; [1]Department of Brain and Cognitive Sciences, MIT

One of the most robust statistical properties of natural images is that contours are correlated across spatial frequency bands. However, the rules of perceptual grouping across spatial scales might be different as the observer approaches an object (adding HSF), or steps away from it (losing HSF). We manipulated contiguity across spatial scales by using hybrid images that combined the LSF and HSF of two different images. Some hybrids perceptually grouped well (e.g. two faces), and others did not (e.g. a highway and bedroom). In Experiment 1, observers performed a 2-AFC task while walking towards or away from the hybrids, judging how similar the hybrid was to each of its component images. In Experiment 2, conditions of an object moving towards or away were simulated by having images zooming in and out. Results in all experiments showed that when the observer and object are approaching each other, observers represent object SF content as predicted by their contrast sensitivity function: they add HSF to their representation at the appropriate rate. However, when observers or objects are receding from each other, observers show a perceptual hysteresis, hanging on to more of the high spatial frequency image than they can see (23% real vs. 50% perceived). This hysteresis effect is predicted by the strength of perceptual grouping between scale spaces. As we move through the world and attend to objects, we are constantly adding and losing information from different spatial scales. Our results suggest different mechanisms of on-line object representation: we tend to stick with our first grouping interpretation if we are losing information, and tend to constantly reinterpret the representation if we are gaining information.

Acknowledgement: Funded by an NSF Career award (IIS 0546262) and NSF grant (IIS 0705677).

9:15 am

21.24 **Testing filter-overlap models of contour integration**

Keith May[1,2] (keith@keithmay.org), Robert Hess[1]; [1]McGill Vision Research, McGill University, Montreal, Canada, [2]Vision Science Research Group, University of Bradford, UK

Most models of contour integration belong to one of two broad classes: those with explicit connections that link different regions of space (association field models, e.g. Field, Hayes & Hess, 1993, Vision Research, 33, 173-193), and those which depend on spatial overlap in the filter responses to adjacent elements (filter-overlap models). In some filter-overlap models, processing occurs separately within each orientation channel. These models do not adequately account for human foveal contour detection performance because (1) their performance decreases too rapidly with increasing curvature (Hess & Dakin, 1997, Nature, 390, 602-604), and (2) their performance decreases as the contour becomes smoother (Lovell, 2005, Journal of Vision, 5(8), 469a), while human observers generally show the opposite effect (Pettet, 1999, Vision Research, 39, 551-557; Lovell, 2005). The filter-overlap model's ability to detect smooth or highly curved contours can be improved by allowing it to link spatially-overlapping filter responses from adjacent orientation channels. We set up two types of orientation-linking filter-overlap model. One used 1st-order filters to detect snakes (i.e. contours composed of Gabor elements parallel to the path of the contour); the other used 2nd-order filters to detect ladders (in which the elements are perpendicular to the path). Both models were good at detecting smooth, highly curved contours, but showed little effect of contour smoothness or curvature. In contrast, human performance on snakes increased substantially with increasing smoothness and, for the most jagged contours, decreased substantially with increasing curvature. Human performance on ladders showed little effect of smoothness (unlike separate-channels filter-overlap models), but was strongly disrupted by an increase in curvature (unlike orientation-linking filter-overlap models). Thus, neither type of filter-overlap model could account for the pattern of results for snakes or ladders. We conclude that, despite their successful detection performance, filter-overlap models are not realistic models of contour integration in human vision.

Acknowledgement: This research was funded by the Natural Sciences and Engineering Research Council of Canada (RGPIN 46528-06 awarded to Robert F. Hess)

9:30 am

21.25 **Independent Measures of Adaptation and Aftereffect**

Kai-Markus Mueller[1,2] (muellerkm@mail.nih.gov), David H. Do[1,3], David A. Leopold[1]; [1]Laboratory of Neuropsychology, NIMH, NIH, [2]International Max-Planck Research School Tuebingen, [3]Department of Psychology, University of Minnesota

Visual aftereffects are common research tools in psychophysics. A major rationale underlying this research is that the visual system recalibrates during adaptation, e.g. through inhibition or through shifting the norm. This idea can be traced back to Gibson (1933) who investigated adaptation to a curved line. His subjects reported (1) "adaptation" (subjective straightening of the curvature over time) and (2) negative aftereffect (appearance of opposite curvature in a subsequently presented straight line). Here we explored the relationship between these two phenomena, particularly the dynamic perceptual changes associated with the adaptation effect. The subtle adaptation effect is difficult to measure using traditional psychophysical approaches. Accordingly experiments have almost exclusively concentrated on the subsequent aftereffect, which can be studied objectively using nulling or forced choice procedures. Here we present a new psychophysical approach that allows us to investigate directly dynamic aspects of the process of adaptation. Subjects adapted to a curved line and reported curl motion – either curling or uncurling. By applying subthreshold curling movement to the line and using a staircase procedure, we were able to cancel the subjects' perceived straightening of the line. We measured the extent of adaptation using both this dynamic nulling technique, as well as classical static nulling of the subsequent aftereffect to a briefly presented pattern. Both techniques provided a robust measure of curvature adaptation. Interestingly, in neither technique did the level of adapting curvature in the tested range affect the magnitude of the effect. Although the two techniques provided similar mean trends, magnitudes of adaptation and aftereffect across subjects did not correlate. Our approach of dynamic nulling of subjective adaptation provides an effective tool to probe dynamics of visual adaptation during the adaptation phase itself.

Acknowledgement: Division of Intramural Research Programs at the National Institute of Mental Health

09:45

21.26 The visual system uses different estimators for different distributions in a novel task even without feedback or the possibility of learning

Laurence T. Maloney[1,2] (ltm1@nyu.edu), Pascal Mamassian[3]; [1]Psychology, New York University, [2]Center for Neural Science, New York University, [3]CNRS & Université Paris

Purpose. Bayesian decision theory (BDT) is often used as a model of visual processing with the assumption that visual uncertainty is Gaussian and that estimators minimize variance (MV) or maximize posterior probability (MAP). BDT applies equally well to other distributional families and the resulting MV and MAP estimators can be very different from that appropriate for the Gaussian. Our goal is to examine whether the visual system has the same facility in selecting optimal estimators when the distribution family is not Gaussian.

Methods. We selected two distributional families, the circular Gaussian and the Uniform on a circular arc. Samples were presented as points on an invisible circle centered on fixation. The distributions were equated for variance and the true center of each distribution was distributed uniformly on the circle from trial to trial. In an initial training phase, eleven naïve participants were trained to discriminate the distributions (identified only as "A" and "B") . Eight participants with estimated d'>1 continued on to the second, estimation phase. They were told that a block of 300 trials contained samples of size 9 drawn from the now familiar A (or B) distribution and asked to estimate the center of the (invisible) distribution by adjusting a circular cursor. No feedback occurred. They then repeated this task for the other distribution. Prior training ensured that participants understood the task. Analysis. We characterized both MV/MAP estimators and observers' performance by the weight assigned to each point when the sample is ordered. We could then compare them.

Results. Participants deviated significantly from MV/MAP in judging both distributions, but they spontaneously selected different estimators for each distribution. The difference between the pattern of weights for the two distributions was qualitatively correct. The visual system uses different estimators even without feedback or the possibility of learning.

Acknowledgement: Supported by NIH EY08266 (LTM) and Chaire d'excellence (PM).

Saturday, May 10, 10:30 am - 12:15 pm
Talk Session, Vista Ballroom

3D Perception and Image Statistics

Moderator: David Knill

10:30 am

22.11 The subjective reliability of a newly recruited visual cue is similar whether or not a long-trusted cue is also present in the stimulus

Benjamin Backus[1] (bbackus@sunyopt.edu); [1]Vision Sciences, College of Optometry, SUNY Midtown Manhattan

The adult human visual system robustly recruits stimulus position (i.e. visual direction) as a cue for disambiguating the apparent rotation directions of 3D figures, as the result of training during which position is paired with binocular disparity and occlusion (Haijiang, Saunders, Stone & Backus, 2006). How should we measure the system's reliance on the newly recruited cue? Backus & Haijiang (2007) used conflict stimuli to quantify reliance in units of disparity, but one can also measure reliance in units of decision noise using probit analysis (Dosher, Sperling & Wurst, 1986). We hypothesized that reliance on the new cue would generalize completely from binocular to monocular viewing. Each of six trainees viewed 480 training stimuli and 480 test stimuli in alternation. 2/3 of the test stimuli contained small binocular disparities that agreed or conflicted with the new position cue. The remaining test stimuli were monocular. The the new cue was differently effective across trainees, from 0.6 to 5.8 normal equivalent deviations (NEDs), but had similar effects for monocular and binocular stimuli within each trainee. Across trainees, mean difference ± SE was 0.1±0.4 NED, with r = 0.89 (p <0.02). The results are consistent with a model in which the visual system chooses one or the other perceptual interpretation according to subjective reliabilities, determined by the cues, that act like Bayes factors. Additivity of effects is predicted by identifying the cues either with log likelihoods or with "equivalent Bernoulli experiments" to estimate a posterior Bernoulli probability. Explaining perceptual bistability differs from explaining rivalry because one can ignore the time course of decision making. Unlike rivalry, binary perceptual decisions can easily be treated within existing theoretical frameworks for cue combination, which makes bistable stimuli highly appropriate for testing quantitative models of cue recruitment and cue combination.

Acknowledgement: NIH R01-EY013988, NSF 617422

URL: http://www.sunyopt.edu/research/backus

10:45 am

22.12 Image statistics for 3D shape estimation

Roland Fleming[1] (roland.fleming@tuebingen.mpg.de), Yuanzhen Li[2], Edward Adelson[2]; [1]Max Planck Institute for Biological Cybernetics, [2]Dept. of Brain and Cognitive Sciences, MIT

Most accounts of 'Shape-from-X' start with a computational theory of a particular cue, then outline methods for extracting relevant data from the image. Here we take the opposite approach, starting with image statistics and investigating how they might be exploited to estimate shape across variations in lighting, reflectance and texture. We rendered a large number objects and looked for image statistics that vary systematically with properties of the shape. We find several simple measurements — derived from filters at different orientations and scales — yield surprisingly reliable information about 3D shape. In a series of experiments we show that changes in these statistics predict certain successes and failures of human perception.

In a gauge probe task, shape perception remained remarkably constant across changes in surface reflectance (glossiness, albedo). Although the images differ substantially on a pixel-by-pixel basis, the orientation statistics remain stable across these reflectance changes, suggesting they could be the basis of human performance.

In another task, observers were presented with shaded objects that had been subjected to certain shape transformations. The task was to adjust the magnitude of shear or stretch of a textured object until it appeared to be the same shape as the shaded object. Subjects underestimate the shear transformation for shaded objects, and the scaling transformation for textured objects, consistent with the predictions derived from our image statistics analysis. Thus, differences between cues may be predicted by a common front end.

In another task, we applied transformations to texture and shading that elicit illusions of 3D shape. The strength of the illusions correlates with the induced changes in the orientation and scale statistics. Together, these findings suggest that to understand 3D shape perception, it is useful to reformulate the problem in terms of the image measurements made by the front end of vision.

Acknowledgement: RF supported by DFG grant 624/1-1

URL: http://www.apgv.org/VSS_08/index.html

11:00 am

22.13 Prior expectations in slant perception: Has the visual system internalized natural scene geometry?

Ahna Girshick[2,1] (ahna@nyu.edu), Johannes Burge[1], Gennady Erlikhman[1,5], Martin Banks[1,3,4]; [1]Vision Science Program, UC Berkeley, [2]Center for Neural Science, New York University, [3]Psychology Department, UC Berkeley, [4]Helen Wills Neuroscience Institute, UC Berkeley, [5]Cognitive Sciences, University of Pennslyvania

In perceptual experiments, the perceived slant is frequently less than the physically specified slant. We show that this slant underestimation can be successfully predicted by a probabilistic model that combines current measurements with a prior expectation of zero slant. From the geometry of natural scenes, one can make a prediction about the shape and spread of the prior. The probability that a line of sight will intersect a surface rotated by a random amount about a vertical axis is a half-cosine distribution centered at 0deg. We asked whether the visual system behaves as if it has internalized this predicted distribution of likely slants. The probabilistic model predicts different effects of the prior depending on the reliability and slant of the surface. Estimating the visual system's internal prior from measured psychophysical data is challenging because observer responses are affected by both the prior and the unknown likelihood. To measure the visual system's prior, we presented two slanted planes and observers indicated which was more slanted. The stimuli were either regular grid-like textures for which slant was reliably discriminated (R) or irregular textures for which slant was unreliably discriminated (U). A range of base slants was presented in three types of trials: UvsU, RvsR, and UvsR. To eliminate any cues that could bias the visual system towards slant estimates of zero, we used real surfaces. We found that observers systematically underestimated the slant of the unreliable stimulus relative to the reliable stimulus in a manner consistent with the probabilistic model. From the psychophysical data we inferred the spread and shape of the internal prior distribution using a technique similar to Stocker and Simoncelli (2006). The priors reconstructed from the data were peaked at zero slant and were similar to the theoretical expectation.

Acknowledgement: NIH, NSF, AOF Ezell Fellowship for JB

11:15 am

22.14 **Learning shape-specific Bayesian priors for depth perception**

David Knill[1] (knill@cvs.rochester.edu); [1]Center for Visual Science, University of Rochester

Purpose: We have previously shown that humans learn to down-weight the figure compression cue to slant in an environment containing a large proportion of randomly shaped figures. We proposed a model in which observers use image information alone to match their internal models of the statistics of figure shape to the statistics of their environment. To further test the model, we tested whether subjects could learn different statistical models for different shape categories, leading to shape-contingent weighting of the compression cue. Methods: Subjects viewed stereoscopic images of elliptical and diamond shaped figures and adjusted a 3D line probe to appear perpendicular to the surface. We measured cue weights for circles and square diamonds using test stimuli that were near-circular ellipses and near-square diamonds presented at a slant of 35o (containing 5o conflicts between the compression cue and the stereoscopic cues). Test trials were embedded in a large set of trials containing images of ellipses and diamonds rendered at slants between 20o and 40o. In the first two "baseline" sessions of the experiment, the non-test figures were circles and square diamonds. In the final three "training" sessions the shapes of some of the figures in the non-test trials were randomized. In one condition, the ellipses were randomly shaped; in the other, the diamonds were randomly shaped. No feedback was given. Results: While observers' gave equal weights to both types of figure in the baseline conditions, they later gave less weight to the compression cue for the shape category that was randomized in training (Mean weight change = .15). Conclusions: Humans can learn different prior models for categorically different shapes, so that in one environment, figure shape can be more salient as a slant cue for one type of figure than another, while in another environment, it can be less salient.

Acknowledgement: Research supported by NIH grant EY-17939

11:30 am

22.15 **Nonlinear Biases in the Perception of 3D Slant from Texture**

James Todd[1] (todd.44@osu.edu), James Christensen[1], Kevin Guckes[1]; [1]Ohio State University

Data obtained from slant discrimination studies with textured surfaces (e.g., Knill & Saunders, Vis Res, 2003) have consistently shown that the reliability of observers' slant estimates is higher for large slants than for small slants, but the opposite result has been reported for the variability of slant estimates that are obtained using an adjustment task (Todd, et al, Vis Res, 2005). In order to determine the reliability of slant estimates from discrimination thresholds, it is typically assumed that observers' judgments are veridical except for internal random noise. This assumption is necessary because thresholds can also be affected by any systematic biases in perceived slant. Indeed, the results from prior discrimination studies are perfectly consistent with a changing bias as a function of depicted slant rather than a change in reliability, and this could potentially reconcile the conflicting results that are obtained using matching tasks. In an effort to confirm this possibility, the research described here was designed to measure the psychophysical mapping between physical and perceived slant from texture, under viewing conditions that are similar to those employed in previous studies. Observers were presented on each trial with two pairs of adjacent surfaces with different slants, and they were asked to adjust the slant of one of those surfaces so that the apparent angle between each pair was equated. The results reveal that there is an upward curving psychophysical function between physical and perceived slant, such that a depicted angle between relatively shallow slants appears significantly smaller than the same depicted angle between steeper slants. These findings indicate that the assumptions employed in prior discrimination studies for shape from texture may not be valid, which may also make it necessary to reconsider how discrimination procedures are employed for the investigation of cue combination.

Acknowledgement: This research was supported by a grant from NSF (BCS-0546107).

11:45 am

22.16 **Blur and accommodation are metric depth cues**

Johannes Burge[1] (jburge@berkeley.edu), Robert Held[2], Martin S. Banks[1,2,3]; [1]Vision Science Program, UC Berkeley, [2]Joint Graduate Group in Bioengineering, UCSF / UC Berkeley, [3]Psychology Department, UC Berkeley

Focus cues—blur and accommodation—are regarded as very weak depth cues. The research that led to that assessment has, however, been greatly limited by an inability to present focus cues in a fashion consistent with natural viewing. We recently developed a novel volumetric display that allows the presentation of near-correct focus cues along with standard depth cues like binocular disparity. We used the display to re-examine the usefulness of blur and accommodation as cues to depth. We created stereograms with anisotropic textures that created disparities specifying a disk in front of a background. Probability-based theories of cue combination predict that as the disparity signal becomes less reliable, the percept should be more heavily determined by the focus cues. We varied the reliability of the disparity signal by changing the dominant orientation of the texture. Reliable (texture vertically oriented) and unreliable (texture horizontally oriented) disparity signals were presented in three conditions: i) focus cues specified zero depth, as they do in conventional 3d displays; ii) focus cues and disparity specified the same depth, as they do in natural viewing; iii) focus cues specified more depth than disparity. We presented stimuli in two intervals and observers reported the interval with more apparent depth. As expected, when focus cues specified zero depth, subjects saw less depth when the disparity signal was unreliable than when it was reliable; when focus cues specified more depth than disparity, the effect was reversed: subjects saw more depth with unreliable disparity. Based on pupil-diameter fluctuation, accommodative fluctuation, and optical aberrations, we computed the theoretically expected depth-from-focus likelihood functions. They are reasonably similar to the likelihood functions estimated from the data. These results show that focus cues provide a metric depth signal that is combined in a statistically reasonable fashion with disparity.

Acknowledgement: AOF William C. Ezell Fellowship, NIH and NSF

12:00 pm

22.17 **Superior Occipital Regions Track Perceived Viewing Distance in Two Dimensional Images**

Marian Berryhill[1,2] (berryhil@psych.upenn.edu), Geoffrey Aguirre[3], Ingrid Olson[1]; [1]Department of Psychology, Temple University, [2]Center for Cognitive Neuroscience, University of Pennsylvania, [3]Deparment of Neurology, University of Pennsylvania

Perceived depth is apparent in two-dimensional images due to the presence of monocular depth cues. Consequently, viewing distance, the distance between the observer and the observed, is implicitly included in visual images. The present study used a continuous carry-over fMRI design (Aguirre, 2007) to identify focal adaptation and distributed cortical patterns reflecting implied viewing distance. Stimuli were photographs of 40 objects positioned at 4 viewing distances within a naturalistic background, and the background alone. Stimuli were presented continuously, every 1500 msecs. The sequence of implied viewing distances was specified by a fourth-order counterbalanced m-sequence, whereas the particular object positioned at that distance was randomized per trial. Subjects performed an object categorization judgment orthogonal to the manipulation of viewing distance. Presentation of any stimulus compared to the empty background evoked broad activations throughout dorsal and ventral visual areas. Adaptation analysis examined the response modulation as a function of the change in viewing distance across trials. Only the bilateral superior occipital gyrus (corresponding to V3d) demonstrated recovery from adaptation proportional to the change in viewing distance, apart from absolute viewing distance. In a separate analysis, the distributed pattern of cortical response to stimuli at each viewing distance, independent of stimulus features, was submitted to linear support vector machine (SVM) classification. Area V1 voxels provided accurate classification, as expected given the greater angular size of stimuli at the near viewing distance. Importantly, the optimal classification site for viewing distance was not the superior occipital region identified by within voxel adaptation. This suggests that the V3d site can represent viewing distance by a within voxel population code. Studies of a patient with bilateral parieto-occipital lesions also suggest that this region is critical for accurate distance perception. Viewing distance is represented automatically in superior occipital regions similar to those that process binocular disparity (stereopsis).

Saturday, May 10, 10:30 am - 12:15 pm Talk Session, Royal Palm Ballroom 4-5

Object: Neural Mechanisms

Moderator: Frans Verstraten

10:30 am

22.21 Retinal Position and Object Category Effects in Human Lateral Occipital Cortex

Rory Sayres[1, 2] (sayres@psych.stanford.edu), Kalanit Grill-Spector[1, 2]; [1]Psychology Department, Stanford University, [2]Neurosciences Program, Stanford University

Object-selective regions of human cortex, including the lateral occipital complex (LOC), are known to be sensitive to the retinotopic position of object stimuli, as well as the category of object. However, there has been little quantitative measure of the extent, organization or relative magnitude of these effects. Further, the relationship between different functionally-defined cortical regions is unclear: while the LOC is defined by preferential responses to objects over non-object images, the retinotopic maps LO-1 and LO-2 are known to be located in the vicinity. We sought to relate measures of object selectivity and retinotopy with a series of fMRI experiments. We imaged six subjects in a 3T MRI scanner using a standard retinotopic stimuli, as well as block-design experiments in which different object categories were presented at six distinct retinotopic positions. We then examined responses in region LO, a subset of the LOC positioned posterior to hMT+ along the lateral cortical surface.

We found substantial retinotopic modulation by checkerboard wedge and ring stimuli in LO. LO exhibited a modest overlap with LO-1 and LO-2, and retinotopic modulation in LO extended well beyond the boundaries of LO-1 and LO-2. Further, LO showed a pronounced lower visual field bias: more LO voxels represented the lower contralateral visual field during the retinotopic mapping experiment, and the mean LO response was higher to objects presented below fixation than above fixation. Finally, we examined how object category and retinal position affect the distributed response across LO. We found a stronger effect of position than category on the distributed LO response: response patterns to two stimuli were more correlated if the category was the same than the position. These results indicate that retinal position affects BOLD response at least as strongly as category, and these effects may be explained by retinotopic organization in LO.

Acknowledgement: We thank Serge Dumoulin for insightful discussion.

10:45 am

22.22 How Translation Invariant are Object Representations in the Human Posterior Fusiform Gyrus?

Mark D. Lescroart[1] (lescroar@usc.edu), Kenneth J. Hayworth[1], Irving Biederman[2]; [1]Neuroscience Graduate Program, University of Southern California, [2]Department of Psychology, University of Southern California

There is some uncertainty as to the extent to which object representations in late ventral stream visual areas may be translation invariant. Grill-Spector et al. (1999), using faces in an adaptation paradigm, concluded that the representations in LOC were invariant to translation. The stimuli in that study were large (>10˚ of visual angle) and were translated over relatively small distances (5.6˚)—about half the stimulus diameter. Alternatively, several groups have now found retinotopic organization in lateral and ventral occipital cortex (Larsson et al 2006, Brewer et al 2005). Consistent with a position-specific representation in late ventral visual areas is the recent single unit work in macaque IT by Op de Beeck et al (2000) and DiCarlo and Maunsell (2003). These investigators reported cells with receptive fields as small as 1 degree of visual angle (the preferred stimuli for these cells was ~.5˚).

We investigated whether adaptation effects in the posterior fusiform region of LOC would show position sensitivity when stimuli were translated by more than one stimulus diameter. Subjects viewed a sequence of two object images. All stimuli were presented iso-eccentrically, 4.5˚ from fixation. The objects subtended 2.3˚ and the second stimulus was translated either 0˚, 2.3˚, 4.6˚, or 9.0˚—zero, one, two, or four stimulus diameters, respectively. The subject's task was to detect whether S2 was a different object than S1—which occurred on 16% of the trials.

Objects translated a distance of one stimulus diameter produced a minimal release from adaptation compared to the 0˚ condition, but both larger translations produced a significant release from adaptation (equal in magnitude for both). This result could explain the apparent conflict among the previously cited studies: translation effects in the posterior fusiform may only be manifested when the extent of the translation is greater than the extent of the object.

Acknowledgement: This work was supported by NSF BCS 04-20794, 05-31177, & 06-17699 to IB

11:00 am

22.23 Orthogonal representations of object category and location in object selective cortex

Thomas A. Carlson[1,2,3] (tom@wjh.harvard.edu), Hinze Hogendoorn[1,2,3], Hubert Fonteijn[2,3], Frans A. J. Verstraten[2,3]; [1]Vision Sciences Laboratory, Harvard University, [2]Helmholtz Institute, Experimental Psychology Division, Universiteit Utrecht, Utrecht, The Netherlands, [3]F.C. Donders Centre for Cognitive Neuro-imaging, Radboud Universiteit, Nijmegen, The Netherlands

Theories of object recognition often call upon the notion of invariance to account for our ability to recognize objects across many naturally occurring transformations (e.g. size and viewpoint), including changes in spatial position. To investigate this, we measured brain activity using fMRI while subjects viewed four categories of objects (faces, houses, animals, and cars) displayed to four locations in the visual field. In our analysis, we first used principal component analysis to decompose the responses of object selective areas into a set of orthogonal component activation patterns. These components were used by a linear classifier to decode the category of the object displayed to the observer. The results of the classification analysis showed that object selective areas robustly code the position of objects. We further investigated how the brain supports our ability to recognize objects across different locations. In an examination of the individual components, we found subsets that retain the ability to extract object category information across different locations. These components, which are orthogonal to components that rely on position, could be utilized to solve the problem of invariance. Notably, this represents a population response solution, which is consistent with recent modeling efforts. The orthogonality of these representations is exemplified in our analysis of FFA and PPA. In terms of the components that specified object category, the specialization of these areas was clear. The preferred category had more object category components; these components also accounted for a large proportion of the object related activity in these areas. In contrast, the representation of space in these areas was found to be roughly equivalent for the preferred and non-preferred object categories.

11:15 am

22.24 The 'Parahippocampal Place Area' Responds Selectively to High Spatial Frequencies in Humans and Monkeys

Reza Rajimehr[1] (reza@nmr.mgh.harvard.edu), Kathryn Devaney[1], Jeremy Young[1], Gheorghe Postelnicu[1], Roger Tootell[1,2]; [1]NMR Athinoula A. Martinos Center, Massachusetts General Hospital (MGH), Harvard Medical School, [2]Laboratory of Brain and Cognition, National Institute of Mental Health (NIMH), National Institutes of Health (NIH)

Defining the exact mechanisms by which the brain processes visual objects remains an unresolved challenge. Valuable clues to this process have emerged from the demonstration that clusters of neurons ('modules') in primate inferotemporal (IT) cortex apparently respond selectively to specific categories of visual stimuli. However, lower-level visual cues which might underlie these category selectivities have not been extensively tested. Here we show that at least part of the 'category-selective' response in one of these brain areas (Parahippocampal Place Area - PPA, which apparently responds selectively to images of places) actually results from a lower-level selectivity for high spatial frequencies, which are emphasized in object borders and details. This lower-level selectivity was demonstrated in multiple fMRI tests, both in humans and monkeys. In humans, the PPA responses were strongly correlated with the spatial frequency content of different computer-generated 3D shapes. In addition, we found a near-doubling of the (normally-small) response to naturalistic images of faces in the human PPA, when such images were filtered to pass only high spatial frequencies. The same fMRI experiment in awake monkeys revealed a PPA homologue in macaque, and a striking double-dissociation between sensitivity to stimulus category (places/faces) versus spatial frequency (higher/lower) in the monkey homologues of PPA and FFA (Fusiform Face Area), respectively. These results suggest that a neural selectivity for high spatial frequencies might arise naturally in PPA, to encode object borders and details of scenes, during place-related cortical processing (e.g. for navigation or environmental vigilance). By the same token, the lower-level spatial selectivity shown here likely accounts for at least some of the higher-order 'category selectivity' reported in the previous studies of PPA.

11:30 am

22.25 Imaging prior information in the visual system

Scott Gorlin[1] (gorlins@mit.edu), Jitendra Sharma[1,2,3], Hiroki Sugihara[1,2], Mriganka Sur[1,2], Pawan Sinha[1]; [1]Department of Brain and Cognitive Sciences, MIT, [2]Picower Institute for Learning and Memory, MIT, [3]Martinos Center for Biomedical Imaging, Mass. General Hospital

Prior information and experience with visual stimuli enhance our ability to recognize images, but where and how does this facilitation occur in the brain? Using stimuli which temporally evolve out of noise and then degrade again, we show that recognition of degraded stimuli persists past the level of noise required for initial recognition, a phenomenon known as hysteresis. Furthermore, using machine learning algorithms, we can quantify the amount of information a given brain region or neuron contains about the stimulus as the subject learns the coherent image. Here we show how distinct brain regions from prefrontal cortex to V1 contain more information about degraded stimuli with prior knowledge, and that local information in the brain persists in line with behavioral hysteresis. Interestingly, behavioral and neural hysteresis depends critically on the complexity of the stimuli, so that prior information seems to be encoded over complex, real-world features, but not simple stimuli such as oriented gratings.

11:45 am

22.26 Neural correlates of music reading expertise

Yetta Kwailing Wong[1] (yetta.wong@vanderbilt.edu), Isabel Gauthier[1]; [1]Psychology Department, Vanderbilt University

Studies of the functional specialization of the visual ventral pathway have heavily focused on face-selective (e.g. Allison et al., 1994; Kanwisher et al., 1997) and letter-selective areas (e.g. Cohen et al., 2000; James & Gauthier, 2006). However, focusing on just two areas makes it difficult to distinguish between competing theories of the functional organization of higher visual cortex. This fMRI experiment expands the focus of expertise studies by investigating neural specialization for the perception of musical notation. In a block-design fMRI experiment, observers with considerable expertise reading music and complete novices performed one-back matching judgments on musical notes, Roman letters and mathematical symbols. Whole-brain analyses revealed a widespread neural network selectively engaged in the expert perception of musical notation, including bilateral early visual areas (V1/V2), bilateral inferior temporal areas, parietal areas, primary and associative auditory areas, parts of superior temporal sulcus and frontal areas including supplementary motor cortex. The activation in most of these areas was also correlated with the perceptual threshold for matching note sequences, an index of visual expertise in this domain. In contrast, face- and letter-selective regions did not show expert responses to musical notations. These results suggest that a distinct but equally widespread network of cortical areas is engaged by expert perception of musical notation, compared to other types of expertise. This is consistent with the process-map account, which assumes that there are not "expertise areas" in the brain: Any part of the visual system, for instance, can be recruited by expertise depending on the specific constraints of the task and properties of the stimuli. Learning about qualitatively different domains of expertise can facilitate the development of a general theory of how experience shapes cortical selectivity.

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12:00 pm

22.27 Circular inference in neuroscience: The dangers of double dipping

Nikolaus Kriegeskorte[1] (kriegeskorten@mail.nih.gov), William K. Simmons[1], Pat S. Bellgowan[1], Chris I. Baker[1]; [1]Laboratory of Brain and Cognition, NIMH

A neuroscientific experiment typically generates a large amount of data, of which only a small fraction is subjected to detailed analysis and presentation in a publication. This inevitable selection is a major determinant of the final conclusion, and selection among a set of noisy measurements can render circular an otherwise appropriate analysis, invalidating statistical tests. The issue of circularity is particularly important in both electrophysiological and neuroimaging experiments. Here we focus on neuroimaging and argue that the field needs to adjust some widespread practices to avoid the circularity that can arise from selection. Faced with even more parallel sites than electrophysiology (typically on the order of 100 000 voxels), neuroimaging has developed rigorous methods for statistical mapping. This powerful approach avoids selection altogether: by analyzing all locations equally, while accounting for the fact that multiple tests are performed. However, selective analysis is still commonly used to focus on a particular brain region and, in fact, statistical mapping can form the basis for defining a region of interest (ROI). Further analysis of such functionally defined regions must take the selection bias into account. This problem is well understood in theory and one solution is to use independent experimental data to analyze the ROI. In practice, however, the selection bias is often ignored and important claims rely on questionable circular analyses. In order to demonstrate the problem, we apply analyses widespread in the neuroimaging literature to data known not to contain any experimental effects: functional magnetic resonance imaging (fMRI) data acquired from a resting human subject performing no explicit task. This exercise shows that widespread analysis procedures can produce spurious effects in the context of both univariate activation analysis and multivariate pattern-information analysis. We conclude by suggesting some simple guidelines for better practice in research and reviewing.

Saturday, May 10, 8:30 am - 12:30 pm Poster Session, Royal Palm Ballroom 1-3

Binocular Mechanisms 1
Eye Movements, Search and Attention
Motion: Higher Mechanisms and Illusions

Binocular Mechanisms 1

23.301 Depth, but not Surface Orientation, from Binocular Disparities

Pascal Mamassian[1] (pascal.mamassian@univ-paris5.fr); [1]Laboratoire Psychologie de la Perception, CNRS & Université Paris Descartes, France

Binocular disparities are informative about the three-dimensional shape of objects as well as their spatial layout in the scene. Is the visual system equally efficient in representing shape and depth? This question is difficult to answer because of their non-commensurate dimensions, namely depth is measured as a distance from the observer whereas shape can be represented as surface curvature or local surface orientation. We addressed this issue by comparing two stimuli, a "step" stimulus representing fronto-parallel surfaces in different depth planes and a "slant" stimulus representing surfaces oriented in depth. Importantly, the stimuli differed only by a simple depth-irrelevant manipulation. More specifically, stimuli were composed of a series of vertical lines at crossed (C) or uncrossed (U) disparities in the order C-C-U-U-C-C-U-U etc. Small horizontal lines connected consecutive pairs of same disparity to produce the step stimulus, or they connected consecutive pairs of dissimilar disparity to produce the slant stimulus. It is important to note that the horizontal lines did not add any new binocular disparity, so the two stimuli were identical in terms of the amount of depth displayed. Discrimination thresholds were measured for both stimuli (front/back or left/right slant judgments). We found that disparity thresholds were at least ten times smaller for step as compared to slant stimuli, even though the two stimuli contained the same binocular disparity information. In addition, disparity thresholds for slant stimuli increased linearly with object size whereas thresholds for step stimuli remained roughly constant for the range of sizes used. These results suggest that at least two three-dimensional representations are extracted from binocular disparities, one representing the distance from the observer, the other surface orientations, and that most of the binocular information is lost to generate the latter.

Acknowledgement: Chaire d'excellence from the French Ministry of Research

23.302 **The orientation disparity field accounts for a slant by tilt anisotropy**

Carlo Fantoni[1] (fantoni@psico.units.it), Walter Gerbino[1]; [1]University of Trieste, Department of Psychology and B.R.A.I.N. Center for Neuroscience

Despite extensive research on stereoscopic cues, whether stereoscopic slant is based on point vs. orientation disparity is still a matter of debate. We measured slant sensitivity for stereoscopic planar patches covered by: back-projected straight lines with random orientation (Experiment 1) and random dots (Experiment 2). Surfaces were inclined around both horizontal (H) and vertical (V) axes, and were viewed through a circular aperture on a fronto-parallel screen hiding their boundaries. Three reference patches were used with increasing simulated tilt: 113, 123, 143 deg. The second patch had a simulated slant of 66-deg; while the first and the third were less slanted (56-deg) but had opposite H/V inclinations. In a sequential matching task observers judged whether the reference patch was more/less slanted than a test patch with the same tilt but a variable amount of maximum disparity [from -0.33 to 0.33 in seven steps including the 0].

In both experiments a slant by tilt anisotropy was found with slant sensitivity decreasing as the tilt of the reference increased. Discriminability for test patches with smaller disparity than the reference decreased as the tilt increased, and vice versa for test patches with larger disparity. Results are consistent with a model that extracts surface orientation via the implicit knowledge of the family of (H, V, convergence angle)-triplets compatible with the stereoscopic images; while they cannot be explained by either the linear combination of (H, V, convergence angle)-parameters or the maximum amount of disparity.

We show that the family of compatible (H, V, convergence angle)-triplets is derivable from the relation between the local orientation disparity and the average orientation of projected surface markings (in random dot stereograms inferable from the horizontal shear angle of corresponding groups of dots) and discuss how the orientation disparity field can account for slant biases without assumptions on viewing geometry.

Acknowledgement: MUR-PRIN grant n. 2005119851

23.303 **Orientation difference, spatial separation, intervening stimuli: What degrades stereoacuity and what doesn't**

Bart Farell[1] (bart_farell@isr.syr.edu), Fernandez Julian[1]; [1]Institute for Sensory Research, Syracuse University

Stereoacuity varies with relative stimulus orientation: As the orientation difference between two stimuli increases, so does the minimum disparity required for discriminating the depth difference between the stimuli (Farell, 2006 J.Neurosci.). For neighboring stimuli, this effect might be due to local contour interactions. To evaluate this possibility, we varied the spatial separation between filtered noise patches presented at various retinal eccentricities. To further determine how orientation difference affects stereoacuity, we interposed irrelevant noise patches of various orientations and disparities between the two stimuli to be judged.

Noise patches had spatial frequencies of 1 c/d ±2 octaves and orientations confined to ±15° of the mean. The difference in mean orientation between the two test patches varied between 0° and 90°.

Test patches were horizontally separated (center to center) by 2.2, 4.5, 6.7, or 9° of visual angle. Subjects judged whether the farther patch was on the left or the right.

Stereoacuity for all subjects fell gradually as eccentricity and stimulus separation increased (though thresholds could not be measured at 9° separation for all subjects). Stereoacuity fell with orientation difference at approximately the same rate at all eccentricities and separations. This argues against local interactions as the source of the orientation effect. Interposed noise patches had no systematic effect on stereoacuity regardless of their relative orientations or depths (except for improved performance when all orientations were identical and spacing was close).

A difference in stimulus orientation interferes with optimal stereoacuity directly. This effect is not mediated by local contour interactions between the stimuli. Nor can local interactions overcome this interference: Intervening stimuli with orientations intermediate between those of the target stimuli do not improve stereoacuity via transitive processing across small local orientation differences. Therefore, the locus of the orientation effect is to be found in the relative disparity computation itself.

23.304 **Computation of the Geometric Inputs to Depth Perception**

Keith Stroyan[1] (keith-stroyan@uiowa.edu); [1]Math Department, University of Iowa

We have written flexible software to compute various stimulus quantities for depth perception. It uses 2D "pin hole" optics of the eyes, and has a easily controlled variables to help inform research questions by giving precise computations.

One set of sample computations compares retinal disparity, parallax due to "head bobbing," and parallax due to walking 1 m/sec while observing pairs of objects. When the objects are in the 10m range, all these are useful in fine depth discriminations with the smallest on the order of 10 min of arc. In the 100m range, retinal disparity and head bobbing parallax are in the 1 minute of arc range, near the threshold of perception, while walking parallax is an order of magnitude larger. In the 1km range, retinal disparity and head bobbing parallax are sub-threshold (less than 0.1 min), while walking parallax is still in the 5 minute of arc per second range. At the viewing distances and speeds of the automobile driving, motion parallax provides input quantities two orders of magnitude larger than binocular stereopsis or head bobbing.

The software can also compute horopter and curves of constant retinal disparity. For a fixate at 400m farther objects need to be almost 4km away to be perceived as more distant. This demonstrates that retinal disparity is not useful at such long distances.

The horopter is also computed for an observer with her head aimed at the fixate and again with her head aimed in a different direction, but still fixed on the same point. The curves are markedly different. Perhaps this kind of head turning could contribute to depth perception at longer distances.

Various other kinds of head or eye motion could be easily computed with the software to help decide which sorts of geometric inputs are perceivable.

23.305 **Individual differences in depth perception: are biases correlated with eye position?**

Julie Harris[1] (julie.harris@st-andrews.ac.uk), Adrien Chopin[2], Katherina Zeiner[1]; [1]School of Psychology, University of St. Andrews, Scotland, UK, [2]CNRS and Universite Paris Descartes, France

We have previously shown that scene configuration can result in biases in relative depth perception. If a pair of points is separated both vertically, and by a depth difference some observers perceive greater depth between the points if the top is the farthest point, or vice-versa (Harris et al, VSS 2007). Here we explored whether individual differences in eye position, specifically in cyclovergence, could account for these biases.

In a single experiment, observers performed both a relative depth judgement and a psychophysical cyclovergence task. For the relative depth judgement, observers viewed two intervals. In each they saw a pair of dots, one above the other, with a depth separation between them. The task was to decide in which interval the depth separation was larger, or smaller. The dot pair could appear in two configurations: in one the upper dot was presented behind the screen plane, the lower dot presented in front (and vice-versa for the other). We compared conditions in which a test stimulus was presented in the same configuration as the fixed standard stimulus (e.g. test and standard: upper far, lower near), with conditions in which the configurations were opposite (e.g. test: upper far, lower near; standard: upper near, lower far). Immediately after each depth trial, cyclovergence was measured using a horizontal nonius line technique.

If an observer exhibited cyclovergence, one would expect a consistent bias to see one of the configurations as containing more depth than the other. Across a number of observers, we found only a very weak correlation between depth bias and cyclovergence. Further, the amount of cyclovergence measured was considerably smaller than that required to account for the biases. Our results therefore suggest that eye position differences due to cyclovergence cannot account for the large idiosyncratic biases found across observers.

23.306 Propagation of depth from Temporal Inter-ocular Unmatched Features and Binocular Information

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Previous studies (Brooks & Gillam, 2006) have shown that temporal interocular unmatched (TIOU) information can result in a perception of a subjective surface with quantitative depth perceived at the object boundary. The present study investigated the conditions in which quantitative depth of the subjective surface can be determined from TIOU information. In Experiment 1 three vertically aligned dots translated horizontally at a constant speed until occluded by an opaque non-textured surface. The subject'ss task was to adjust two probe dots to match the apparent depth of the surface boundary. Under these conditions TIOU information did not provide quantitative depth of the occluding surface. In Experiment 2 multiple columns of dots were displayed with only one column of dots occluded by the subjective surface at any given time. Under these conditions, the perceived depth of the occluding surface increased with an increase in the temporal interocular gap, demonstrating that surrounding disparity information provides information useful for recovering quantitative depth from TIOU features. In Experiment 3 a single vertical line was presented which translated horizontally until being partially occluded by the subjective surface, providing ordinal depth information. The translation speed of the line and the horizontal width of the surface were varied. The results indicated that the perceived depth of the occluding surface decreased as its width increased, even though the temporal interocular gap and translation speed indicated constant depth information. These results, considered together, (1) support the conclusion of previous research that TIOU information can provide quantitative depth information, (2) demonstrate that adjacent disparity information may provide a metric by which quantitative depth from TIOU information is perceived, and (3) demonstrate that occlusion allows for the propagation of local depth provided by TIOU information.

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23.307 Binocular disparity as a cue to perceive direction

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When a target is observed binocularly, the viewing direction (e.g., 30 deg rightward against straight ahead) causes both horizontal and vertical disparities. Some studies showed the effect of retinal cue in perceiving direction of viewing, however, the gain was low (Banks, et al., Berends, et al.). The oculomotor cue probably suppresses the retinal cue. This research attempts to reduce the influence of the oculomotor cue and examine the retinal cue as a cue to perceive direction of viewing. An excessive usage of extraocular muscle probably deteriorate accuracy of signaling eye position (i.e., proprioception); for example, one holds his eyes onto a limit position of the range of eye movement for a while, then moves his eyes toward straight ahead. In our experiment, a subject was asked to keep his eyes onto a limit position, upper right or upper left, for 15 seconds before each presentation of a test stimulus. The stimulus was random-dot stereogram displayed on a rear-projected screen in a dark room. The subject observed the stimulus through stereo shutter glasses. The center of the stimulus was always on the median plane of the subject, however, a disparity pattern consisted of horizontal and vertical disparities was given to the stimulus to simulate direction of viewing. The subject was asked to adjust the direction of an unseen pointing stick by hand to indicate perceived direction of the center of the stimulus. The results were as follows: the retinal cue is effective in perceiving direction, the effect is weak without pre-observing eye movement, and pre-observing eye movement increases the effect of retinal cue on direction perception.

23.308 Stereo matching problem is resolved at population level in the early stage of extrastriate visual cortex

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Stereoscopic vision depends on the correct matching of corresponding features between inputs from two eyes, as false matching destroys the perception of depth. At what level the brain can discriminate correct matches from false ones is an important issue in stereoscopic vision. It has previously been shown that the majority of neurons in V1 tuned to correlated random dots stereograms(RDS) also responded to anticorrelated random dots stereograms(ARDS), a stimulus in which inputs to left and right eyes do not match with each other. Therefore, completion of the stereo matching problem must be solved at levels beyond V1. To examine this, we compared the neural population responses in three cortical areas, V1, V2, and V4 to RDS and ARDS in macaque monkeys. With the intrinsic optical imaging method, we found that ensemble activity patterns in V2 and V4 contain robust information related with stereoscopic depth. We are able to decode which of seven possible levels of horizontal disparities defined by RDS a monkey was viewing by a pattern classification method. Such information was not encoded in V1 as the correct rates of predictions based on activity patterns in V1 were close to random level. Furthermore, we tested whether disparity information defined by false matches were encoded in a similar way in V2 and V4. Seven disparity levels defined by ARDS were used. We found it is impossible to decide which horizontal disparities the monkey was viewing either from ensemble activity of V2 or V4. Thus, neurons in V2 and V4 respond to correct matches and reject false ones at least in population level. These results not only support and extend our previous findings regarding topographic representation of horizontal disparity in V2, but also indicate that the neural substrate for discarding stereoscopic false matches lies in early stages of extrastriate visual cortex.

23.309 Interocular transfer of fMRI adaptation in stereodeficient observers

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Simultaneous binocular input during a critical period after birth is necessary to maintain and develop the structure of the visual system, otherwise visual processing might be disrupted. If binocular vision is impaired during this period subjects can develop alternating fixation (ensuring normal monocular function of each eye) or amblyopia (vision in one eye is impaired). Testing the interocular transfer of figural adaptation after-effects is one way to investigate binocular integration of the visual input psychophysically. In this study, we investigated binocular integration using orientation-selective fMRI adaptation. We tested 20 normally-sighted subjects and 18 subjects with impaired binocular visual development (10 with alternating fixation and 8 with unilateral amblyopia). In all investigated cortical areas, normally-sighted subjects showed significant monocular orientation-selective adaptation that partially transferred to the non-adapted eye. Observers with impaired visual development showed monocular orientation-selective adaptation, but this adaptation did not transfer to the non-adapted eye. These results demonstrate that fMRI adaptation is a useful tool for the investigation of the neuronal mechanisms of binocular integration in the adult human brain.

23.310 Decoding depth order and three-dimensional shape perception from human cortical activity of dorsal and ventral areas

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Recent studies of primate brain showed that almost all areas of the visual cortex contain neurons that respond to binocular disparity. However, the functional differences among these areas are largely unknown. From binocular disparity, we perceive three-dimensional spatial layouts of multiple objects and three-dimensional shape of a single object. We hypothesize that these two types of the depth perception from binocular disparity are carried out by different cortical areas. This classification corresponds to the distinction between a dorsal pathway that concerns with spatial relationships of objects and a ventral pathway that concerns with object shape. We used the decoding technique (Kamitani & Tong, 2005) and compared the prediction accuracy of these two types of depth perception between cortical activities of dorsal and ventral areas. fMRI signals (1.5 T, 3 x 3 x 3 mm voxels) were measured while subjects viewed random dot stereograms. For the spatial depth perception among multiple objects, we showed three independent surfaces with different depth planes. The center surface was closer or further from the other two surfaces which were positioned on the same depth plane. For the three-dimensional shape perception, we showed a single convex or concave curved surface. A linear decoder (support vector machine) was trained to classify voxel intensity patterns induced by far/near position or convex/concave shape. Then the decoder was evaluated with independent test data. In results, area hMT+ showed better performance for classification of depth order than that of three-dimensional shape. In contrast, area LOC showed better performance for three-dimensional shape than depth order. These results suggest that the dorsal pathway area hMT+ concerns with the perception of three-dimensional layouts of multiple objects and the ventral pathway area LOC concerns with the perception of three-dimensional shape from binocular disparity.

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23.311 **The development of coarse stereopsis in school aged children**

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The conventional view of binocular vision is that the visual input from the two eyes is fused to produce the percept of a single scene. In doing so, the stereoscopic system also provides extremely high-resolution information about the relative depth of objects in space (fine stereopsis). However, reliable stereoscopic depth is also obtained from images with very large disparities that cannot be fused into a single image (coarse stereopsis). While there is some evidence that stereoacuity improves with age, very little is known about the development of coarse stereopsis.

We compared performance in children (5-6, 11-12 years) and adults on computerized tests of fine and coarse stereopsis. Stereoscopic stimuli were presented using liquid crystal shutter glasses. On each trial, cartoon characters were presented simultaneously above and below a fixation marker. The stimuli were displaced in depth by equal amounts in opposite directions and the observer's task was to indicate which character appeared to be closer in depth. We assessed perceived depth for a set of fine (0.02, 0.08, 0.17, 0.33, 0.67 degrees) and a set of coarse (1, 2, 2.5, 3, 3.5 degrees) disparities.

The younger children were above 80% accuracy at all disparities. Performance was poorest at the smallest disparity, and they showed a shallow decline in accuracy with increasing disparity in the coarse range. Surprisingly, for both the adults and older children, accuracy was consistently lower (58% to 71%) at all test disparities. In control experiments we have determined that the decline in performance with age is not due to motivation, changes in interpupillary distance, visual hemispheric asymmetries or the slant of the horoptor. We will discuss these results in terms of a narrowing of Panum's area (Dowd et al., 1980) and the disruptive effect of vergence eye movements with age.

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Eye Movements, Search and Attention

23.312 **Saccadic inhibition during information accrual in a visual search task**

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The gaze control system ought to inhibit saccades under two conditions. On the one hand, saccades should be inhibited when the sudden onset of stimuli threatens to capture attention and divert gaze. On the other hand, saccades should also be suppressed when task-relevant information accrual is ongoing and vulnerable to disruptions in movements of gaze. These two goals need not be mutually exclusive. In order to examine the time course of verbal-to-sensory translation in a reverse Stroop color search task, we delayed onset of target colors by 200, 300 or 400 msec. The result was clear saccadic inhibition that was time-locked to the onset of the color targets. Secondarily, there was little evidence of any saving from the initial presentation of the verbal specification of the target (a color word): For each additional 100 msec of delay of the search targets, there was a corresponding additional delay of 75 msec in response time. In order to reduce saccadic suppression due to the sudden onset of the search array, we employed gradual color changes of initially uniformly gray targets. When initiation of the color fades was consistently delayed by 400 msec, there was still evidence of saccadic suppression during the fade-in of the coloration of the targets, and only partial savings in response times. However, reverse Stroop interference was eliminated in this case. Presumably the delayed presentation of the search array allowed strategic re-encoding (translation) of the verbal information into a searchable sensory code. Whereas saccadic inhibition that was due to sudden onsets was accompanied by disruptions of cognitive processing, saccadic inhibition due to information accrual was not.

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23.313 **The spatial extent of attention for saccades: attentional facilitation compared to inhibition of return in humans and monkeys**

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The aim of the current work was to investigate the spatial extent of attentional facilitation and inhibition of return (IOR) in response to an exogenous cue over time. We used saccade latencies as a behavioral correlate of attentional allocation. Two humans and two monkeys made saccades to visual targets at 136 locations spread across the visual field (9° up/down/left/right) from a central fixation target. In 80% of the trials, a behaviorally irrelevant cue was flashed at one of 4 oblique locations (7° eccentricity) either 50 or 200 ms before the target. In the remaining 20% of the trials, no cue was presented but the same timing was maintained. We calculated average saccade latencies as a function of distance from the cue across all four cue locations normalized relative to saccade latencies when no cue was present. Attentional facilitation was seen when the cue preceded the target by 50 ms. The facilitation was confined to targets presented within the same quadrant as the cued location. In contrast, when the cue preceded the target by 200 ms, we found an inhibition that extended from the quadrant with the cued location to the two adjacent quadrants. The greatest increase in latencies occurred in the cued quadrant with a smaller increase in the two orthogonal quadrants. These differences were similar for both humans and monkeys. These findings suggest two separate mechanisms for attentional facilitation and IOR, with the cue resulting in a much more localized spread during attentional facilitation than during IOR. This is consistent with a low-level local network for attentional facilitation with smaller receptive fields (e.g. superior colliculus) vs. a higher-level network for IOR involving large receptive fields (e.g. parietal or frontal areas).

23.314 **Head-mounted eye-tracking with children: Visual guidance of motor action**

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The primary role of vision is to plan and guide motor actions. Previous research used head-mounted eye-tracking devices to examine adults' eye movements while engaged in everyday activities such as making tea or a peanut-butter sandwich (Land et al., 1999; Hayhoe et al., 2003). The timing and location of adults' fixations are geared toward the objects and locations intrinsic to the task, and intricately linked with the unfolding sequence of motor actions: Adults fixate the intended target before moving their hands or bodies to contact it; after they begin to reach toward the target, their gaze shifts to the next goal.

The current study is the first to use a head-mounted eye-tracker to record 2D eye movements in children freely moving through the environment. Six children (4-8 years old) wore a specially constructed eye-tracker (Positive Science, LLC). Analogous to the adult studies, the children arranged a table place setting to match a model. The children walked back and forth repeatedly across a cluttered room as they selected items from an assortment of cups, bowls, plates, placemats, napkins, and utensils on a tabletop to create their own place setting.

The target and duration of the eye movements were coded during the 3 s intervals prior to and following the moment that children's hands contacted an object while picking it up. Like adults, children relied on visual information to guide their hands to the target: They fixated the target prior to contact, but rarely looked at their hands before touching the target. In contrast to adults, children often fixated their hands after touching the target. But, like adults, they closely monitored ongoing actions while gathering visual information for the next goal. In a second "scavenger hunt" task, we are examining children's visual guidance of locomotion through an obstacle course.

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23.315 **Predicting Eye Movement Trajectories in a Multiple Object Tracking (MOT) Task with Free Viewing**

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We previously reported that eye movements are similar across repetitions of the same trajectories for objects (targets and distractors) in MOT trials (Fazl, A., & Mingolla, E. (2007). [Abstract]. Journal of Vision, 7(9):902).

Can we therefore predict eye movement trajectories from object paths in novel trials? In the present experiment subjects viewed two, three, or four targets among a maximum of 8 distractors in a MOT task, while their eye movements were recorded. Objects were 1^o in diameter and were traveling at a constant speed of 9 ^{o}/sec in a field of 30^o X 30^o. They bounced off the edges of the display and off each other. We found that the distance from the foveation spot to a particular target i (d_ETi) was highly correlated with a measure of that target's "clutter", i.e. the sum of distances of all other objects to that target. The clutter scores for other targets, naturally, were negatively correlated with the magnitude of d_ETi; the more clutter around other targets, the more the foveation was attracted away from target i. We found that the eyes tended to move closer to a target that was surrounded by other targets, rather than by distractors.

To quantify the relative contribution of clutter scores of targets and distractors on the d_ETi, we performed a multiple regression with d_ETi as the dependant variable. The coefficients of this regression showed that the clutter of a target by other targets is about 4 times more effective in attracting the eyes to that target as compared to clutter by distractors. Our model could predict about 70% of the variance in d_ETi for the scenes that it was trained on, and about 65% on novel scenes. Our prediction accuracy increased from two to three to four targets.

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23.316 **How inactivation of the superior colliculus can cause a constant eye position offset during object tracking**

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Humans track extended objects even when there are no foveal targets to guide eye position. We recently studied the contribution of the superior colliculus (SC) to this behavior. When primates tracked the invisible center of an object defined by two peripheral bars, SC activity was dominated by neurons in the SC's retinotopic map representing the center's location. Inactivation of these neurons caused constant eye position offsets, with no other motor deficits. Such offsets indicate a biased estimate of object location, but it is not clear how they emerge or why they are constant.

We developed a data-driven model of SC activity during our task. By measuring the responses of 117 neurons having a range of preferred eccentricities, we estimated the spatial extent of the activity representing object location. We then simulated the effects of inactivation by scaling the estimated activity profile with a 'suppression' function, describing the spatial extent of the inactivation. This function was obtained by measuring visually-guided saccade latencies in each experiment: after inactivation, latencies increased for some locations but not others, providing an estimate of which SC neurons were affected.

According to our model, inactivation caused an imbalance of activity across the two SC's, even though the object and gaze were aligned. This imbalance explains the emergence of an offset and its direction, but not its constancy. Such constancy was achieved through visual feedback of object location. For each simulated inactivation experiment, there existed an offset for which the retinotopic object location gave rise to a balanced activity profile across the two SC's, eliminating any further need to deviate gaze.

These results explain why a constant eye position offset occurs after SC inactivation, and they support the conclusion that the SC contains a distributed representation of behaviorally-relevant locations, distinct from its representation of saccade motor commands.

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23.317 **More than meets the eye: Investigating expert and novice differences in action video games**

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Prior studies have demonstrated that extended experience with action video games correlate with improved performance on a range of attentional tasks. This effect is commonly observed in functional field of view tasks, where video game players have shown enhancements in visual attention with increased gaming experience (Green & Bavelier, 2003). While these results have been replicated several times, no studies have assessed how improvements in visual attention might affect behavior in the game environment. Here we perform the first in-vivo investigation of the effects of gaming experience on eye movements. In this task, experts and novices performed a detection task in the context of an action video game. The current study asked experts (with more than 8 hours/week of video game playing) and novices (with less than 30 minutes/week of game playing) to perform a detection task using an action video game. Participants viewed a movie of the first person shooter "Quake 4", where a series of 30 target figures were inserted at either 2 or 6 degrees of visual angle from the center of the screen. Participants were instructed to keep their eyes focused on the center of the screen and respond when they detected a target. Participant's eye movements were recorded along with their manual responses. Performance results replicated earlier expertise studies, with experts responding significantly faster and more accurately than novices. Eye movement results indicated that experts fixated significantly less often than novices, but fixated for longer overall durations. This suggests that the improvements in performance are due in part to changes in visual attention, as experts may leverage their larger visual span to more efficiently detect the presence of targets onscreen.

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23.318 **Optimal continuous-time control of eye movements during visual search**

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We derive an expression for the amount of information about target location obtained in an infinitely small time period during visual search for a target embedded in a background of dynamic white noise. We show that as the target detectabilities (d-primes) across the visual field approach zero, the information collected by the ideal searcher becomes monotonically related to the weighted sum across the current posterior probability distribution of the target's location (weights = squares of the d-primes). Hence to continuously control the flow of information optimally a searcher that can instantly move its eyes anywhere without cost should, at each instant in time, move its eyes to maximize the dot product of the current posterior distribution with the square of the d-prime map. Interestingly, with human-like d-prime maps, such a searcher sometimes makes extended fixations lasting up to several hundred ms in addition to many short fixations (dozens of ms). Human eye-movements are not cost-free, it takes time to initiate the movements and travel, and during travel visual information collection is interrupted. The human eye-movement controller is also uncertain about where the eyes will land because of random scatter around the intended landing point. When the optimal eye movement controller with human d-prime maps takes these costs of moving the eyes into account, it can be made to exhibit a distribution of fixation durations qualitatively similar to humans by adjusting a single free parameter that specifies the length of a look-ahead time over which the expected information gain (for a given considered eye movement) is computed. The look-ahead time that produces human-like fixations is consistent with a simple neural computation (one taking a few dozen ms). Apparently, large saccadic eye movements and long fixation durations may be rational even for an eye movement system that could move its eyes continuously.

23.319 **Scan pattern adaptations to repeated visual search**

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Changes to visual scans were examined during repeated visual search across two experiments. There were significant scan pattern adjustments when relatively unique stimuli were searched, and greater adjustments when stimuli were searched repeatedly. Changes occurred despite participants being unaware that some stimuli repeated. Differences between scan patterns could result from either chaotic or systematic changes in behavior. We hypothesized that changes in scan patterns were systematic, and argue that the changes reflect adaptations to the task environment.

Skill acquisition is the process of adapting behavior with experience. Adaptation can occur at relatively low and high levels of behavior (Gray & Boehm-Davis, 2000). Similar to acquiring a skill, visual scans could be adapted to a set of stimuli with experience. To conclude that scans were adapted to stimuli, data had to meet three criteria. First, the number of fixations to find the target must be reduced with experience (Criterion-1). Second, the similarity of scan patterns had to increase with experience (Criterion-2). Third, scan patterns from repeated stimuli must become similar at a faster rate than patterns from relatively unique stimuli (Criterion-3).

In experiment-1, participants performed 720 trials in the repeating visual search paradigm (RVSP; 360 mostly unique trials +12 trials repeated 30 times, each). In experiment-2, participants performed the RVSP with or without a simultaneous auditory letter classification task. Criterion-1 and Criterion-2 were met in the first experiment, and all three criteria were met in the second experiment. Moreover, scan pattern similarities were reduced when performing a secondary auditory task. The results indicate that scan patterns were adapted to regularity within the search stimuli.

References

Gray, W. D., & Boehm-Davis, D. A. (2000). Milliseconds matter: An introduction to microstrategies and to their use in describing and predicting interactive behavior. Journal of Experimental Psychology-Applied, 6(4), 322-335.

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23.320 **Memory for objects and locations in visual search**

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Memory for scenes is important. How we use memory when directing eye movements during visual search is an important aspect of visual cognition. To investigate the use of gaze during recall for objects and location, we asked subjects to look at an image containing objects randomly placed within a grid on a white background, after which they were asked to recall if an object had been present in that display. They then had to immediately saccade over an empty grid to the location where that object had been. While they could successfully recall the presence of an object, subjects were surprisingly poor at recalling its spatial location using an eye movement. Additionally, the identification of correct locations was not evenly distributed. Although targets appeared in all locations with equal probability, subjects more likely to be correct when the target appeared in the upper left quadrant. These results suggest that memory for location is poor in certain circumstances and the implications of this, along with further experiments, will be discussed.

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23.321 **Presaccadic deployment of attention: what is the trigger?**

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During the preparation of a saccadic eye movement a visual stimulus is more efficiently processed when it is spatially coincident with the saccadic target as compared to when the visual and saccadic targets are displayed at different locations. We have previously characterized the time-course of this selective deployment of visual resources (visual attention) to the saccadic target, by means of a dual task, where the execution of a saccade constitutes the primary task, while an orientation discrimination judgment at different moments and locations during saccade preparation is the secondary task. We have shown that a dramatic selective improvement of discrimination performance at the saccadic target is achieved within 150-200ms and this dynamics represents a characteristic signature of saccade preparation across several experimental conditions. Some electrophysiological and modelling studies have recently suggested that a presaccadic attentional enhancement in early visual areas should be time-locked to saccade onset. This enhancement could represent the neuronal substrate of the observed perceptual advantage at the saccade target. To address this hypothesis, we tested whether, in human subjects, the characteristic time-course of the selective visual improvement at saccadic target is locked in time to the onset of the eye movement. For this purpose we aimed at decorrelating across trials the time delay between cue and visual probe from the time delay between visual probe and saccade onset. In particular, we wanted to broaden the distribution of saccadic latency. In order to do this we modified our dual task in two different ways (Go-NoGo task and different cue duration task), such that the decoding of central visual instruction becomes more compelling, thereby increasing latency variability. Our results show no significant improvement of visual performance as a function of temporal proximity to saccade onset, questioning the time-locking hypothesis.

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23.322 **Low-level Fixation Search in Natural Scenes by Optimal Extraction of Texture-Contrast Information**

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We construct the beginnings of a low-level theory of visual fixations in natural scenes by the formulation and verification a Barlow-type hypothesis for fixation selection—where the fixation patterns are designed to maximally contrast and textural information. We first briefly overview optimum contrast-based fixation strategies in natural scenes [1] and thereafter develop an optimum texture-based fixation selection algorithm based on our computational theory of non-stationarity measurement in natural images. In particular it is shown how a simple relative coding error measure between sub-patches of a window (that defines the image scale of analysis) can effectively measure the non-stationary structure of natural scenes which subsequently can be employed for the optimal extraction of textural information. Finally we propose a simple coupling of the optimal texture-based and contrast-based fixation algorithms which exhibits robust performance for fixation selection in natural images. The performance of the fixation algorithms are evaluated for natural images by comparison to actual human fixations performed on the images. The fixation patterns thus obtained outperform randomized, Gaffe-based [2], and Itti [3] fixation strategies in terms of matching human fixation patterns in terms of mutual information. These results also demonstrate the important role that contrast and textural information play in low-level visual processes in the HVS.

[1] R.G. Raj, W.S. Geisler, R.A. Frazor, and A.C. Bovik, "Contrast statistics for foveated visual systems: Fixation selection by minimizing contrast entropy," J. Opt Soc Amer A, vol. 22, pp. 2039-2049, Oct 2005.

[2] U. Rajashekar, I. van der Linde, A.C. Bovik, and L.K. Cormack, "GAFFE: A gaze-attentive fixation finding engine," IEEE Trans Image Processing, to appear, 2008.

[3] L. Itti, C. Koch, A saliency-based search mechanism for overt and covert shifts of visual attention, Vision Res, vol. 40, no. 10-12, pp. 1489-1506, May 2000.

23.323 **Pro-active Gaze Control in Squash**

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In the natural world, the brain must handle inherent delays in visual processing, particularly during dynamic tasks, such as athletics. A possible solution to visuo-motor delays is prediction of a future state of the environment based on the current state and properties of the environment learned from experience (Wolpert, 2007). We tracked the eye movements of four skilled squash players, recording simultaneously from two players wearing RIT lightweight wearable eye-trackers. Performance for the four players was similar. When it was a player's turn to hit the ball, he mostly pursued the ball, but made an anticipatory saccade to the front wall, arriving 152 +/- 28 msec before contact with the wall, with an accuracy of 9.2 +/- 1.6 deg. After the ball bounced off the front wall, the player resumed pursuit within 184 msec. If the ball was on a trajectory to hit the side or back wall, players made an anticipatory saccade ahead of the ball to a point in space where the ball would pass approximately 220 msec later. The accuracy of this saccade was 2.6 deg in two subjects. This reveals a complex, highly accurate spatial prediction when both player and object move rapidly. In all trials, players stopped pursuit and held gaze stable in space about 160 msec before hitting the ball. At this time, no useful visual feedback about the ball can occur, and holding gaze may help provide a stable reference frame for the swing or allow preparation of the next eye movement. These data suggest that prediction of future state, based on current ball trajectory and experience with the ball is important for programming saccades. Such experience-based prediction may, in general, be a good strategy for gaze deployment.

Wolpert, D (2007) Probabilistic models in human sensorimotor control. Human Movement Science, 26, 511-524.

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URL: http://www.cps.utexas.edu/Research/Hayhoe/mhmovies.html

23.324 **Low and high level changes in eye gaze behavior as a result of expertise**

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What changes in eye gaze behavior are a result of visual expertise with a stimulus class? To address this question, eye gaze was tracked while expert fingerprint examiners and novices performed a fingerprint matching task. The display was configured such that there was one fingerprint in noise and one clear fingerprint placed side-by-side. Data were analyzed in two ways. 1.) Statistics such as saccade length and fixation duration were computed in order to determine the low-level changes, if any, that occur as a result of expertise. 2.) Computational methods such as spatial density analysis and Hidden Markov Modeling were employed to reveal the spatial and temporal effects of expertise. Using this combination of simple and complex analyses, we are able to draw conclusions about how expertise manifests itself through eye gaze behavior as well as the functional level which these effects take place.

23.325 **Avoiding Collisions in Real and Virtual Environments**

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The importance of learning in controlling gaze is implicit in the task dependence of fixation patterns in natural vision (e.g. Land, 2004; Hayhoe & Ballard, 2005). However, this issue is relatively unexplored in unconstrained environments with no obvious task. Previously we studied whether experience influences gaze distribution in a real walking environment, in which individual pedestrians behaved in characteristic manners. Subjects walked around a central structure with pedestrians who veered towards the subject for approximately a 1 sec period. Three of the walkers ("Rogue", "Unpredictable" and "Safe") followed a script: Rogue went on a collision path every time he approached the subject, Unpredictable veered on half the occasions, and Safe never veered. Probability of a potential collision clearly modulates fixation probability. Subjects look at Rogues more than Unpredictable and Safe. Following a switch in roles of Rogue and Safe, subjects quickly learned to adjust gaze priorities according to collision probabilities. In our present study we compared performance in the real environment with a virtual environment where the potential collisions could be made in a more controlled way. Probability of fixating pedestrians was clearly increased with the increased probability of that pedestrian colliding. Further, subjects quickly adjusted to the manipulation of collision probabilities of pedestrians. Though there was ~ 10 % overall reduction in probability of looking at pedestrians in VR compared to the real walking experiment, the pattern of results remained the same. Somewhat reduced fixation probabilities in VR might be the result of a less behaviorally relevant environment, or the need to devote more time controlling walking in it. However, the similar pattern of results as in the real walking experiment validates the virtual reality paradigm and confirms the pro-active nature of gaze deployment in the natural world.

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23.326 **Interesting Locations in Natural Scenes Draw Eye Movements**

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Parkhurst and Niebur (2003, Vision Science Society) collected data from over 1000 internet subjects, who were asked to indicate the five most interesting points in a variety of natural and artificial scenes. They found a high degree of consistency in the selected locations across subjects, particularly for early selections. Moreover, they showed that these interest points clustered around areas determined to be high in visual salience by a purely stimulus-driven computational model of attention.

We recorded eye movements from a new group of 21 laboratory subjects as they free viewed the same set of images for five seconds. The first five fixations for each subject were significantly more likely to land on locations rated as interesting by the internet subjects compared to chance levels. Consistent with previous findings, fixated areas were also higher in visual salience. In addition, we ran a number of cross correlations between internet subjects' combined interest maps, comprised of all points in each image they indicated as being interesting, and our laboratory subjects' fixation maps, comprised of all points in each image they fixated. We found that 93 out of 100 images had a higher cross correlation than would be expected by chance. Additionally, 40 out of 100 images had a higher cross correlation between their saliency and fixation maps than chance.

These results extend previous findings that showed interesting regions of images (distinct objects) are also salient (e.g., Elazary & Itti, Vision Science Society, 2006). Furthermore, subjectively determined interesting regions appear to be as strong a predictor of human eye fixations as computational models of attention, if not stronger. This may be due to the fact that these interest points reflect bottom-up factors, such as visual salience, as well as top-down factors, such as scene semantics, that influence eye movements.

23.327 **Do the eyes count? The role of eye movements in visual enumeration**

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Enumeration of displays that contain five or more objects is notoriously difficult. It depends on a serial counting algorithm in which each object is indexed and each indexing event increments a counter. The algorithm continues until every object has been indexed. Then the value in the counter equals the numerosity of the display. This theory predicts a linear increase in response time (RT) with numerosity. Typical data confirm this prediction, showing a slope of 300 ms/object. The role of eye movements in visual enumeration tasks is not understood. The displays are exposed until subjects report the numerosity, so RT can be 3000 ms or more, allowing several eye movements. We investigated the role of eye movements in enumeration, measuring eye movements while subjects enumerated displays of 5-12 objects. We tested the hypothesis that eye movements play a critical role in visual enumeration: Eye movements are the indexing events that drive increments of the counter. This hypothesis predicts that subjects should move their eyes once for each object in the display, so that the number of fixations should increase linearly with the number of objects with a slope approaching 1.0. The data were largely consistent with this prediction. RT increased linearly with the number of objects in the display (r = .991) with a slope of 262 ms/object. The number of fixations also increased linearly with the number of objects (r = .991) with a slope of .835 fixations/object. Preliminary analyses suggest that subjects may not have fixated each object directly (few fixations fell directly on the objects) but nevertheless they made about one fixation for each object. We suggest that eye movements are not made to foveate the objects, but rather, to provide motor outflow that is synchronized with visual indexing and drives the increments of the counter.

23.328 **Biological Motion in Natural Scenes Captures Eye Movements**

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Previous studies suggest that the human perceptual system may be particularly tuned to biological movements, thus allowing for faster detection of biological (e.g., humans) as opposed to non-biological objects (e.g., cars) in the environment. This sensitivity to biological motion has been demonstrated for degraded stimuli, such as point light walkers, and for natural dynamic scenes. Using a visual search task, we previously showed a decrease in search time when observers searched for human targets compared to non-human targets. To gain further insights into how observers detect target scenes amongst distractor scenes, we combined response-time measurements with eye-movement measurements, as eye movements are thought to reflect search strategies that observers may use. Circular search arrays of two, four, six or eight movies were shown on a monitor. Participants searched for a target movie which was either present or absent in this array while their eye movements were tracked by an infra-red eye tracker. On two separate blocks, targets were either movies displaying humans or machines. Distractors were movies displaying the other category. For both human and machine targets, search times increased with set size. However, observers were faster in detecting human target movies amongst machine distractors than vice versa. This advantage was also shown in the number and duration of fixations to target scenes. Overall, these results suggest that movies displaying humans capture more attention than movies displaying machines, which is in accordance with the idea that the perceptual system is tuned to detect biological motion.

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23.329 **Looking as if you know: Eye guidance preceding object recognition**

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At one instance there is just a bunch of objects in the refrigerator, in the next, you clearly discern the package of milk. How do we select visual information before perceptual organization? We addressed this question in two recognition experiments involving pictures of fragmented objects. In Experiment 1, participants preferred to look at the object rather than a control region 25 fixations prior to explicit recognition. Furthermore, participants inspected the object as if they had identified it around 9 fixations prior to explicit recognition. In Experiment 2, we investigated whether semantic knowledge might explain the systematic object inspection prior to explicit recognition. Consistently, more specific target knowledge made participants scan the fragmented stimulus more efficiently. For instance, the control region was rejected faster when participants knew the object's name. Both experiments showed that participants were looking at the objects as if they knew them before they became aware of their identity. The findings are consistent with a predictive account of object recognition, where eye movements are guided by an object hypothesis to regions providing high information gain.

23.330 **Examining scanpaths and inhibition of return as a function of task instruction during scene viewing**

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Yarbus (1967) demonstrated that the pattern of eye movements and fixations that people make is affected by specific task instructions as to which objects in a painting should be attended, but to date, little systematic investigation of this issue has been conducted. In the present study, we examine how eye movements change when individuals are trying to search for something in a scene relative to when they are trying to memorize a scene, rate how much they like a scene, or simply freely-view a scene. Moreover, in the present study, we examine whether inhibition of return occurs in scene viewing tasks as a function of task instruction. Inhibition of return (IOR) refers to the finding that people are slower to detect a target or make an eye movement to a previously searched location. It has been suggested that the purpose of IOR is to aid visual search by biasing attention towards novel locations. What is not known, however, is whether the IOR effect extends to other complex tasks besides search in which it would also be useful to continually orient to novel locations. Consequently, scanpaths and saccadic reaction times are examined as a function of task instruction to determine whether IOR also influences memory, rating, and free-viewing tasks.

23.331 **Stimulus contrast and the remote distractor effect: differential effects for foveal and peripheral distractors**

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It is well known that a distractor stimulus presented simultaneously with the saccade target prolongs saccadic latency (remote distractor effect, RDE). We examined the influence of target and distractor contrast on the RDE. Subjects were asked to make a saccade to a target Gabor presented either to the left or right of a central fixation stimulus. Distractors were likewise Gabors and presented either foveally or peripherally (contralateral to the target) after offset of the fixation stimulus.

For foveal distractors, the influence of distractor contrast was minimal. However, the RDE increased with increasing target contrast. For low target contrasts, even negative RDE values were observed, i.e. shorter latencies in the presence of a distractor compared to the no distractor control condition. We suggest that this facilitation was due to a general increase in saccadic latency for low target contrasts. We conclude that the distractor serves two complementary functions: first it acts as a true distractor, sparking a rapid but transient perturbation of saccade initiation. Second, it acts as a warning signal for target appearance, facilitating saccade initiation. As this latter effect builds up slowly, it is only observed for targets yielding long latencies or when the distractor is presented well before the target.

For peripheral distractors, we obtained inverse results: there was no significant effect of target contrast, but the RDE increased for increasing distractor contrast. We argue that the discrepant results for foveal and peripheral distractors do not contradict the notion of a uniform saccade map in the superior colliculus in which fixation neurons in the rostral pole form an extension of the caudal build-up cells. Rather, the stronger foveal input at the rostral pole compared to peripheral input at more caudal sites might account for the discrepancies.

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23.332 **Oculomotor competition when working memory is occupied**

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Because our eyes can only fixate one location at a time, there is a continuous competition for gaze between the visual elements. Crucial for successful goal-directed behavior is therefore the correct selection of the relevant element ('target') in the presence of competing but irrelevant elements. How does the brain determine which element to select and which to ignore? By adding a dual task to a visual search experiment, the different cognitive processes involved in oculomotor target selection can be revealed. Here, two experiments are presented in which participants were required to make an eye movement to a target while ignoring a single distractor. Simultaneously, participants performed an n-back test which is known to occupy working memory (e.g. n = 2). Previous studies have indicated that performance on the antisaccade task is impaired when an n-back test is added. However, the effects of an occupied working memory on inhibiting task-irrelevant items is unknown within the oculomotor domain. In the first experiment, more erroneous eye movements were made to the distractor when working memory was occupied. However, there was no increased distractor effect on saccade latency with a 2-back task. In a second experiment, there was no visual search necessary to find the target. Again, no increased distractor effect was observed. Saccade trajectories deviated away from the distractor, but saccade deviations were similar for the different memory conditions, although the overall saccade latency was lower when working memory was occupied. Because there was no increased distractor effect on saccade latencies and trajectories, the results indicate that oculomotor inhibition of an task-irrelevant distractor is not mediated by mechanisms involved in working memory. However, the finding that more erroneous eye movements were made to the distractor when working memory systems were occupied seems to indicate that these processes are involved in keeping task instructions active.

Motion: Higher Mechanisms and Illusions

23.333 **Feature-tracking Mechanism Dominates Motion Perception as the Retinal Illuminance Decreases**

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Purpose: When a sine-wave grating presented at the central retina moves by 90°, the perceived direction of motion depends on the duration of a blank average-luminance inter-stimulus interval (ISI). At short ISIs, the perceived motion direction is reversed. This is predicted from the biphasic temporal response of first-order motion detectors. At longer ISIs, the perceived direction becomes veridical, suggesting the operation of a feature-tracking mechanism. Here, we measured the effect of ISI on the perceived direction of moving gratings at different retinal illuminances and eccentricities. Procedure: Subjects judged the perceived direction of high contrast (30 x threshold) moving 0.25 cpd gratings. Results: Under photopic conditions, at 20° eccentricity in the upper visual field, motion reversal was stronger with short ISIs, and perception did not become veridical at longer ISIs. In the lower visual field, performance was more similar to that in the central retina. Under mesopic and scotopic conditions, motion reversal disappeared in central vision, but strong motion reversal was still observed in the periphery. When the stimulus covered both central and peripheral visual fields, no motion reversal was seen. Conclusions: In photopic vision, both first-order and feature-tracking mechanisms operate in the central and lower visual fields, while the first-order motion mechanism dominates strongly in the upper visual field. This suggests the feature-tracking mechanism is attention-based. As retinal illuminance decreases, the relative contribution of the feature-tracking mechanism in central retina becomes larger but perception at the periphery depends on a biphasic first-order motion mechanism. When both central and peripheral visual fields are stimulated simultaneously, the feature-tracking mechanism in the central retina determines the perceived direction of motion.

23.334 **Visual competition between ambiguous and unambiguous motion signals in grating patterns**

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A rigid square-wave grating is illusorily perceived as a deforming latex stuff when observed in dynamic viewing. Observers refer an orthogonal expansion to the bands and a shrinking distortion throughout the grating when moving the head either towards or away from the pattern. We call that phenomenon "Accordion Grating". The reported orthogonal-to-the-bands expansion cannot be trivially depending upon the reduction of the viewing distance. Furthermore, afterimage could not account for the perceived deformation affecting only the dimension orthogonal to the grating bands. According to Gori and Yazdanbakhsh (in press), that illusory effect can be instead understood by considering the competition between motion signals (Gurnsey et al., 2002) originating from two different motion-processing units (Lorenceau et al., 1993). Thus, ambiguous signal from contour units would compete with veridical motion cue from line terminator units. If the contour units will win the competition the illusory effect will be perceived. Confirming that hypothesis, the illusory effect is drastically reduced when using bands composed by small rectangles, which minimise the activity of the contour units, or with a grating arranged as concentric circles pattern. Finally, the illusory effect disappears by using iso-luminant colours. That suggests the involvement of the magno-cellular pathway in the phenomenon.

Gori S, Yazdanbakhsh A, in press Perception.

Gurnsey R, Sally S L, Potechin C, Mancini S, 2002 Perception 31, 1275–1280

Lorenceau J, Shiffrar M, Wells N, Castet E,
1993 Vision Research 33, 1207–1217

23.335 **Two streams make a bounce: Induced motion reversal by crossing the trajectories of two motion sequences**

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A 2-D display depicting two objects moving towards one another, coinciding and then moving apart is equally consistent with "streaming", where the two objects' motions are unchanged throughout the sequence, and "bouncing", where the objects reverse their motions after coinciding. Observers predominantly perceive streaming (Bertenthal et al, 1993; Sekuler & Sekuler, 1999). If a transient (visual, auditory, tactile, etc) is presented near the instant of coincidence, perceived bouncing dominates (e.g. Sekuler et al, 1997; Watanabe & Shimojo, 1998). Indeed, it has been argued that transient stimuli possess a special status, strongly influencing the interpretation of continuous stimuli (Shimojo & Shams, 2001). We found that bounce perception is elicited by adding a second non-transient orthogonal motion sequence such that the two trajectories cross at the center of the display, and investigated whether or not the coincidence of all four disks at the center is critical for the promotion of bounce perception by varying the relative speeds of the disk-pairs. Two disk-pairs traced orthogonal oblique (±45 deg) trajectories intersecting at the fixation point. Disks on the same oblique trajectory moved at equal but opposite velocities (6.72, 13.44, or 20.17 degrees/second). Observers fixated the center of the display and reported whether one of the oblique pairs of disks, indicated before each trial, appeared to stream or bounce. When all four disks simultaneously coincided at the center of the display, bouncing dominated (>80% of trials). Otherwise, bouncing was reduced but still occurred on 30-50% of trials, more than previously reported for comparable displays. The perceptual outcome of an ambiguous motion sequence can be determined by an accompanying motion sequence along an orthogonal trajectory. In the absence of any transient stimuli, perceived bouncing can be promoted and is most pronounced when all four disks simultaneously coincide at the center of the display.

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23.336 **Induced motion with chromatic stimuli**

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Motion in a part of visual field induces subjective motion of adjacent stationary stimuli. This induced motion is classified into motion contrast and assimilation according to the direction of induced movement. Contrast type of induced motion could be explained by motion contrast detector. Such a detector is physiologically plausible since center-surround antagonism in the receptive field of motion sensitive neurons is well established. Assimilation could be accounted for by neuron with no inhibitory surround. Since previous studies on induced motion mainly used achromatic luminance-defined stimuli, it remains unclear what types of local motion signal contributes to the two types of motion induction. In the present study, we investigated whether induced motion occurs with isoluminant chromatic stimuli. Inducer stimuli were vertical sinusoidal gratings moving horizontally and presented above and below the test stimulus. The test was a counterphasing sinusoidal grating whose amplitude ratio of the leftward and rightward components was varied to obtain a motion nulling point for each condition. It was shown that chromatic stimuli induced motion assimilation but not motion contrast in the condition where motion contrast with achromatic stimuli occurred. Induced motion with chromatic stimuli was not affected by luminance noise mask, suggesting the results were not caused by luminance contamination. The motion assimilation with chromatic stimuli was prominent when temporal frequency or chromatic contrast of inducer was sufficiently high. We also examined the condition where either the inducer or the test was achromatic and the other was chromatic. The results showed that achromatic motion induced motion assimilation of chromatic stimuli while chromatic motion had little effect on achromatic target. The present results suggest that spatial antagonism for chromatic motion, if any, is less efficient than that for achromatic motion, while chromatic motion provides significant input to the integrative mechanism which has no inhibitory surround.

23.337 **Vection induction is determined by the world coordinate**

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We have reported that the ground stimulus is more effective than the ceiling in inducing vection (Sato et al., 07 ECVP). The ground dominance effect (GDE), however, had been demonstrated only when the observer was standing upright, and it was not clear which coordinate system (e.g. retinal/world) determines the ground and the ceiling. To examine this point, in this study, we had observers evaluate vection strength induced by either the ground or the ceiling stimulus while keeping one of the following three positions; upright, upside-down, or 90 deg tilt (sideways). The ground and ceiling stimulus (random-dot pattern) were projected upper or lower 1/3 of a large screen (75 deg horizontally X 65 deg vertically). The motion of the dots simulated a forward motion of the observer (1.7 m/s). In each trial, both ground and ceiling stimulus was presented first as a standard, then, a test (either the ground or ceiling alone) was presented for 60 sec. Observers were asked to make magnitude estimation for the vection induced by the test stimulus relative to that by the standard. Observers were asked to press a button while they perceived vection to measure the latency and duration of vection. It was found that the head orientation had little effect on the GDE in vection. In an additional experiment, observers in the sideways position observed the stimulus that was also rotated sideways. That is, the orientation of the stimulus was upright according to the retinal coordinate. In this condition, although vection of normal magnitude occurred, no GDE was identified. These results, thus, indicate that the ground dominance of vection occurs according to the ground defined by the external or the world-centered coordinate instead of the retinal or the body centered coordinate.

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23.338 The role of hMST in the perception of object movement during self-movement

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Neurophysiological research (Eifuku & Wurtz, 1998, Journal of Neurophysiology) has identified MST as a potential site for the detection of scene-relative movement. Using fMRI we investigated the role of area hMST in the same task in humans. First using standard localisers we identified hMT+, hMST and hMT, along with disparity sensitive, motion sensitive, and retinotopic regions. Next we confirmed that pure object movement (a moving object viewed from a stationary viewpoint) activated the same network of motion-sensitive areas as pure self-movement (movement of a viewpoint through a rigid scene). We then attempted to isolate areas specialised for scene-relative movement. Observers viewed (through anaglyph stereo glasses) twenty-five 3D objects randomly positioned within a volume in peripersonal space, directly ahead. Amongst the scene objects was a target object that was identified by a significant difference in size. We simulated the lateral translation of the observer and a compensatory counter-rotation of the head to maintain fixation on the centre of the volume of objects. We compared BOLD response (15 second period box-car) when the target object was a part of the rigid scene against when the target object moved independently of the scene. There was some variation in individuals' responses, but the results suggest a central role for hMST.

23.339 The internal model of visual gravity contributes to interception of real and apparent motion as revealed by fMRI

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Predictive mechanisms for target interception based on 'tau' (Lee, Perception, 1976) have been revealed in fronto-parietal networks (Field and Wann, Curr. Biol., 2005; Merchant and Georgopoulos, J. Neurophysiol., 2006). The mechanisms underlying interception of falling targets are less understood. A recent fMRI study indicated that neural populations in the vestibular network encode visual gravitational acceleration (Indovina et al., Science, 2005). Here we presented 1g (natural gravity), 0g (constant speed), -1g (reversed gravity) targets in smooth motion (RM) or long-range apparent motion (AM) during fMRI to test whether the vestibular network provides a sensory code or an internal model of visual gravity. We expected that a sensory mechanism selective for downward image accelerations should be engaged only during interception of 1g targets, but an internal model should be engaged also by 0g targets which are mistaken for gravitational. Moreover, finding similar activity patterns with either RM or AM would exclude that the activation merely reflects differences in low-level spatiotemporal properties of the stimuli, and would indicate generalization of the internal model across low-level and high-level motion. We found that both 1g and 0g targets engaged the vestibular network in RM and AM, and in addition engaged a higher-level motion region of inferior parietal lobule in AM (Claeys et al., Neuron, 2003). Therefore, internalized gravity constrains the matching process used to interpret and intercept targets' vertical motion.

23.340 Neural substrate of the perception of phi (pure) movement

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Recent developments in understanding the distinction between phi (pure apparent movement) and beta (optimal apparent movement), led to what is called "magniphi", a very vivid phi stimulus (Steinman et al., Vision Research, 2000). With this stimulus in hand it was possible to show that the neural substrates, as well as the perceptions of these different kinds of motion, are different. This was done by using functional magnetic resonance imaging (fMRI) experiment. In this experiment, 18 subjects underwent fMRI at 1.5T (8 subjects, 32 axial slices, TR/TE=3000/40 ms) or 3.0T (10 subjects, 37 axial slices, TR/TE=3000/30 ms). Two white-on-black visual stimuli were used: (i) one dot moving through nine positions around the fixation point, or (ii) eight dots rotating through the same nine positions. Two rates were used: 220 ms/revolution or 40 ms/revolution in clockwise or counterclockwise direction. These conditions were presented with 3 s duration using an event-related paradigm with ISI=15 s and a temporal jitter that was an integer multiple of 3 s. Eight dots shown at high rate lead to magniphi; the remaining three conditions lead to beta motion. Each of the conditions was presented 45 times over the course of 12 runs. Fourteen out of 18 datasets have been processed by using statistical parametric mapping 5 (SPM5) to perform random effect analysis between stimulus conditions and a rest condition. These results were thresholded at $pFDR<0.05$ to identify differential activities favoring magniphi. We found statistically strong bilateral activities in superior colliculus and pulvinar favoring magniphi. There was no difference in activities along the dorsal visual processing stream except in the right MST, bilateral SPL, and bilateral BA6 areas, which were stronger activated by one or more beta stimulus conditions, although this stream was significantly stimulated by both magniphi and beta in general.

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URL: http://psych.purdue.edu/Magniphi/

23.341 Paradoxical motion perception observed through contrast-alternating multiple-slit-viewing

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It is known that the human visual system can extract motion from a moving pattern presented through an array of horizontal slits, each having one pixel width (Multiple-Slit-Viewing, MSV). Here we developed a new motion display in which the contrast of a pattern moving behind the slits keeps its original polarity or reverses to its negative alternatively (contrast-alternating MSV). In other words, this configuration is a variant of reversed-phi motion in alternating the contrast of a moving pattern not in the time domain (every frame), but in the space domain (every slit). To investigate the effect of contrast alternation in the space domain on motion perception, we asked participants (n=7) to report the perceived direction of the moving stimuli (upward or downward) under either standard or contrast-alternating MSV conditions by button-press (2AFC) while changing the width of interslit bands (from 0 to 8 pixels) and the monitor refresh rate (60, 75, or 100 Hz). Motion direction observed through standard MSV gradually degraded and eventually became indistinguishable as the width of the interslits increased. On the other hand, perceived motion under contrast-alternating MSV was intruded on by components moving in the direction opposite to the pattern shift behind the slits, depending on the width of the interslit bands and the monitor refresh rate. Counter-intuitive phenomena we found were that the participants reported the pattern-shift direction quite accurately (better than 75%) under contrast-alternating MSV in moderately wide interslit width conditions, while motion discrimination performance under standard MSV was chance level. We will further show that the power spectrum distribution of two MSV motion stimuli, weighted with the spatiotemporal sensitivity window (centered at 1.2 cpd and 3 Hz), can account for the motion discrimination limit under standard MSV, and the reversed motion perception and subsequent enhanced motion discrimination performance under contrast-alternating MSV.

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23.342 Stimulus factors that influence the perceived direction of Tilt-induced Motion

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We have described Tilt-induced Motion (TIM), a variant of the barber-pole illusion, in which a drifting grating is viewed through an obliquely-oriented aperture, inducing an illusory vertical motion in the aperture, even though the aperture is in fact stationary (Caplovitz, Paymer, & Tse, VSS 2007). The effect appears to be strongest when the terminator motion vector has an upward component, and the motion direction orthogonal to the orientation of the grating has a downward component. We raised the hypothesis that conflicting terminator and component motion sources can lead to a misattribution of motion information to the stationary contours of the aperture. We further hypothesized that the direction of the illusory motion is influenced by both local and non-local configural cues.

In the current set of experiments, we tested the first of these hypotheses by removing terminator motion from the stimulus. Here we replaced the drifting grating with a drifting random dot field, thereby eliminating terminator motion entirely. We found that in this case, for certain directions of motion, the TIM illusion persists – thus it does not arise solely from a conflict between terminator and component motion sources.

In another set of experiments, we tested the second hypothesis by measuring the perceived direction of TIM under different stimulus configurations. We will discuss the influence that orientation of the short edges of the aperture (which were always vertically oriented in the original experiments) has on the perceived direction of TIM. In addition, TIM can be influenced by using obliquely oriented grey "tracks" that seem to guide the illusory motion. Because there is no real motion along these tracks, they serve as non-local configural cues.

23.343 **Why does Rotating Tilted Lines Illusion rotate?**

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Gori and Hamburger (2006) presented the Rotating Tilted Lines Illusion (RTLI). Moving back and forth in front of this pattern makes the circle of lines appear to rotate in a clockwise and counterclockwise direction, respectively.

The building blocks of the illusion are very simple: lines. This enables one to investigate the underlying mechanisms of the illusion directly. We reviewed the previous modeling works in this respect (Grossberg and Mingolla 1993; Gurnsey, Sally et al. 2002) and proposed an explanation of the illusory phenomenon based on a competition between the two types of neurons in primary visual cortex, namely end-stopped and contour cells (Pack, Livingstone et al. 2003; Yazdanbakhsh and Livingstone 2006). The illusion can be described based on the weighted average of the response of the two types of cell populations. A simple model for the integration of the two motion signals is proposed and discussed.

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23.344 **Can depth information affect the Enigma Illusion?**

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In 1981, Leviant devised a figure named Enigma eliciting spontaneous perception of rotary motion in absence of real motion. The figure consists of a ray pattern made by narrowly spaced black and white radial lines onto which three chromatic rings are superimposed. A spurious rotation is perceived on the rings. There have been many attempts to explain this intriguing phenomenon, but there is not a commonly accepted explanation that can integrate all the (sometimes contradictory) experimental data. The aim of the present study was to understand if Enigma elicits the same illusory motion also when the rings are not on the same plane of the background. To test this hypothesis we separated at various distances in depth the background of the Enigma illusion and the rings. The size of the rings, in terms of visual angle, was always kept constant. The independent variable was, therefore, the binocular disparity, that changed as a function of the distance of the rings from the background. The observers' task was to rate the strength of the illusory rotary motion perceived on the rings by using a five points scale. The results showed that the effect becomes weaker as the distance between the rings and the background increases. Thus it seems that when binocular disparity increases, the radial lines cannot influence any more the appearance of the rings. It is possible then that the background and the rings are processed as two independent objects. Conclusions will be discussed within the relevant literature.

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23.345 **The effect of metacontrast masking on the Fröhlich Effect**

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The onset of a moving object is often times perceived as being displaced forward in it's motion trajectory; this visual illusion is called the Fröhlich Effect. One explanation of this displacement states that the early portion of the motion trajectory is masked by the later, and thus the actual onset of the object is simply erased from conscious awareness (Kirschfield & Kammer, 1999). However, other studies have produced results inconsistent with this explanation (Müsseler & Aschersleben, 1998; Cai, 2003). Whether masking is actually present in the Fröhlich Effect has never been directly measured. We measured it in this study. In Experiment 1 we found that in order to be detected, a color marking the first frame of a moving bar had to be at a higher saturation level than that of an identical control flash. This indicates that the first frame of a moving bar is indeed susceptible to masking. In Experiment 2 the first frame of the moving bar either had fully saturated color, resulting in no masking, or desaturated color, resulting in full masking. Consistent with Cai (2003), the onset of the fully saturated bar was perceived to be displaced forward in it's motion trajectory; however, the desaturated bar exhibited an even larger displacement. In Experiment 3 we found, using a classic metacontrast masking paradigm (Breitmeyer & Ögmen, 2006), that a fully saturated colored circle (a marker) is only partially masked when spatially surrounded and temporally followed by an annulus, whereas a desaturated version of the circle is fully masked in the same situation. In sum, we found that masking is indeed present, and is likely to play a role in the Fröhlich Effect. Interestingly, we also found that masking cannot account for the whole Fröhlich effect. Thus, the Fröhlich effect is likely to result from multiple perceptual mechanisms.

Acknowledgement: We thank UW Grant 135-G412

Saturday, May 10, 8:30 am - 12:30 pm Poster Session, Royal Palm Ballroom 6-8

Attention: Selection and Modulation 1
Faces: Inversion and Viewpoint Effects
Multisensory Processing: Low Level

Attention: Selection and Modulation 1

23.401 **A Taxonomy of Visual Attention**

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It is widely believed that there are two types of spatial attention: voluntary and involuntary attention. We expand this taxonomy by demonstrating that there are at least two mechanisms of involuntary attention.

The first is a serial search mechanism and is related to finding the target in a display. In a spatial cueing task, observers have a tendency to search for the target beginning at the cued location (valid trials). If the target is not at that location, observers then search other locations (invalid trials). Hence RTs are faster on valid than invalid trials.

The second mechanism occurs at the response decision stage. A spatial cue primes a response to any stimulus that appears at the cued location. This mechanism can be characterized by a formalism called the accumulator model (Usher & McClelland, 2001).

The serial model predicts that as the number of display positions increases, the cueing effect will increase. The accumulator model makes the opposite prediction. In most tasks, observers must both find the target (serial search) and decide which target was present (accumulator model). Which of the two mechanisms will limit performance will depend on whether finding the target or discriminating the target is more difficult.

We varied the number display positions in a spatial cueing task. We found that when there were no distractors the cueing effect decreased as the number of display positions increased, supporting the accumulator model. When there were distractors, the cueing effect increased as the number of distractors increased, supporting the serial search model.

Thus involuntary attention is mediated by at least two different mechanisms: serial search and response decision. We've begun to explore whether different involuntary attention effects (e.g., inhibition of return, contingent capture) are caused by the serial search or decision (accumulator) mechanisms.

23.402 **A visual redundant-signal effect strongly depends on attention even for probability summation**

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When two targets are associated with the same response in a speeded task, the response time is facilitated when both targets are simultaneously presented compared to when only one target is presented. This redundant-signal effect can be mediated by probability summation (race model) or by signal integration (co-activation) over and above probability summation. Previous results suggested that attending to redundant stimuli is necessary for signal integration. Here we report that probability summation also depends strongly on attention. We used stimuli that produced probability summation and manipulated attention using exogenous cueing (a flashed rectangle). A robust redundant-signal effect occurred in the attended condition where the redundant targets were presented within the cued region, but the effect was substantially reduced or absent in the ignored condition where the targets were presented in the un-cued region. Attention is thus crucial for a redundant-signal effect even for probability summation.

23.403 **Facilitatory effects of expectation on object discrimination**

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Although it is well known that expectation of low-level attributes (locations and features) can facilitate processing of simple visual stimuli, less is known regarding effects of expectation on processing of more complex, real-world stimuli. Here, a series of experiments reveals effects of object category expectation on performance of a visual discrimination task. Participants viewed morphed images composed of varying ratios of pairs of faces or places and indicated which original face or place dominated each image. Cues preceding each image could be valid (60% of trials), neutral (20% of trials) or invalid (20% of trials) with respect to object category. Performance was measured across a range of difficulty levels, generating separate psychometric and chronometric functions for each validity condition. Valid cues resulted in faster reaction times (RTs) relative to neutral and invalid cues, and steeper psychometric functions relative to the invalid condition, indicating facilitated discrimination after valid category expectation. Inspection of the chronometric functions confirmed that the RT facilitation does not reflect priming of the response. Furthermore, this expectation-dependent facilitation could not be explained by attention to spatial location or to low-level stimulus attributes. These findings demonstrate that expectation at the level of object categories can facilitate processing of complex visual stimuli.

23.404 **Attentional Control Settings Affect Attention but Not Perception: A Study of Gaze Cues and Pupilometry**

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The human visual system is calibrated by an observer's goal state such that attention is only allocated to stimuli possessing task relevant properties. In the present research we investigated whether such attentional control settings extend to perceptual processing. To answer this question we made use of gaze cues - centrally presented schematic faces, with eyes either gazing left or right, which have been shown to generate reflexive shifts of attention to peripheral locations. Our study produced two novel findings. First, the shifts of attention generated by gaze cues are contingent on the schematic face being presented in a task relevant color. In other words, gaze cues are sensitive to attentional control settings. Second, when a face is presented upright at fixation, it causes a contraction in pupil size relative to when the same face is presented upside-down. Importantly, this contraction of pupil size does not depend on the face being presented in a task relevant color. That is, gaze cues that were outside the attentional control setting did not generate shifts of attention even though they were perceived as faces. These results demonstrate that processing within the visual system can be calibrated to prevent task irrelevant stimuli from capturing attention, but not from being perceived.

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23.405 **Partially valid cueing and spatial filtering reveal different kinds of selection**

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The nature of selective attention was investigated for partially valid cueing and spatial filtering. The task was to judge the contrast polarity of a brief flash of light of varying contrasts. For both paradigms, a location was cued and responses to stimuli at cued locations were compared to responses to stimuli at uncued locations. For partially valid cueing, a stimulus at a cued location was more probable than a stimulus at an uncued location. However, the task was to respond to a stimulus at any location. For spatial filtering, the task was to respond to stimuli at the cued location and ignore stimuli at the uncued location. It was therefore inappropriate to respond to a stimulus at the uncued location in the spatial filtering task. We considered the predictions of two selection hypotheses: contrast gain and all-or-none mixture. For the contrast gain hypothesis, information from a stimulus at an uncued location is attenuated on all trials. Thus, increasing contrast can overcome the attenuation. For the all-or-none mixture hypothesis, information from a stimulus at an uncued location is blocked completely on some fraction of the trials. Thus, increasing contrast cannot overcome the block. Results for cueing are consistent with the contrast gain hypothesis and reject all-or-none mixture. In contrast, results for spatial filtering are consistent with the all-or-none mixture hypothesis and reject contrast gain. One interpretation is that spatial filtering is limited by the imprecise localization of the cued location. We argue that spatial filtering reveals an aspect of the selection process that was hidden with cueing paradigms.

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23.406 **Cue salience modulates the effects of exogenous attention on apparent contrast**

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Goal: Exogenous spatial attention can be automatically engaged by brief peripheral cues. However, because studies of exogenous attention use highly salient precues to reliably engage it, little is known about the cueing threshold (i.e. degree of salience required to engage attention). Does exogenous attention have an "all-or-nothing" effect above some critical cue salience, or does it increase gradually? We explore this question by assessing attentional effects on apparent contrast (Carrasco, Ling & Read, 2004; Fuller, Rodriguez & Carrasco, 2007) as a function of cue contrast.

Methods: We first obtained psychometric functions for a 2AFC cue localization task, at 7° eccentricity, 3° above the horizontal meridian, over a range of seven cue contrasts. In the main experiment, a brief single precue was presented at one of the same peripheral cue locations or at fixation (neutral), followed after a 110 ms SOA by two 4° Gabor stimuli at 7° eccentricity on the horizontal meridian. Observers reported the orientation of the stimulus that was higher in contrast. By assessing which stimulus observers perceived as higher in contrast, we obtained psychometric functions and their concomitant points of subjective equality (PSE). The magnitude of the attention effect was calculated for each of five cue contrasts as the difference between the PSEs with the peripheral and the neutral cues. We tested for cue bias in a separate session using 100% contrast post-cues (cues presented after the stimuli), instead of precues.

Results: Observers perfectly localize the cue at ~8% cue contrast. The attentional effect on apparent stimulus contrast emerges only above this level of cue contrast, and increases continuously with cue contrast. There is no attentional effect with the post-cue, ruling out cue bias. Despite its automaticity, the magnitude of exogenous attention's benefit modulates over a considerable range of cue salience. It is not "all-or-nothing."

23.407 **Bilateral Superiority in Detecting Gabor Targets Among Gabor Distracters**

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Introduction: Previous research has suggested separate limited-capacity attentional tracking systems for the left and right visual hemifields (Alvarez & Cavanaugh, 2005). Evidence for this possibility comes from the finding that the ability to attentionally track three seconds of target-motion is significantly greater for bilateral than for unilateral stimuli (Alvarez & Cavanaugh, 2005). The present study addressed whether similar bilateral superiority occurs at much briefer stimulus durations (<200 msec) when detecting briefly flashed Gabor targets.

Method: Twenty-four Denison University undergraduates completed a 2x2 within-subject experiment in which the independent variables were laterality (bilateral versus unilateral) and Gabor distracter (present versus absent). Each trial began with a pair of either bilateral or unilateral attentional cues indicating the peripheral positions (12 deg from fixation) at which the Gabor targets (diagonal orientation, 183 msec) would appear, if present. In an attempt to overwhelm the neural resources dedicated to detecting Gabor targets in each lateral visual field, half of the trials (randomly) contained irrelevant Gabor distracters presented between the attentionally cued Gabor-target positions. After correctly identifying a foveally flashed letter that controlled fixation, participants judged whether Gabor targets had been present or absent at the attentionally cued positions.

Results: When distracters were absent, bilateral and unilateral detection (d') were statistically indistinguishable (F(1,23)=1.29, p=0.268, n.s., partial eta squared = 0.053). By contrast, when distracters were present, detection (d') was significantly greater bilaterally than unilaterally ($F(1,23)=23.266$, $p<0.001$, partial eta squared = 0.503). Discussion: Like the previous attentional-tracking data (Alvarez & Cavanaugh, 2005), the present distracter-dependent bilateral superiority in detection is consistent with independent capacity limits for the left and right visual hemifields. Because crowding effects and masking effects are distinguished by distracter-induced impairments in detection (Pelli, Palomares, & Majaj, 2004), the present distracter-induced reduction in unilateral detection is consistent with masking but not with crowding.

URL: http://personal.denison.edu/~matthewsn/vss2008.html

23.408 **Expansion and Contraction of the Attentional Focus Is Influenced by Top-Down Factors**

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Jefferies and Di Lollo (2007) proposed a spatiotemporal model in which the focus of attention shrinks and expands linearly over space and time. Exogenous factors such as stimulus contrast and luminance are known to influence the rate of this modulation (Jefferies, Enns, & Di Lollo,2007). Do endogenous factors also influence that rate? Although there are some hints to this effect (Ghorashi et al., 2003), this issue has not been studied directly. We adopted Jefferies and Di Lollo's paradigm in which Lag-1 sparing is used to index the spatial extent of the focus of attention. When two sequential targets are inserted in a rapid stream of distractors, perception of the second target is impaired at short inter-target lags (AB deficit). Paradoxically, this deficit is not obtained when the second target appears directly after the first (Lag-1 sparing). In the current study, two streams – one of random-dot patterns, the other of random digits – were presented one on either side of fixation. The first target (a letter) appeared unpredictably either in the dot-stream or in the digit-stream, and the second target (another letter) appeared – again unpredictably – in either the same stream as the first or in the opposite stream. To monitor the rate of shrinking of the attentional focus, we varied the SOA between successive items in each stream. The condition of principal interest was when the targets appeared in different streams: if endogenous factors play a role, it should be more difficult to disengage attention from the meaningful (digit) stream than from the meaningless (dot) stream. If so, we expected greater Lag-1 sparing when the second target appeared in the digit stream because attention was still engaged in that location. The results confirmed this expectation, strongly suggesting that top-down factors influence the shrinking and expanding of the attentional focus.

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23.409 **Perceptual consequences of visual performance fields: The case of the line motion illusion**

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Goal: Illusory line motion (ILM) is the illusion that a line, preceded by a small dot (cue) near one end, is perceived to shoot out from the dot even though the line is physically presented at once. ILM can also counter the perception of physical line motion when the two are opposed. Does this illusion result from apparent motion, exogenous spatial attention, or both? Given that exogenous attention speeds visual processing unequally at cardinal locations (North>South>East, West; Carrasco, Giordano & McElree, 2004), we hypothesized that the contribution of attention to ILM would follow this same pattern across locations.

Method: We characterized psychometric functions of perceived line motion direction, for 1.5° stimuli with varying amounts of physical line motion (8 levels, 0 to 37 ms/deg sequential presentation) toward or away from the local cue element, at four cardinal locations. We used three cue conditions to separate the effects of attention from apparent motion–a single cue adjacent to the stimulus to draw attention to its location, a distributed cue with elements near all four possible stimulus locations, and no visual cue. Because the local visual input near the stimulus is the same for both visual cues, the single cue combines attention and apparent motion effects whereas the distributed cue does not engage focal attention.

Results: Distributed and single cues generate identical effects at East and West, but the effect of the single cue is progressively greater at South and North locations. We conclude that both apparent motion and attention can generate ILM, their relative contributions varying by location. The effect of attention is most clearly separable at the North, where its effect on processing speed is strongest and the mechanism underlying apparent motion may be relatively weak due to the slower speed of processing at that location.

23.410 **Attention to hierarchical level influences spatial frequency processing**

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Ample evidence indicates that different neural mechanisms support the efficiency of processing global and local levels of hierarchical stimuli (Navon patterns),al though the nature of these mechanisms is debated. Some studies have associated global versus local perception with the use of relatively low versus relatively high spatial frequencies, respectively (e.g., Ivry & Robertson, 1998). Others have implicated differences in saliency of the two levels as the relevant variable (e.g., Mevorach et al., 2006). However, both camps agree that hierarchical perception is at least partially flexible, and perceptual strategies can be applied to the low-level visual characteristics of the display depending on the demand characteristics of the task. We explored the nature of this relationship and asked if imposing a global or local bias would induce a subsequent bias to process low or high spatial frequencies, respectively. Participants viewed pairs of hierarchical Navon displays and were asked to make same/different judgments on the global and local levels in separate blocks. Following each hierarchical display, compound spatial frequency gratings appeared, and participants made orientation judgments on either the low or high spatial frequencies. The association between global versus local perception and the processing of low versus high spatial frequencies was corroborated. Participants were faster at reporting the orientation of low than high spatial frequency gratings during the global attention block, and they were faster at reporting the orientation of the high than low spatial frequency gratings during the local attention block.

23.411 **Endogenous, sustained attention alters contrast appearance**

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Goal: Exogenous, transient attention alters appearance along a number of perceptual dimensions including contrast (Carrasco, Ling & Read, 2004). However, it remains unclear whether endogenous, sustained attention also changes appearance. Here we tested the effect of endogenous attention on perceived contrast.

Methods: A central cue prompted observers to direct attention to one of two peripheral locations at eight degrees of eccentricity or to both locations (focused versus distributed attention, respectively). Two RSVP letter streams were shown at those locations for 1.2 s, followed by two independently tilted Gabor patches adjacent to the letter streams (40 ms). For focused-attention trials, observers directed attention to the cued RSVP stream and detected a target letter ('X'); for distributed-attention trials, observers monitored both streams for the target. A target was presented on 20% of total trials, and observers indicated target detection by pressing a key. The rate of the RSVP stream was dynamically adjusted to maintain a high detection performance (~90%). When observers did not detect the target, they reported the orientation of the higher contrast Gabor patch. One of the Gabors was the Standard (32% contrast) while the other was the Test, whose contrast was chosen from one of 9 levels around the Standard (13%-77%).

Results and Conclusion: Performance on the RSVP detection task was better for peripheral than neutral trials, indicating that attention was effectively deployed to the cued location. This deployment of attention caused a systematic shift in the psychometric functions for appearance: the stimuli in the cued location were perceived to have higher contrast than stimuli in the uncued location. In addition, attention improved performance on the orientation discrimination task. A control experiment ruled out a cue-bias explanation of the effect. These results indicate that endogenous, sustained attention also alters appearance.

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23.412 **Spatial attention to an invisible adaptor can increase the magnitude of adaptation**

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Can spatial attention increase the amount of adaptation even when the adaptor was invisible? Kanai et al. (2006) showed that spatial attention could not modulate the amount of tilt aftereffect when the adaptor was invisible. In this study, we asked the same question but used different methods. The period of adaptation was longer and the contrast-decrement detection task was used to modulate participants' attention. We first measured contrast thresholds of a sine grating for each participant using QUEST method. We then had participants adapt to the gratings with the same spatial frequency and orientation. The two adaptors were presented in the left and the right visual field of a non-dominant eye and they were made to be invisible using binocular rivalry. They were suppressed by two pinwheel gratings presented in a dominant eye. The duration of perceiving adaptors was less than 3% of the entire adaptation period. Initial adaptation period was 1 minute and adaptation was maintained by 5 second top-up. To modulate attention during adaptation, participants performed the contrast-decrement detection task on one of the two pinwheel gratings (suppressors). Participants asked to report occurrences of contrast decrements in one of the two pinwheel gratings. Contrast decrements were independently occurred in each visual field regardless of participants' locus of attention. The contrast threshold in the attended field was elevated significantly more than that in the unattended field. However, this trend was not observed in the yoking condition in which the two adaptors were not presented during adaptation. Note that participants' percept was the same in this condition as in the adaptors-present condition because only pinwheel gratings were perceived even when adaptors were present. These results suggest that spatial attention can modulate the effect of adaptation even when the adaptor is invisible.

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23.413 **The behavioural temporal dynamics of attention with multiple uncued locations**

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Introduction: Previously, the temporal dynamics were assessed in a cueing task across two locations using classification images to measure information use (Shimozaki, Vision Sciences Society, 2007). Results suggested parallel processing of the cued and uncued locations with no delay at the uncued location, inconsistent with serial descriptions of visual attention (e.g., Posner, 1980). It is assumed that attentional costs increase with the number of locations (set size effects); thus, the goal of this study is assessing the temporal dynamics with more than one uncued location.

Method: Two observers participated in a yes/no contrast discrimination task of vertical Gabors (1 cpd, 1 octave bandwidth, full-width, half-height) appearing 7.5° from central fixation across 2, 3, or 4 locations (set sizes). Half the trials contained a high-contrast Gabor signal (15.6% mean peak contrast on a 23.4% mean peak contrast pedestal) appearing at one location and the pedestal at the other locations, half the trials contained the pedestal at all locations, and participants judged for signal presence. The stimuli were presented for 272 ms divided into 12 intervals (22.7 ms), with the contrast of each Gabor varying randomly from interval to interval (Gaussian, sd = 11.7% contrast). A dark 4° square cue appeared simultaneously with the stimuli and indicated the location of the signal with 70% validity; therefore, the signal appeared at each uncued location on 30%, 15%, or 10% of the signal present trials for set sizes of 2, 3, and 4, respectively.

Results: Set size effects for percent correct were modest, while cueing effects (valid hit rate – invalid hit rate) increased with set size, reflecting the decreasing validity of each uncued location with set size. Across set size, results from the classification images found no evidence of a delay of information use at the uncued locations relative to the cued location.

23.414 **The creaky attentional gate: temporal changes in the spatial extent of attention in elderly and young observers**

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When stimuli are presented in rapid succession, processing of the first target stimulus interferes with the processing of the second – a phenomenon known as the attentional blink (AB). This interference is thought to reflect a lack of processing resources left for dealing with the second target. However, processing of the second target is not always impaired: in cases of Lag-1 sparing, a target stimulus that appears directly after the first is processed effectively, and observers correctly identify both targets. By presenting targets in separate RSVP streams on either side of fixation, Jefferies and Di Lollo (2007) used the phenomenon of Lag-1 sparing as a tool of convenience for monitoring how the extent of a spatial window of attention shrinks and expands over time. The window initially encompasses both possible target locations, then reflexively narrows to the location of the first target. If the second target is presented directly after the first in the opposite stream, the incidence and magnitude of Lag-1 sparing may be used to evaluate how quickly the attentional window narrows to the location of the first target. In this study, we compared the time course of the narrowing of the attentional window in older and younger observers. Older observers are slower to detect and/or process the first target presented in the RSVP streams, delaying initiation of the shrinking of the attentional window. This leads to greater Lag-1 sparing in older observers than in younger observers. Although older observers are slower to start shrinking the window, the time course of shrinking once started is similar to that of younger observers. Consistent with previous findings, older observers experience a larger AB deficit at Lag-3 when the targets appear in the same stream, implying that intervening distractors disrupt processing of the second target to a greater degree with age.

Faces: Inversion and Viewpoint Effects

23.415 **The Inversion effect of Chinese Character**

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Do we recognize characters by parts, or as a whole? It is of interest for visual word recognition of non-alphabetic scripts such as Chinese. We probe this question by applying the inversion effect (IE). IE of face recognition refers to the finding that the inversion of faces results in a more serious decrement of performance than natural objects (Yin, 1969). Researchers suggest that the IE of face provides the evidence for the holistic encoding of faces (e.g. Diamond & Carey, 1986; Tanaka & Farah, 1993). Current studies examine whether recognition of Chinese Characters also show IE, and hence, the holistic processes. Four types of stimuli including high- and low-frequency real characters (RCh), pseudo-characters (PsCh), and non-characters (NCh) were used as materials. Stimuli were presented both upright and upside down in a lexical decision task. Results show IE in RCh but not PsCh and NCh. Separated analysis for RCh revealed frequency by inversion interaction indicating that subjects showed larger IE when process LF characters than process HF characters. We conclude IE was clearly elicited while processing Chinese characters, but the overall patterns do not resemble to the familiarity effect of inverted face. Holistic processing may not the only factor to determine the patterns in character processing. The roles of decomposition, familiarity, and mental rotation were discussed.

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23.416 The influence of eye and mouth position on judgments of face orientation

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This study investigated whether humans judge the orientation of a face based on the absolute or relative positions of features. The stimuli were schematic faces, consisting of an outer elliptical contour and either two eyes plus mouth (EM condition), or the eyes or mouth presented alone (E and M conditions). The eyes and mouth were located at five different heights within the outer contour. Eye and mouth height were combined factorially, yielding a total of 25 stimuli in the EM condition, and 5 stimuli in each of the E and M conditions. On each trial, a stimulus was presented for 250 ms and participants (n=16) judged whether the face was upright or inverted using a 4-point confidence scale. The EM, E, and M conditions were performed in different blocks. In the E condition, faces were judged upright whenever eye height was equal to or higher than the center of the face. In the M condition, faces were judged upright whenever mouth height was equal to or less than the center of the face. Upright judgments for faces with the feature (eyes or mouth) in the center of the face suggested an upright bias. In the EM condition, orientation judgments were influenced significantly by the relative heights of the eyes and mouth: faces were judged as upright whenever the eyes were higher than the mouth, even when both features were unnaturally located in the upper- or lower-half of the face. In summary, human judgments of face orientation were based on both the absolute and relative positions of eyes and mouths, and there was a bias to perceive faces as upright.

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23.417 Face adaptation aftereffects reveal norm-based coding for upright and inverted face shape

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Face adaptation research -- whereby prolonged viewing of a manipulated face systematically alters the otherwise normal percept of the next presented face -- has the potential to bridge psychological face theories and their neural correlates. For instance, it has been shown that upright face shape is encoded in a norm-based fashion, implicating opponent coding mechanism at the neural level (Robbins et al., 2007). The current study tested whether inverted face shape is encoded in a norm-based or exemplar-based fashion. Norm-based coding (two oppositely and broadly tuned neural pools) predicts aftereffects will increase in size as the distortion level of the adaptor becomes more extreme; exemplar-based coding (multiple narrow band pools) predicts a decrease. Our distortion shifted eyes up or down relative to other features. Results show a greater shift in the face perceived as normal following adaptation to extreme adaptors (e.g., eyes up by 50 pixels to near hairline) than closer-to-average adaptors (e.g., eyes shifted up by 5 pixels), supporting norm-based coding for both upright and inverted faces. Further, the aftereffects were also used to model the neural tuning curve for face shape in both orientations. This study suggests that norm-based strategy might be applicable for any class of objects whose members share the same basic configuration, although the neural details might differ.

23.418 Face discrimination at various phase orientations

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Background. A hallmark of face processing is that individual features strongly interact over space, providing an integrated representation of features and their spatial relations. Once the face is inverted, feature spatial interactions are attenuated and mainly local feature information is extracted, leading to strong discrimination and recognition deficits. Face inversion was recently demonstrated to largely stem from the disrupted processing of the vertical spatial relations organising features (e.g. eye height) in a given face, whereas the perception of horizontal relations (e.g. interocular distance) is mildly affected by inversion. Altogether, these findings suggested that upright face perception largely relies on the extraction of vertically-oriented information.

Methods. Here we further investigated the prevalence of vertically oriented information in face processing. We measured discrimination performance to upright and inverted faces filtered to preserve Fourier amplitude at vertical and horizontal phase orientations selectively.

Results. Upright face discrimination showed differential sensitivity across phase orientation angles. Namely, subjects matched upright face stimuli better when they contained vertically- than when only horizontally-oriented phase information was available. This profile did not merely reflect the orientation spectrum of the stimuli, since it did not replicate when faces were inverted.

Conclusion. The present results support the view that upright face discrimination relies on vertically-oriented more than horizontally-oriented information. Follow-up studies will explore whether these phase effects are specific to faces or whether they can be found with other stimulus categories.

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23.419 Upright face advantage in visual information processing under interocular suppression only available for the low spatial frequency pathway

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Previous studies have shown that both low-level and high-level properties contribute to the strength of a stimulus in interocular competition. Indeed, stimuli of greater perceptual strength (e.g., high contrast) emerge from suppression faster than stimuli of weaker perceptual strength (e.g., low contrast). Recent studies have shown that stimuli of greater familiarity or recognizability also have a competitive advantage when processed under suppression. For example, upright faces emerge from suppression faster than inverted faces. It was also suggested that high and low spatial frequency components in face images selectively contribute to identity (FFA) and emotional expression (amygdala, Pulvinar, Superior Colliculus) analysis, respectively (Vuilleumier, et al. 2003). It is unclear however, whether it is the high-frequency-identity-analysis system or the low-frequency-expression analysis system that is behind the competitive advantage for upright compared to inverted faces. Thus in the current study, we tested whether the upright face advantage in interocular competition is stronger for the low or high spatial frequency component. Subjects were presented in one eye with upright and inverted face images that were either low- or high-pass filtered, while high contrast dynamic Mondrian noise patterns were presented to the other eye. Due to interocular suppression, subjects initially perceived only the dynamic noise. Subjects were asked to respond by button press as soon as an image was detected emerging from the noise pattern. Similar to what we have found before, results showed that it took less time for the upright faces to emerge from suppression than the inverted faces, but only in the low-pass filtered face image condition. This pattern of results suggests that it is the low-frequency-face-expression analysis system that is responsible for the upright face processing advantage under suppression.

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23.420 The Face Inversion Effect Is Nothing "Spatial"

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Face identification accuracy declines and response time increases when stimuli are presented upside-down compared to when they are presented upright (Yin, 1969). This face inversion effect (FIE) is one of the most robust findings in the face literature. Here, we investigated whether inversion leads to qualitative changes in spatial frequency use. Participants were instructed to identify 10 individuals from 20 grayscale face photos. Stimuli were constructed by randomly sampling the spatial frequency information in the images using 45 Gaussian "bubbles" with a standard deviation of 1.5 octaves applied to the logarithm of spatial frequencies (Gosselin & Schyns, 2001; Fiset et al., 2006, VSS). By adding white Gaussian noise, performance for upright faces was adjusted to about 80% and 92% correct (mean response time of 1496 ms), in the accuracy and the response time versions of the task, respectively. The same amount of Gaussian noise was applied to the inverted faces; this led to a performance of 52% and 72% correct (with a mean response time of 1935 ms), in the accuracy and response time versions, respectively, thus demonstrating a clear FIE. Our results show the same spatial frequency band peaking at approximately 9 cycles per face width (octave width of about 2) in all conditions. The present findings thus do not support that inversion leads to qualitative changes at the spatial frequency level. They rather suggest that the same spatial frequencies are processed more efficiently during upright face identification.

23.421 **Face Shape Discrimination is Insensitive to Inversion**

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Recognition of a human face relies on successful matching of the features and their spatial arrangement to a stored representation. Yet our ability to do this is greatly impaired when a face is inverted. This is likely associated with the decrease in responses to spatial differences in fusiform face area, a face sensitive region of the brain, when a face is inverted (Kanwisher, Tong, & Nakayama, 1998). Despite this, perceptual tasks such as the estimation of intraocular distance or eye to mouth distance are unaffected by inversion (Schwanniger, 2003). We asked whether face shape discrimination involving comparisons between faces that were elongated or otherwise geometrically deformed is impaired by inversion. We found that face shape discrimination is not subject to the traditional face inversion effect. This is true whether the comparisons are simultaneous or sequential. We conclude that orientation does not affect our ability to perceive spacing information. We suggest that the face inversion effect observed with recognition results from an incompatibility between the orientation of the observed face and its memory trace. As suggested by Rock (1974), the processes involved with mental rotation may be overtaxed when attempting to recognize an inverted face, but mental rotation is unnecessary for face shape discrimination.

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23.422 **Inversion disrupts both configural and featural face processing equally**

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Previous studies that used configural vs. featural information manipulations in the investigation of the face inversion effect have reported a confined effect to configural manipulations, widely interpreted as reflecting the dominance of configural information in face processing. We suggest that such hypothesis is based on studies where configural and featural task difficulty were mismatched. Specifically, the featurally altered faces were easier to discriminate than the configurally altered ones when upright. In two experiments we compared the size of the inversion effect between configurally and featurally altered sets of faces when upright performance of both conditions were intentionally matched or mismatched. The magnitude of the inversion effect was comparable for configural and featural conditions when the sets of stimuli were well matched for discriminability, but diverged when the sets were intentionally mismatched. The results provide support against the view that inverted faces are processed in a qualitatively different way.

23.423 **Processing upright and inverted faces in acquired prosopagnosic patients with no object recognition deficits**

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Individual faces are notoriously difficult to discriminate and recognize when they are presented upside-down, an effect that supposedly reflects the disruption of holistic/global processing. Since acquired prosopagnosia has been associated with a deficit in holistic face processing, a reduced/abolished effect of face inversion is expected in such patients. However, previous studies have provided mixed results, showing not only a decreased (e.g. Marotta et al., 2002), or abolished FIE (e.g. Delvenne et al., 2004), but also a better performance for inverted stimuli in some cases (e.g. Farah et al., 1995). These discrepant results may be due to the selection of patients with general object recognition problems, and may also be confounded by associated upper visual field defects.

To clarify this issue, we conducted an extensive behavioral investigation of upright and inverted face processing in two cases of selective acquired prosopagnosia: PS (Rossion et al., 2003) and GG. First, there was no effect of inversion for the two patients at the Benton Face Matching Test, contrary to normal controls. Second, PS and GG both showed a significantly decreased effect of inversion in a simultaneous ABX face matching task across viewpoint changes. Third, pictures of faces and cars were presented at two orientations, in an ABX simultaneous matching task. While both patients showed small effects of inversion for cars in the normal range, they both showed significantly decreased inversion effects for faces. Finally, PS had to identify personally familiar faces and did not show any advantage for the upright orientation, in contrast with two controls familiar with the faces.

Overall, these results indicate that the differential processing of upright and inverted faces is affected following prosopagnosia, reinforcing the view that a key aspect of the impairment in acquired prosopagnosia lies in the inability to form an individual holistic facial representation.

23.424 **Nonlinear relationship between holistic processing of individual faces and picture-plane rotation: evidence from the face composite illusion**

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It is well known that the integration of facial features into a global/holistic representation is dramatically disrupted by picture-plane inversion. To investigate the nature of this observation, we tested for the first time the so-called face composite effect at various angles of rotation (0° to 180°, 7 angles). During an individual face matching task, subjects perceived two identical top halves of the same face as being slightly different (increase of error rates and RTs) when they were aligned with different bottom parts. This face composite illusion was equally strong for stimuli presented at 0° until 60° rotation, then fell off dramatically at 90° and remained stable until complete inversion of the stimulus. This non-linear relationship between orientation and holistic processing supports the view that inversion affects face processing qualitatively. Most importantly, it rules out the hypothesis that misoriented faces are perceptually realigned by means of linear rotation mechanisms independent of internal representations derived from experience. Altogether, these observations suggest that a substantial part of the face inversion effect is accounted for by the inability to apply an experience-derived holistic representation to an incoming visual face stimulus that it is flipped horizontally or beyond that orientation.

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URL: http://www.nefy.ucl.ac.be/Face_Categorisation_Lab.htm

23.425 **Independent Discrimination of Left/Right and Up/Down Head Orientations**

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The great majority of head and face discrimination studies have utilized either frontal or left/right rotated views of the head, while virtually none have examined the up/down direction or interactions between these two dimensions. A principal component (PC) analysis of head shapes defined relative to the bridge of the nose suggests that just three components can encode head shape across ±40° horizontally and ±20° vertically. Furthermore, these PCs suggest that horizontal and vertical head orientations may be represented orthogonally.

To test these hypotheses, discrimination thresholds for head orientation were measured for left/right discrimination among head shapes that were either oriented up, frontal, or down in the vertical dimension. Thresholds were found to be independent of vertical orientation. A control experiment randomized the vertical orientation from trial to trial and showed that left/right orientation discrimination was unaffected. An analogous result was obtained for discrimination of head orientation in the up/down direction with randomization across left/right orientations. Thus, discrimination of vertical head orientations is independent of horizontal head orientation, a result consistent with the PC analysis.

In further studies we are using head orientation aftereffects following adaptation (Fang & He, Neuron, 45, 7930800, 2005) to characterize receptive fields responsible for the representation of left/right and up/down head orientations. These results imply that the visual system can estimate head orientation independently in two dimensions, and this may greatly simplify the process of individual face encoding and recognition.

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23.426 **Representations of facial identity over changes in viewpoint**

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Neuroimaging studies have established ventral temporal (VT) cortex as a brain region involved in human face processing. To be useful for face recognition, neural representations must operate robustly over changes in three-dimensional viewpoint. We carried out an fMRI experiment to examine the brain response activations for facial identities as they varied across viewpoints, and for viewpoint when facial identity varied. Five participants were scanned while performing a one-back task on faces presented in identity-constant blocks (faces varied in viewpoint) and in viewpoint-constant blocks (faces varied in identity). The stimuli consisted of four male faces viewed from four viewpoints ranging from the frontal (0 degrees) to the profile (90 degrees) in increments of 30 degrees. The four identities included two face-"anti-face" fairs (cf., Leopold et al., 1999), which were created to be maximally dissimilar from each other. We applied a pattern-based classifier to the task of discriminating brain response patterns for individual facial identities and viewpoints. Voxels used for the classifier were selected from VT brain regions found to be responsive to faces in a standard localizer scan session. The classifier was a linear discriminant analysis that operated on a representation of the scans projected onto their principal components. For each participant, classifiers were applied to the task of discriminating all possible pairs of identities and all possible pairs of viewpoints. Within the individual participants, moderate but above chance discrimination levels were found for facial identities and viewpoints, although discrimination patterns were not entirely uniform across the participants. These results suggest that it may be possible to apply pattern classification techniques to the complex task of discriminating the subtle neural codes involved in face representations.

23.427 **The effect of training on the recognition of faces across changes in viewpoint**

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Recognizing a face from a novel viewpoint requires processing the structural properties of the face that are reliable cues to identity and view-invariant. One such property may be second-order relations (e.g., spacing between eyes and mouth). In Experiment 1, we investigated whether 10-year-old children's and adults' recognition of faces across changes in viewpoint could be improved through training, and whether training results were correlated with sensitivity to second-order relations. Over two one-hour sessions 10-year-olds and adults (n = 10) were trained to make same/different judgments about facial identity between faces seen from different viewpoints. Consistent with previous studies (e.g. Mondloch et al., 2003), 10-year-olds were worse overall than adults. However, both groups improved at a similar rate during training, with 10-year-olds' final accuracy being comparable to adults' accuracy prior to training. There was no correlation between performance on the viewpoint training task and sensitivity to second-order relations either before or after training in either age group, perhaps because observers may have learned to match specific views of the training faces and not a general skill. In Experiment 2, we investigated whether training adults (n = 12) would be more effective if novel faces were introduced as training progressed over the two-day period. Improvement in matching faces across changes in viewpoint transferred from the first 7 facial identities to the next 7 identities, a result suggesting that training improved a general skill in view-invariant recognition. However, improvement failed to transfer to the third set of 7 identities and was not correlated with sensitivity to second-order relations, results suggesting that the learning also involved the linking of view-specific exemplars. Collectively, the results indicate that improvements in recognizing faces across changes in viewpoint involve both view-specific and view-independent processes, and are not directly related to sensitivity to second-order relations.

23.428 **The First Spike Counts: A Model for STDP Learning Pose Specific Representations for Estimating View Direction**

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Perceptual investigations demonstrate that a person's view direction can be reliably estimated on the basis of perceived head orientation and eye gaze (Langton et al.,TICS 4,2000). VanRullen & Thorpe (Vision Res.42,2002) proposed a feedforward model which employs neural rank order coding to achieve sparse representations of objects (faces). The unsupervised development of a neural face representation can be modeled by utilizing STDP learning (Masquelier & Thorpe,PLoS Comp. Biol. 3,2007). STDP learning is a highly evidenced mechanism of Hebbian learning based on the temporal order of spike generation of the pre- and postsynaptic neuron at a particular synapse (Bi & Poo,J.Neurosci.18,1998). We applied a model of STDP to automatically learn different face poses.

As input we sequentially probed the model by images of faces in different pose conditions. Neural activities were generated by convolving the image by differently scaled orientation selective Gabor filters which responses subsequently undergo shunting competition. Activations (resembling the spike rate of neurons) were converted into spike firing latencies (temporal spike order) followed by lateral inhibition. Further processing is limited to a maximum number of neurons that fire early. The spike times were then transferred to a category layer where prototype neurons are dynamically allocated and their synaptic weights are trained by applying the STDP learning rule.We demonstrate that the model automatically finds an appropriate number of output neurons depending on the statistical regularities of the input patterns. Furthermore, we show that these neurons become selective to different face poses that were repeatedly given as input to the model.

In conclusion, rank order coding in combination with STDP learning is a very efficient and rapid scheme that can be used to robustly learn intermediate level representations of face patterns, such as face poses. The resulting sparse representation of prototypes enables reliable head pose estimates in mutual visual communication.

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23.429 **View-dependent Adaptation to Familiar and Unfamiliar Faces in the Human Brain**

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People are extremely proficient at recognizing faces that are familiar to them, but are much worse at identifying unfamiliar faces. We used fMR-adaptation to ask whether this difference in recognition might be reflected in the relative view-dependence of face-selective regions in the brain. Differences in the response to faces and non-face objects were used to define face-selective regions in 20 subjects. We compared the response in each ROI to familiar and unfamiliar faces in 3 experimental conditions: 1) same identity, same image (same/same); 2) same identity, different image (same/different); 3) different identity, different image (different/different). Although the low-level image variation between the same/different and different/different conditions was comparable, these manipulations had no effect on the recognition of familiar faces. We predicted that, if the neural representation of faces is view-independent, adaptation to repeated images of the same face should be apparent even when they are shown from different views. Each experimental condition was repeated 8 times in a counterbalanced block design, with each block containing 10 images presented at a rate of 1/sec. We found a reduced response (adaptation) to the same/same condition compared to the different/different condition for both familiar and unfamiliar faces in the fusiform face area (FFA), but not in the superior temporal sulcus (STS). However, there was no significant difference in the response to the same/different and different/different conditions for familiar or unfamiliar faces. A whole-brain analysis showed a distributed pattern of view-dependent adaptation (same/same <different/different) that extended beyond the face-selective areas, including other regions of the ventral visual stream and a region in the right inferior frontal lobe. However, this analysis failed to reveal any regions showing significant view-independent adaptation (same/different <different/different). These results suggest that structural information about faces is represented in a distributed network using a view-dependent neural code.

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23.430 **A single holistic representation of spacing and feature shape in faces**

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Background. A common view is that spacing information in faces (i.e., distance between centres of the major feature) is coded differently from local feature information (e.g., shape or colour of eyes), with only the former being considered configural. Classically, this view was supported by findings that, while sensitivity to spacing changes is substantially impaired by inversion of the face, inversion had little or no effect on perception of feature changes. Method. We reviewed the 17 published studies relevant to this claim. Results. The size of the feature inversion effect varies substantially across studies. Several studies show very large features inversion effects – both relative to the response scale (i.e., independent of spacing inversion effects) and relative to spacing inversion effects in the same study. We evaluated various proposals that have been made to explain discrepancies across studies. We found patterns of feature inversion effects could not be explained by task, by whether feature trials were blocked or mixed with spacing trials, or by whether performance level for upright was matched to that for spacing. We found a strong relationship between the size of the feature inversion effect and the extent to which the feature change includes colour/brightness: dramatic colour-only changes produce no inversion effect while shape-only changes produce large inversion effects. We also found evidence of stimulus set size effects: for moderate colour changes, inversion effects can occur with large stimulus sets but are absent with small sets (e.g., the "Jane" faces). Overall, feature tasks produce no inversion effect only when the task can be easily solved by attention to nonface information. Conclusions. A holistic representation of face identity codes both spacing-between-blobs and exact feature shape. We review fMRI evidence suggesting the location of this convergent representation might be the Fusiform Face Area.

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23.431 **The role of external head contours in face processing in the human occipitotemporal cortex**

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While a human observer can easily recognize a face with only internal face features, such as eyes, noses or mouths, the presence of an external head contour can affect the face recognition greatly. We used fMRI technique and the well-known face inversion effect, or impaired recognition performance on upside down faces, to investigate how the human occipitotemporal cortex processes internal and external face information.

BOLD activations were collected from eight observers in a 3T Bruker scanner (EPI, TR=3s, TE=40ms) with block design runs (epoch length: 18s, 6 cycles per run). We used seven types of face stimuli: whole faces with both internal features and external head contours, external contour-only and internal feature-only and their inverted version, and a face with upright internal features but an inverted external contour. The fusiform and the occipital face areas (FFA and OFA respectively) were first identified by contrasting BOLD activation to upright faces and their phase scrambled versions.

Contrasted with their own inverted versions, the whole faces showed greater activation in both the OFA and FFA. The internal feature-only produced greater activation than their inverted counterparts in the OFA and posterior the FFA while the external contour-only produced greater activation in the anterior FFA than their inverted versions. The whole faces showed greater activations in the FFA than internal feature only. The differential activations were observed both in the FFA and the when contrasted between the whole faces and the faces with only external contour inverted. The result suggests that face processing in the OFA mainly utilizes information from internal features. The external contour information plays a significant role in face processing only in the FFA.

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23.432 **The Fusiform Face Area spontaneously codes spatial relations in faces**

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Neuroimaging studies implicate the fusiform face area (FFA) in face individuation, but what computations allow it to represent distinct identities? Behavioral research indicates that face individuation relies on sensitivity to subtle spatial relations in faces, but no studies have shown that face-selective cortex represents this information. We used a sensitive fMR-adaptation paradigm to demonstrate that the FFA spontaneously codes spatial relations in faces. Participants (N = 16) viewed four kinds of adaptation blocks: relational blocks in which a single upright face was shown with various feature spacings, inverted blocks in which a single inverted face was shown with various feature spacings, same blocks in which a single upright face was presented repeatedly and different blocks in which a different upright face was shown on each trial. The FFA was identified using a standard localizer task. The FFA responded more strongly to a single face presented with various feature spacings (relational blocks) than to repeated presentations of an identical face (same blocks). Moreover the response to spacing variations was as strong as the response to a series of distinct identities (different). There were no interactions with hemisphere. These results suggest that the FFA can use variations in spatial relations to individuate faces. This sensitivity to spatial relations may also help the FFA integrate features into holistic face representations. We found little sensitivity of the FFA to spatial relations in inverted faces (inverted blocks). The orientation-selectivity is consistent with behavioral evidence that spatial relations are difficult to code in inverted faces, making the coding of upright and inverted faces qualitatively distinct, and with neuroimaging evidence that the FFA is the locus of behavioral face-inversion effects.

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Multisensory Processing: Low Level

23.433 **Position discrimination of auditory stimuli in early visual cortex**

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The traditionally accepted unimodal nature of primary visual cortex has been challenged by functional and anatomical evidence of early visual neurons receiving nonvisual input in cats (auditory: Morrell, 1972; Fishman and Michael, 1973), primates (auditory: Falchier et al., 2002), and blind (tactile: Sadato et al., 1996; Cohen et al., 1997; auditory: Gougoux et al., 2005) and sighted (tactile: Zangaladze et al., 1999; Merabet et al., 2004) humans. The present study measured the precision of auditory spatial coding in early visual cortex. In an fMRI experiment, subjects performed a 5AFC spatial discrimination task in which they were presented with spatially specific auditory stimuli in 5 locations across a range of 20 degrees in the frontal plane. The task was to indicate via button press the apparent location of each stimulus. We found that early visual cortex (V1/V2) as well as occipito-parietal regions (cuneus/precuneus) contained regions that discriminated between the spatial locations of the stimuli, i.e., spatially closer stimuli elicited more highly correlated activity than did more separated stimuli. Importantly, these regions often exhibited greater selectivity for the perceived, rather than physical, stimulus position, as calculated from incorrect responses. These results suggest that top-down connections to early visual areas carry spatial information from higher-order auditory cortical areas.

23.434 **The locus of auditory-visual integration in the human brain**

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Purpose and methods: In order to investigate spatio-temporal profiles of auditory visual integration in human brain, we measured human MagnetoEncepharoGram (MEG) activities when auditory pip signals and visual Gabor signals were presented either (1) simultaneously or (2) asynchronously with the time delay of +/- 300ms with the auditory duration of 30ms and visual duration of 100ms. These were compared with MEG signals with only auditory or visual stimulations.

Results: We found a significant increase of MEG activities around SOA of 160ms in the posterior inferotemoporal visual area when auditory and visual signals were presented simultaneously without time delay. The magnitude of the activities significantly increased compared with that of visual only, or auditory only conditions. Such activities disappeared with the time delay of +/- 300ms. Furthermore, the evoked response of SOA around 100ms enhanced possibly due to rapid interaction from visual to auditory streams.

Discussion: These results indicate that visual and auditory signals were integrated at the high level visual area of IT when they are presented simultaneously with relatively fast time course, demonstrating non-linear integration process of auditory visual signals in the human brain.

URL: http://www-karc.nict.go.jp/d333/english/kenkyu_in/tanaka/index.html

23.435 **Auditory-visual interactions in a patient with bilateral occipital lobe lesions**

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MC is a 38-yr old right-handed female who, apart from some sparing in rostral calcarine cortex, has suffered extensive bilateral hypoxic ischemic cortical damage encompassing her occipital cortices extending dorsally into the temporal lobe bilaterally and the right posterior parietal cortex. Conventional perimetry demonstrated some preserved visual motion perception in her upper left quadrant, but no detection of static stimuli. Despite the extensive damage in visual areas, MC's auditory system is intact. Accordingly, MC was tested on several studies in order better understand the interaction between auditory and visual perception. 1) For instance, although MC was better than chance at indicating whether a silent video contained a face that was talking or nodding (i.e., she appeared to detect mouth motion), this information did not influence her auditory perceptual identity of spoken words (i.e., no McGurk effect), nor did it help her identify speech sounds presented in background noise. 2) Interestingly, in an auditory noise burst localization task, visual transients presented in MC's upper right visual quadrant were associated with slower response times to sounds relative to when no transients were present. In contrast, visual transients presented in her upper left visual quadrant were associated with faster response times relative to when no transients were present. 3) Finally, although MC showed a marked inability to perceive material properties of objects (e.g., textures) through vision, she had no problem carrying out a similar auditory task that involved discriminating dynamic sounds of various manipulated materials (e.g., crumpling paper, plastic, styrofoam, or aluminum foil) from scrambled versions of these sounds as well as from non-verbal human vocalizations. Functional magnetic resonance imaging (fMRI) in this study demonstrated that her material-properties auditory ability relied on regions in the right parahippocampus and posterior middle temporal areas bilaterally.

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23.436 **Cross-modal selective attention effects on steady-state visual evoked potentials (SSVEPs)**

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Our previous results revealed that spatial attention induced synchronization-based response gain in SSVEPs. In that study, the attended and competing stimuli were visual. Here, we investigated whether attentional response gain generalized to cross-modal conditions. Auditory and visual stimuli were presented, and at the beginning of each trial the modality to be attended was indicated. Observers either attempted to detect a brief color change (120 ms) in the visual modality or a brief sound intensity change (100 ms) in the auditory modality. These targets occurred on 10% of the trials. The intensity of the competing auditory stimulus was perceptually matched to that of the visual stimulus, which was a circular grating flickered (16.7 Hz) at the center of the screen (2.7 seconds/trial). We monitored the SSVEPs induced by this stimulus. There were four experimental conditions: attend visual/ignore auditory, ignore visual/attend auditory, attend visual presented alone, or attend auditory presented alone (making auditory and visual attention equally frequent). SSVEPs were analyzed only for non-target trials. To find evidence of attentional response gain, we used three contrasts: near threshold, intermediate, and saturation level. In cross-modal conditions, we found evidence consistent with response gain, in that attentional modulation of SSVEPs was stronger for higher contrast stimuli. SSVEPs for attended visual stimuli were comparable with or without the competing auditory stimulus. In a second experiment, we quantitatively examined cross-modal interference by pairing the highest-contrast visual stimulus with sounds of varying intensities. Overall, SSVEPs diminished as a function of increasing auditory intensity, demonstrating an intensity-dependent cross-modal interference. In summary, the auditory stimulus interfered with visual processing in proportion to its intensity, and visually directed attention boosted SSVEPs consistent with response gain.

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23.437 **Audiovisual multisensory facilitation: A fresh look at neural coactivation and inverse effectiveness**

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Four experiments examined temporal properties of audiovisual multisensory integration. Experiment 1 measured sensitivity (d') and reaction time (RT) to 100 ms auditory (A) (1 KHz tone) and visual (V) stimuli (1 c/d Gabor), and to audiovisual (AV) combinations with stimulus onset asynchronies (SOAs) from -100 to +200 ms. Over the course of 100 trials A and V unisensory stimulus intensity was titrated to ensure a criterion sensitivity (d' = 2). For RT, significant violations of Miller's inequality (implying neural coactivation) occurred only for simultaneous AV presentation (AV SOA = 0 ms). Experiments 2-4 were identical to Experiment 1 with the following exceptions. In Experiment 2, auditory stimulus intensity was adjusted to clamp performance in auditory-only trials at a d' = 2 while visual stimulus contrast was tripled to produce a visual sensitivity of d' > 4. Relative to Experiment 1 mean visual RT decreased by 99 ms, and AV SOAs producing neural coactivation expanded to include those for which the visual stimulus preceded the auditory stimulus by 60 ms. In Experiment 3, visual stimulus contrast was adjusted to clamp performance in visual-only trials at a d' = 2 while auditory stimulus intensity was tripled to produce an auditory sensitivity of d' > 4. Relative to Experiment 1 mean auditory RT decreased by 106 ms, and AV SOAs producing neural coactivation expanded to include those for which the auditory stimulus preceded the visual stimulus by 60 ms. In experiment 4 the intensity of both A and V stimuli were tripled. Although mean RT to both stimuli decreased by >100 ms relative to Experiment 1, neural coactivation occurred only for AV SOA=0 ms. Neural coactivation was, however, significantly greater than in Experiment 1. These results have implications for neural coactivation models and the generality of the inverse effectiveness rule.

23.438 **Learning associations between simple visual and auditory features**

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It has recently been shown that exposure to new visual features can lead to a strengthening of the representation of those features in adult humans (Falconbridge et al. VSS '07). Is this plasticity confined to features within visual modality or does it extend to crossmodal features? The aim of this study was to discover if passive exposure to novel auditory-visual feature correlations can lead to the learning of crossmodal features in human adult sensory system. METHODS: We performed two experiments. In each experiment, we exposed subjects to a visual feature that was coupled with an auditory feature during an exposure phase, and we tested the detection/discrimination of the visual feature in absence or presence of the auditory feature before and after the exposure. In both experiments, one visual feature (V1) was coupled with a specific tone (A1) and another visual feature (V2) was presented in silence. In Experiment 1, V1 and V2 corresponded to two sinusoidal gratings of orthogonal orientation and the task during test sessions was a 2IFC contrast detection task. In Experiment 2, the V1 and V2 corresponded to two orthogonal motion directions, and the task during test sessions was 2AFC motion discrimination. RESULTS: Exposure caused a relative improvement in visual performance for the exposed pairing V1A1 compared to V1, V2, and V2A1 conditions. Comparing d' and criterion for auditory-coupled conditions vs. silent conditions before and after exposure suggests that this learning is due to a change in sensitivity rather than a change in bias. CONCLUSIONS: These results suggest that auditory and visual stimuli are integrated at an early stage of visual processing, and that low-level AV features can be acquired even in adulthood. Exposure to a coupled auditory stimulus can facilitate detectability and discriminability of a visual stimulus, specific to the exposed feature pairing.

23.439 **Haptic movements enhance visual motion aftereffect**

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Purpose We perceive object movements though various modalities such as vision, audition and somatosensation, An important question is how motion signals from different modalities are integrated. The present study investigated the influence of haptic information provided by hand movements on visual motion perception measuring motion aftereffect (MAE). Methods A visual stimulus was a radial grating, which was rotated either by the observer's hand movement or by the hand movement data recorded in a previous session. In the former condition, the visual motion synchronized with the hand movements while it did not in the latter condition. In the adaptation with hand movements, observers rotated the arm of a haptic device with the right hand for 20 sec, and the signal from the device rotated the radial grating. The rotation of the radial grating was either in the same direction as the hand with the same speed as the hand, the opposite direction with the same speed, or the same direction with a different speed. In the adaptation without the hand movements, the radial grating was rotated using the position signal recorded in the adaptation with the hand movements. After the adaptation, a static radial grating was presented. Observers indicated the time of MAE disappearance by pressing a button. Results and discussion When the visual movements were the same speed and the same direction as the hand movements, MAE duration in the hand movement condition was longer than that in the no hand movement condition. When the visual movements were in the direction opposite to the hand movements, MAE duration in the hand movement condition was shorter than that in the no hand movement condition. Lengthening MAE duration by hand movements decreased with the increase of the difference in speeds between the visual and hand movements. These results suggest that haptic information influences visual motion perception.

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23.440 **Visual, tactile and visuo-tactile motion discrimination**

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We investigated visual and tactile motion perception by measuring velocity discrimination thresholds over a wide range of base velocities and spatial frequencies (0, 3.3, 5 & 10 c/deg). The stimuli used were physical wheels etched with a sinewave profile that could be seen and felt. Two similar wheels were simultaneously driven at specific velocities (either congruent or in conflict, in the same or opposite directions) by two independent, computer controlled, motors. Subject was presented with two separate intervals and required to discriminate in 2AFC interval contained the faster movement, using only visual, only tactile or bimodal information (viewing distance was maintained constant at 57 cm). Both bimodal and unimodal visual and tactile thresholds showed a characteristic "dipper function", with the minimum at a given "pedestal duration". The "dip" (indicating facilitation) occurred over the same velocity range (0.05 – 0.2 cm/sec) at all spatial frequencies and conditions. At detection levels we found no direction-specific facilitation for visual-tactile motion, but an overall improvement (about root two) in the bimodal detection and discrimination thresholds, that were well predicted by the maximum likelihood estimation model. Our results suggest that visual and tactile systems analyze motion with similar sensitivities, and information between them is integrated in an optimal manner.

23.441 **A sound can change four-dot masking**

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Purpose: A sound can temporally attract the perceived occurrence of a flash (temporal ventriloquism). Typically, this has been demonstrated in a visual temporal order judgement (TOJ) task where sensitivity about the order of two visual events (which came first?) is improved when the flashes are flanked by two task-irrelevant sounds. Here, we tested the generality of this finding by studying the consequences of irrelevant sounds in a visual task not involving explicit temporal order judgments.

Methods: A four-dot masking paradigm was used in which perception of a briefly displayed visual target is impaired if followed by four dots arranged in a square (mask). The amount of masking depends on the relative timing (SOA) between the target and the mask. We compared the masking function of a silent condition with ones in which one or two sounds were presented either before, at, or after the target and/or mask.

Results: Sounds presented ~100 ms before the target improved visual discrimination of the target if compared to the silent condition.

Conclusions: Temporal ventriloquism and/or general alerting effects by the sounds could be demonstrated in a task where visual temporal order is irrelevant.

23.442 **The Gestaltist's error revisited with sound**

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Rotation of a fan-like shape at a constant velocity is perceived as "pause-and-go" when the leaves are occluded behind those of a static fan (Petter, 1956). This phenomenon has been attributed to "the Gestaltist's error" (Kanisza, 1979) since only with perceptual grouping of the individual leaves into an object and assuming, like a Gestaltist, that object motion should be continuous even under occlusion will such a phenomenon be called an illusion. Inspired by this intriguing phenomenon (see our demo), we examined why the smooth motion becomes jerky and tested whether adding a sound will affect the motion perception. We manipulated the number of leaves and asked the participants to judge the smoothness of motion in a 2AFC with adaptive staircase procedure. The result showed that reducing the number of leaves enhanced motion smoothness. A collective object account is provided in which (1) the multiple leaves are perceived as multiple objects; (2) attention resource is required for an accurate interpolation of motion speed under occlusion but only for one object at a time; and (3) the moving leaves are treated as a collective object with common motion and thus the motion speeds of each are averaged. We tested this account by adding a sound with different pitch during the occlusion period. Higher threshold speed with sound than without it suggests that sound further disrupts motion smoothness because it attracts attention. Although the possibility of associative learning between jammed sound and slower speed of the fan cannot be excluded, it is not favored because it cannot explain the results of jerky motion with no sound and no effect of pitch on the motion smoothness judgment.

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23.443 **Visual cue influence on three-dimensional haptic angle discrimination**

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Multi-sensory feedback about the shape of objects provides information about their physical reality. This study tested how visual cues and simple haptic shape perception are integrated for three-dimensional angle discrimination. Participants explored a pair of two depth-rotated planes that joined to form a concave angle. A haptic device (Phantom Omni) made it possible for them to touch the virtual planes. As they moved an articulated arm with force-feedback, everything was loose until the location of the cursor coincided with that of the virtual plane. Then the arm stiffened up, although they could feel it slide around on the plane. The range of angles was from 45 to 135 degrees (in increments of 5 degrees). A two-alternative forced-choice task was used to indicate whether the angle was greater than or less than a right angle. The right angle was chosen because of its familiarity in everyday life. Two kinds of two-dimensional visual cues, a cursor location cue and a plane displacement cue, were manipulated. On a CRT display, the cursor location cue indicated the motion of the articulated arm, and the plane displacement cue was a main vertical line and some additional lines that indicated the location of the angle. The obtained data were fitted to a logistic function, and the discrimination threshold was estimated to be 86 degrees with the location cue and 101 degrees without the location cue, while the displacement cue was ineffective. The estimated angle difference was robust in the series of experiments with a variety of visual cues. This difference is considered to come from the integration of the 3D haptic plane and the 2D visual cue.

Saturday, May 10, 8:30 am - 12:30 pm Poster Session, Orchid Ballroom

Faces: Learning and Expertise
Faces: Lifespan Development
Visual Working Memory 1

Faces: Learning and Expertise

23.501 A noise x inversion paradigm reveals the nature of fingerprint expertise for latent print examiners in EEG and fMRI

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In two separate studies we address the nature of the development of expertise using two neuro-recording technologies, EEG and fMRI, which provides converging evidence for how expertise affects visual processing. Using the same tasks in both methodologies, we present both upright and inverted fingerprints and faces to latent print examiners and novices. Additionally we manipulate the stimuli by presenting them in either phase-shifted noise or no noise. In prior work, Busey and Vanderkolk (2005) showed that fingerprint experts show similar EEG latency patterns between upright and inverted faces and fingerprints. In addition, our previous research has also shown that the addition of noise to faces leads to an interaction between inversion and noise. Integrating these two paradigms leads to the presumption that the effects with noise and faces could extend to fingerprints in experts. In addition, findings in the literature showing similar patterns between faces and items of expertise also suggest the possibility for an interaction between expertise and stimulus type. In our particular experiment, electrophysiological results show a scale-invariant interaction between noise and inversion for faces at the N170: the amplitude ordering between upright and inverted faces reverses when faces are presented in noise. This same interaction is found for fingerprints, but only for latent print examiners. This suggests processing differences between experts and novices for this stimulus class. To provide an anatomical interpretation of this data, we discuss the similarities and differences between the fMRI and EEG data. Together the two sets of studies demonstrate the conditions in which noise and inversion interact and suggests that the development of expertise may involve external noise exclusion.

Busey, T.A. & Vanderkolk, J.R. (2005) Behavioral and electrophysiological evidence for configural processing in fingerprint experts. Vision Research, 45, 431-448.

23.502 Expertise and the width of the visual filter in fingerprint examiners

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A possible consequence of expertise could be a narrowing of the filter that is used to process visual information. To investigate this, we added band-pass filtered noise to faces and fingerprints to determine the range of spatial frequencies that are used during processing. Previous work by Tanskanen, Nasanen, Montez, Paallysaho, and Hari (2005) shows that mid-range spatial frequencies are used during face processing. We hypothesize that fingerprints may require a narrower range of spatial frequencies due to their fine spatial structure. During an XAB experiment, fingerprint experts and novices viewed a stimulus in noise and compared this against a clear target and distractor. The masking effectiveness of each of the seven noise bands describes the width of the visual filter used for each stimulus type in both accuracy and EEG measures. In the expert group, we found overall higher accuracy as well as a narrower filter for fingerprints. EEG data showed similar trends, although the estimation of filter width was noisier for the novice group due to their overall lower accuracy. A second experiment with novices confirmed the wider filter for fingerprints in the novice group. These results suggest that experts rely on a narrower subset of visual information that corresponds to the finer spatial structure of fingerprints. Both behavioral and EEG data for faces showed no differences in the width of the filter for either group, suggesting that broadly tuned filters are necessary for face processing. Thus one consequence of expertise may be the ability to exclude noise from a wider range of spatial frequency bands, and the EEG results suggest involvement of perceptual regions of the brain in this process.

Tanskanen T., Nasanen, R., Montez, T., Paallysaho, J., & Hari, R. (2005). Face recognition and cortical responses show similar sensitivity to noise spatial frequency. Cerebral Cortex, 15, 526-534.

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23.503 Are all types of expertise created equal? Effects of expertise on categorization and spatial frequency usage

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A widely held notion is that face and object expertise utilize the same sources of perceptual information. Although much is known about face expertise, the nature of the diagnostic information for object expertise and the stage in the visual processing hierarchy at which it is utilized are still unknown. To address this question, we compared performance and event related potentials (ERPs) of 15 car experts and 15 car novices performing a category verification task. The two groups categorized objects with which they had different levels of expertise (faces, cars, and airplanes) at basic and subordinate levels. To manipulate the information contained in the images we spatially-filtered them comparing performance and ERPs for broadband (BB) images and images that were either high- or low-pass filtered (HSF and LSF, respectively). In both groups, face subordinate categorization relied more on LSFs than on HSFs, while subordinate categorization of airplanes relied more on HSFs. Critically, the experts relied more on HSFs than on LSFs for subordinate car categorization. This pattern of spatial frequency (SF) usage in car expertise contrasts that found in face categorization. The N170, early face-selective ERP was modulated by expertise. In the experts' left hemisphere N170 amplitude in response to cars was equivalent to N170 amplitude to faces, both higher than to airplanes. In novices the N170 in response to cars was equivalent in response to airplanes, both smaller in amplitude than the N170 to faces. However, this effect did not interact with SF or categorization level. Overall, our findings suggest that opposite to some theories of visual expertise, the diagnostic information needed for expert car recognition is qualitatively different from face recognition. Furthermore, expert use of specific SF scales does not occur at the early perceptual stages reflected by the N170 and thus should be related to later post-perceptual processes.

23.504 Can expertise explain why face perception is sensitive to spatial frequency content?

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Biederman & Kalocsai (1997) proposed that differences between face and object recognition exist because the neural representation of faces, but not objects, retains low-level spatial frequency (SF) information extracted by early visual areas. They showed that individuals are better matching identical pairs of faces relative to complementary pairs (with opposite SF and orientation information) but perform equally well with identical and complementary pairs of chairs. Yue, Tjan & Biederman (2006) suggested that this face-specific effect is not due to expertise, since they failed to find increased sensitivity to SF content following training with novel objects. Because their training protocol may be insufficient in establishing any face-like effect, we used naturally occurring car expertise to reexamine this question. In E1, car experts and car novices matched sequentially presented faces and cars. Relative to the study image, the probe could be the same identity with either identical or complementary SF information, or a different identity. All observers showed sensitivity to SF manipulations for both faces and cars, suggesting that such sensitivity can be found with common objects. This effect was not modulated by car expertise. E2 used upright and inverted images to explore whether configural processing (stronger for upright than inverted faces) was the source of the effect. Car novices showed sensitivity to changes in SF content for upright and inverted faces, and cars. However, only faces showed a larger cost of changing SF content for upright images. Expertise does not appear to increase sensitivity to SF content, and configural processing is not sufficient to account for this effect. Indeed, even novice perception of inverted cars was sensitive to SF content. In addition, we conclude that short-term memory for common objects in novices does not solely depend on representations where SF information is absent, such as edge or volume-based descriptions.

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23.505 Prolonged visual experience in adulthood modulates perceptual face processes

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Faces processes require early and long-lasting visual experience and are finely tuned towards own-race and same-age faces in adults. Using the well-known composite face illusion as a marker of the integration of facial features (holistic face perception) we demonstrate here how prolonged visual experience with a specific face category (4- to 6-year-old children faces) alters the face perception system in adulthood. In line with the classical composite paradigm, we created composite stimuli of adult and children faces and asked 18 female preschoolers' teachers (children-face experts) with at least 1 full year of experience with children faces to match the top parts of pairs of either children or adult faces presented sequentially. Similarly to 18 additional female participants (children-face novices), experts were better and faster at matching 2 top parts when they were misaligned as opposed to aligned to distinct bottom parts. Most interestingly, when considering differential response times between aligned and misaligned conditions as a marker of holistic face perception, we found a significantly stronger composite face illusion for adult compared to children faces in novice participants, while it was of equal magnitude in experts. Moreover, the magnitude of the differential face composite illusion between adult and children faces was significantly correlated with the number of years that teachers experienced children faces. Consistent with previous evidence of visual plasticity in adulthood, these results demonstrate the impact of extensive visual experience with faces presenting differential morphological features than adult faces on face perceptual processes, even when the face processing system is fully matured. Moreover, visual experience affects perceptual processes qualitatively, the facial features being not only processed more efficiently but also more holistically for faces that are experienced extensively.

23.506 Transferring localized facial learning across all of face space

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To accomplish the representation of the vast number of known faces, Valentine (1991) proposed that the brain codes faces as points in a multidimensional face space, where the axes correspond to facial attributes. Later researchers (O'Toole, Abdi, Defenbacher, & Valentin, 1993; Wilson & Diasconescu, 2006) have suggested that the axes are formed by extracting the principal components (PC) from a population of faces. As this theory has taken hold, various properties of face space have been examined. For instance, Wilson (2006) showed that learning could have an effect on the properties of face space. Recognition thresholds were significantly better in the regions surrounding learned faces than they were in the regions surrounding novel faces. This study demonstrates a similar effect, wherein participants were shown faces that consistently varied along a particular dimension in face space. Differences between pre- and post-learning thresholds for other faces randomly scattered about face space confirmed that it is indeed possible to transfer increased perceptual discrimination abilities not just to nearby faces, but across all of face space.

Citations:

O'Toole, A. J., Abdi, H., Deffenbacher, K. A., & Valentin, D. (1993). Low-dimensional representation of faces in higher dimensions of the face space. Journal of the Optical Society of America, 10, 405–411.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. Quarterly Journal of Experimental Psychology, 43A, 161–204.

Wilson, Hugh R., Diaconescu, Andreea (2006). Learning alters local face space geometry. Vision Reasearch, 46, 4143-4151.

23.507 A test to explore the learning of multiple novel faces

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In the world, encoding and learning of faces does not occur in isolation. We are exposed to and need to learn multiple faces, including encoding and learning in the presence of other faces. We developed the Progressive Face Learning Test to characterize individual differences in learning multiple novel faces in a short period as well as the effect of interference from other faces learned on learning rates.The test starts with a single face to be learned, which after presentation, is to be identified from a choice of faces, containing the target face and numerous foils.The number of faces to be learned is progressively increased by adding a new face after testing all the faces presented in the previous round.Faces to be learned as well as foils were chosen to be of comparable subjective distinctiveness.The test was used to characterize and compare different aspects of learning of faces like overall performance, learning rates and rate of change of learning rates for individual faces as well as with progressively increasing number of faces. Comparisons were done between people who have normal face recognition ability, above normal face recognition ability ("super-recognizers") and below normal face recognition ability, including prosopagnosics.

23.508 Learning Faces: plasticity and the rehabilitation of congenital prosopagnosia

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In congenital prosopagnosia (CP), the anatomy and activation patterns in ventral occipital temporal cortex (VOTC) have been shown to be grossly normal (Hasson et al., 2003), though finer-grained analyses have demonstrated subtle functional and structural abnormalities in VOTC (Avidan et al., 2005; Behrmann et al., 2007). CP's mostly normal VOTC suggests that they possess an intact neural infrastructure for face processing that may, with the right type and amount of training, be able to support improvements in face identification. We designed a training task that targeted CPs deficits at spatially integrating multiple features. In particular, CPs were trained to integrate spatial information from two areas of the face, the mouth region and the eye region, in order to make a perceptual judgment. After 10 days of training 750 trials each day, several prosopagnosics significantly improved on the standardized Cambridge face memory and face perception tests as well as on memory and matching tasks using novel faces. These individuals also reported face recognition improvements in everyday life. Without any additional training, improvements on the face assessments lasted for a period of months before declining. In one successful case, we compared event-related potentials (ERP) and functional MRI (fMRI) before and after training. ERP results revealed that although the N170 component was not selective for faces before training, its selectivity after training was normal. fMRI demonstrated that training increased functional connectivity between VOTC face-selective regions (right occipital face area and right fusiform face area) and between face-selective regions and an extended network of regions. Together, these results demonstrate that intensive training can improve face identification abilities in CPs and this appears to occur through strengthening of normal neural mechanisms.

23.509 Predicting perceptual expertise from semantic knowledge : an indexed car test for prosopagnosic patients

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Studies of whether the prosopagnosic recognition impairment extends to other objects are confounded by variable expertise of people for other objects. Ideally, performance for non-face object recognition by these patients should be adjusted for premorbid expertise. We explored whether an index of semantic knowledge about cars could predict the performance of healthy subjects in a test of visual recognition of cars. 23 subjects perform three items involving all European, Asian and American cars made from 1950 to the present. First, they used Likert scales to rate their own knowledge of cars from each decade. Second, we administered a semantic questionnaire, asking them to provide the make (manufacturer's name) for all models made in this period. Third, we administered a perceptual test that showed the images of 150 cars, for which they were required to provide decade, model and make if possible. Half of the subjects performed the perceptual test before the semantic, and half the reverse.

Semantic knowledge correlated well with perceptual recognition of make (r=.85) and model (r=.90), but less so with recognition of decade of make (r = .30). A combined perceptual index of Make + 4*(Model) + 0.2*(Decade) yielded the optimum correlation of perceptual knowledge with semantic knowledge (r = .93). Self-ratings correlated moderately with semantic knowledge (r=.57), and with perceptual recognition of make (r=.59), model (r=.54), and decade of make (r = .33). A combined perceptual index of Make + 2.1*(Model) + 0.5*(Decade) yielded the optimum correlation of perceptual knowledge with self-rating (r = .61).

We conclude that semantic car knowledge but not self-rating is a reasonably accurate predictor of perceptual recognition of cars by make and model. A semantic index may be useful for adjusting perceptual recognition scores for premorbid expertise when studying patients with face or object recognition deficits.

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Faces: Lifespan Development

23.510 Perception of mother's face using near-infrared spectroscopy

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Near-infrared spectroscopy (NIRS) can detect the change in hemodynamic responses on infants' brain. Our previous studies used NIRS to measure the concentration of oxy-Hb and total-Hb on infants' face processing (Otsuka et al., 2007; Nakato et al., in press). These studies indicated that (1) the right hemisphere in the brain was activated when infants looked at the upright faces as compared the inverted faces, and (2) the developmental differences between 5- and 8-month-olds appeared in the presentation on the frontal views and the profile views. The results suggest that the right temporal area is dominant for the perception of faces in infants as well as adults.

Recognition of mother's face is important for infants to develop their social communication. Previous studies demonstrated that 3-month-olds could discriminate between their mother' face and stranger' face (Barrera and Maurer, 1981), and the ability of recognition of mother's face is developed by 6 months of the age (de Haan and Nelson, 1997).

We investigated the infants' brain activity on their mother's face presentation by NIRS. The participants were seven healthy 6- to 8-month-olds. The stimuli consisted of full color photo images of 5 vegetables, 5 unfamiliar female faces, and mother face. Infants looked each photo image passively as long as they could.

Our finding was that the data of total-Hb concentrations in the right temporal regions increased in the presentation of both mother's and unfamiliar faces. This result is consistent with the previous NIRS data (Otsuka et al., 2007; Nakato et al., in press) which showed the right temporal regions are involved in perception of faces in infants. And more interestingly, the concentration of total-Hb was greater activated for mother's face, as compared strangers' faces. This increased hemodynamic response implies the specific mechanism for mother's face recognition in infants' brain.

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23.511 Aftereffects reveal enhanced face-coding plasticity in young children

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Children's face recognition ability does not reach adult levels until adolescence, consistent with neurological evidence that change in the selectivity of face-responsive brain regions continues into early adolescence. Yet it is not clear whether this developmental change is qualitative, with children using different kinds of coding mechanisms (e.g., configural or feature-based coding), or quantitative, involving refinement of the mechanisms used by adults. Accumulating evidence suggests that even young children use several qualitatively similar mechanisms to adults. However, little is known about the development of adaptive norm-based coding mechanisms which are central to adult face coding. The face identity aftereffect, in which adaptation to a particular identity enhances recognition of a computationally opposite identity, provides a clear demonstration of adaptive norm-based coding in adults. Eight year old children show adult-like face-identity aftereffects suggesting that the use adaptive norm-based face coding mechanisms is mature by this age. However, it is not known when such mechanisms emerge. We sought evidence for adaptive norm-based coding in young children (4-6 years) using the face identity aftereffect. In a simplified paradigm, children and adults learned to recognise two individual faces (e.g. Dan & Jim) and weaker versions of these faces (reduced identity-strength). Participants then played a game in which 'robbers' (the two adapting faces) were caught by members of one of two teams (the two learned identities and weaker versions) and participants identified the team that caught the robber. Both children and adults showed significant aftereffects but children's aftereffects were significantly larger than adults'. These data suggest that young children use adaptive norm-based coding but show greater plasticity in their norms. Hence, adaptive norm-based coding of faces may emerge early but mature relatively slowly, consistent with quantitative refinement of adult-like mechanisms.

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23.512 The effects of losing an eye early in life on face and emotional expression processing

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There is a large body of research implicating structures within the right hemisphere (RH) are critical for face processing. Developmental research has shown that early in life retinal sensitivity is best in the nasal portion of the retina, which sends crossed projections from each eye to the opposite hemisphere. However, sensitivity in the temporal retina, which sends the uncrossed projections to ipsilateral cortex, develops closer to age two (Lewis & Maurer, 1990). Early visual experience is critical for normal maturation of visual function. People with early-onset congenital cataract have shown face processing deficits (Le Grand et al., 2003). Specifically, left-eye cataracts (RH deprivation), but not right-eye cataracts (left hemisphere deprivation) are related to impairments in face discrimination, showing that visual input to the RH is critical for establishing the neural substrates for face processing. Another ideal method for assessing the role of crossed connections in developing RH structures required for face processing is studying the effects of removing one eye (enucleation) shortly after birth, disconnecting that eye from the brain. As a result, left eye enucleation early in life eliminates input to the RH. We tested individuals with either left or right eye enucleation compared to binocularly and monocularly viewing controls on face discrimination and emotional expression recognition tasks. This included tests of configural, featural, contour and composite face discrimination and intensity of emotional expression recognition. Unlike congenital cataract, left-eye enucleation does not appear to disrupt face discrimination or emotional expression discrimination. Previous research has shown that unilateral enucleation actually facilitates some aspects of spatial vision compared to controls (e.g. Steeves et al., 2004). It is possible that any enhancement in spatial vision in one-eyed observers reverses potential face-processing deficits in these observers with early visual deprivation.

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23.513 A feature story: Similarities among adults, 10-year-olds and cataract-reversal patients in face discrimination

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Adults' expertise in face recognition has been related to their sensitivity to two cues to facial identity—the shape of individual features and the spacing among them. In previous studies we created 8 new versions of a single face: 4 differed from the original only in the spacing of features and 4 differed only in the shape of the eyes and mouth. Results for this feature set indicated little impairment by inversion (Mondloch et al., 2002), adult-like accuracy by 10-years of age (Mondloch et al., 2002) and sparing after a history of early visual deprivation from bilateral congenital cataract (Le Grand et al., 2001, 2003). However, these patterns might have resulted from the inadvertent choice of easily discriminated features, as suggested indirectly by adults' higher accuracy for upright faces in the feature set (M=.89) compared to the spacing set (M=.82). To address this issue we created 20 featural versions of a single face that were then paired to give 60 trials with different faces, intermixed among 60 trials with same faces. Adults' (n=24) accuracy in making same/different judgments was high across all pairings

(M = .91) and did not differ as a function of orientation (p > .20). Furthermore, both 10-year-olds (n=24) and patients treated for bilateral congenital cataract (n=8) were as accurate as visually normal adults (all ps > .20). This pattern held even for the six pairings for which adults' accuracy was less than .85. We conclude that adults are very sensitive to featural differences, that this sensitivity develops by 10 years of age and that sensitivity to features does not depend on either face orientation or visual input during the first few weeks of life.

23.514 Face feature processing in children: What develops and what does not?

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The present study examines children's relative use of internal versus external face regions, as well as their relative use of individual internal features (i.e., eyes, nose, mouth) in their recognition of familiar faces. Children were presented with pictures of their classmates showing: i) the entire face, ii) the outer face (i.e., contour, hair, forehead, and ears), iii) the inner face (i.e., eyebrows, eyes, nose, mouth, cheeks, chin), iv) the eyes, v) the nose, or vi) the mouth. Photographs were sequentially presented in a different random order across participants except for the whole face photographs which were always presented last. Children were asked to identify the child in each photograph. The 4-year-olds (n = 48), 8-year-olds (n = 50), and 14-year-olds (n = 39) who participated had known their respective classmates for only 1 year.

One-sample t-tests (2-tailed) showed that all age groups were above chance in their recognition of whole faces, inner faces, outer faces, eyes, and mouths (p values <.001). However, only 14-year-olds were above chance at recognizing noses (p <.001). A 2 (inner versus outer face) x 2 (stimulus gender) x 2 (participant gender) x 3 (participant age) ANOVA showed that all age groups demonstrated an inner-face advantage in their recognition of familiar peers. A 2 (stimulus gender) x 2 (participant gender) x 3 (eyes, nose, mouth) x 3 (participant age) ANOVA also showed that all age groups were better at recognizing eyes relative to their recognition of noses and mouths. There was also a cross-gender effect at 14 years, with boys showing better recognition of male over female features and girls showing better recognition of female over male features (p values <.05). Main effects of age also showed generally better recognition of inner/outer faces and individual internal features with age.

23.515 Age-related differences in processing capacity for faces

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The ability to recognize a face is a skill that improves with age. There is evidence that these gradual improvements in performance are quantitative rather than qualitative, and have been interpreted as an increase in processing capacity (Itier & Taylor, 2004). We report results from a set of experiments designed to apply a precise, theoretically-motivated measure of capacity (Townsend & Nozawa, 1995) to this developmental question. The first step was to establish that these precise measures of processing capacity could be used successfully in developmental investigations since they had only been used in adult studies. More specifically, Experiment 1 addressed two important questions: (a) whether children could complete the large number of trials needed to effectively use these capacity measures; and (b) whether greater variability of children's response times would prevent clear inferences from being made about changes in processing capacity. To answer these questions we tested children and adults on a redundant target task similar to one implemented by Townsend and Nozawa (1995). To keep the experiment interesting for children, we told participants a story and included story-related feedback after each trial. Experiment 1 results replicated Townsend and Nozawa (1995) for adults, and demonstrated the feasibility of the experimental approach and the intepretability of the resulting data. The purpose of Experiment 2 was to use these measures to test the hypothesis that there are age-related changes in the capacity to process face information, specifically changes in configural and featural information. Taken together, this work suggests (a) precise measures of processing capacity are available to use in studies of children (b) a more precise and theoretically-driven account for age-related changes in the capacity to process faces was possible using these measures.

23.516 Childhood improvements in face performance result from general cognitive development not changes in face perception: Evidence from faces versus objects, inversion and implicit memory

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Despite the remarkable face processing abilities observed in infants, performance on face perception and memory tasks improves across childhood and into adolescence and fMRI reveals late changes in face-specific areas. The important question for understanding the developmental origins of face processing is: Why does performance on face tasks improve with age? There are two possible explanations: (1) the 'special' aspect of face perception (holistic processing) is developing due to extended experience with faces (face specific perceptual development theory) or (2) the improvement seen on face tasks is due entirely to the development of general cognitive factors (general cognitive development theory). Previous studies attempting to differentiate these two theories have suffered methodological issues (e.g., baseline differences across age groups, poorly matched comparison object class, differences in task difficulty across conditions). The present study presents converging evidence from three independent approaches. Experiment 1 showed recognition memory increased at the same rate for faces and a matched object class (Labrador dogs) from 5 years to adulthood. Experiment 2 showed there was no change the size of the disproportionate inversion effect on recognition memory for faces versus Labrador dogs between 7-year-olds and adults. Experiment 3 showed there was no change in implicit memory performance for unfamiliar faces between 5-6 years, 10-11 years and adults despite strong development of explicit memory. Taken together all three experiments strongly support the general cognitive development theory, and argue there is no development in face perception between early childhood and adulthood.

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23.517 Face Inversion Effects in Infants are Driven More by High, Than Low, Spatial Frequencies

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Background: To investigate the mechanisms underlying development of face processing in infants, we used a contrast threshold paradigm to measure face inversion effects (FIEs) for "low" vs. "high" spatial frequency (SF)-filtered faces, with the notion that "low" and "high" SFs tap different visual mechanisms.

Methods: Using forced-choice preferential looking, we obtained contrast thresholds for "low" and "high" SF-filtered faces, for both "upright" and "inverted" images (4 stimulus types per subject). For each age tested, the "low" and "high" SF cutoffs were determined based on the published peaks in contrast sensitivity functions. (For example, for four-month-olds, whose peak is near 0.4 c/deg, "low" was <0.3 and "high" was > 0.5 c/deg.) Face stimuli were 10.8 degrees wide, presented 13.3 degrees to the left or right of monitor center, at one of five contrasts (6.13% - 95%). For each subject, contrast thresholds were obtained for each of the four stimulus types, and a threshold ratio was calculated: Thr-inverted/Thr-upright, separately for "low" and "high" SF-filtered faces. Values greater than 1.0 indicate a face inversion effect (FIE), i.e., lower thresholds (greater sensitivity) for "upright" faces.

Results: Data from four-month-olds show a significant FIE for "high" SF-filtered faces (ratio=1.91, p=0.013), but not "low" SF-filtered faces (ratio=1.10, p=NS).

Conclusions: The mechanisms underlying FIEs in infants (i.e., greater sensitivity to upright faces) appear to be selective for high spatial frequencies. The discrepancy with previous findings suggesting that infant face processing relies more on low spatial frequencies (de Heering et al. 2007) may be explained by proposing that: 1) previous studies did not control for detectability of "low" vs. "high" SFs (i.e., the low SF faces may have simply been more detectable), or 2) reliance on "low" vs. "high" SFs may depend on the nature of the face processing measure, which differs between studies.

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23.518 Children's Sensitivity to Configural Cues in Faces Undergoing Rotational Motion

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The capacity to use configural information, along with local featural cues, is theorized to underlie adults' expertise in processing faces in an upright orientation (Diamond, Carey & Woods, 1980). That is, immature face processing is restricted to local featural information (i.e., eye shape and color), while sophisticated face processing also utilizes configural cues (i.e., distance between the eyes). Mondloch et al. (2004) presented a discrimination task to eight year-olds and adults in which faces, both upright and inverted, differed in either the spacing among local features or the appearance of the local features themselves. They found that the children were as sensitive as adults to featural differences among faces, but their ability to detect spacing differences was not as strong as adults'.

The aim of the current study was to determine whether adding rotational motion to the stimuli during encoding would facilitate configural processing in children. Because the use of motion cues is thought to be fundamental to early three-dimensional representation (Kellman, 1984), we predicted that motion would benefit children in the Mondloch et al. (2004) task, specifically in detecting spacing differences. The encoding condition varied among participants: while some saw still views of the faces during the learning phase, others saw laterally rotating faces. In both age groups, a greater inversion effect was obtained for pairs that differed spatially than those that differed featurally, suggesting that children at least as young as eight years old are able to use configural processing for faces. Contrary to predictions, while motion was beneficial to adults' performance, it was detrimental to children's performance. We are currently investigating whether these results reflect a general inability of children to extract facial form from motion efficiently, or if aspects of the specific task constrained their performance.

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23.519 Holistic Face Processing in Infants using Mooney Faces

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Previous research has shown that infants demonstrate both featural and configural processing of upright faces. However, these studies used face images with easily identifiable features and parts. Bottom-up image segmentation and feature-based strategies could therefore contribute to the perception of these faces, in addition to configural processes. The purpose of the present experiment was to provide a direct test of holistic face processing in infants using Mooney face stimuli (Mooney, 1957). Mooney photographs are two-toned faces (including cast shadow information) that lack individual features and therefore can only be recognized as a face using holistic processing. Bottom-up image segmentation and feature-based parsing operations cannot operate on Mooney faces; to find any facial feature, such as an eye or a nose, one must first identify the image as a face. On each trial, two identical Mooney faces were presented side by side at 2 degrees eccentricity from fixation, one in the upright and one in the inverted orientation, for two seconds. If infants process upright faces holistically, they should preferentially look at the upright rather than the inverted Mooney face. Duration of looking toward the upright Mooney face was divided by the total duration of looking toward both face patterns to obtain a visual preference score. The results revealed that infants preferred the upright Mooney face significantly greater than the chance level, suggesting that infants are able to use purely holistic processing to identify upright faces.

23.520 Age-related changes in face processing

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Older adults show compromised face recognition. One reason may be that ageing results in changes in the ability to encode configural information (e.g, the spatial relations among parts of a face). This possibility was investigated in a bizarreness-rating paradigm. Using a scale from 1(normal) to 7 (bizarre), participants rated normal unaltered faces, and faces that had undergone changes to either spatial-relational properties (eyes and mouth inverted) or component properties (eyes whitened or teeth blackened), presented in different orientations. For unaltered and component-distortion faces, bizarreness ratings increased linearly as orientation increased from 0o to 180o, and did not differ with age. For spatially distorted faces, a number of significant age-related differences were observed. All participants' bizarreness ratings decreased with increasing departures from upright and showed a discontinuity in the function relating orientation and bizarreness between 90o and 120o. However, older adults differed from younger adults in rating spatially distorted faces as less bizarre across all orientations, and this difference was significantly greater in the post-continuity relative to the pre-discontinuity portion of the rating curve. Furthermore, in contrast to younger adults, older adults' ratings of spatially distorted faces and unaltered faces at 180 degrees did not differ significantly. These results suggest that age may bring decreased sensitivity to holistic and local configural information in faces.

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Visual Working Memory 1

23.521 Interactions between visual short term memory and visuospatial attention

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A number of researchers have proposed overlapping visual short term memory (VSTM) and spatial attention processes (Awh and Jonides 2001; Mayer 2007). We investigated the extent to which visual spatial attention and visual short term memory rely on dissociable mechanisms (Oh & Kim 2004; Woodman & Luck 2004; Fougnie & Marois 2006) by asking subjects to perform a standard VSTM task (Pashler 1988; Luck & Vogel 1997) in the presence or absence of a rapid serial visual presentation task (RSVP) at fixation. Importantly, the two tasks did not overlap spatially. When the RSVP task was presented during the maintenance phase of the VSTM task, subjects' capacity on the VSTM task was decreased by approximately one item. To further investigate the interaction between VSTM and visual spatial attention, we varied the onset of the RSVP task relative to the onset of the sample display. When the RSVP task was presented prior to the VSTM task, subjects' VSTM performance showed no impairment. When the RSVP task was presented during the maintenance phase, performance decreased. When the RSVP task overlapped or was immediately following the sample presentation, subjects' performance further decreased. Our results suggest that spatial attention is important for the encoding and maintenance of visual short term memory, and that attention is likely used after the sample display to further encode and/or maintain item identities. Although VSTM and visiospatial attention may utilize similar resources, subjects are still able to perform both tasks at once, implying a separation of the systems.

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23.522 The indirect role of saliency in selection for short-term visual memory

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The bottom-up processes that guide visual attention for the first few fixations following the presentation of a novel scene are reasonably well understood (Itti & Koch, 2001), but the processes guiding short term memory storage are not. Here we test whether a process responsible for directing early attention -- visual saliency -- also plays a role in short term memory storage. Seventeen subjects were shown a natural scene containing ten objects (VanRullen & Koch, 2002) for one second while having their eye movements recorded. They were then asked to recall as many objects as possible from an array of twenty object icons. We performed logistic regression to find that the best predictors of whether an object was recalled are relative eye position and object size. Saliency correlated strongly with eye position (as in earlier experiments), but was not itself a good predictor of recall. We found a strong recency effect among fixated objects that likely explains this discrepancy: more salient objects are fixated earlier, while a limited capacity short term memory queue reduces the probability of recalling objects at early fixations. This suggests that saliency has no direct effect on recall, but can influence it through fixation. The relative importance of eye position and object size suggests a cortical magnification effect wherein a larger representation in cortex leads to a higher probability of recall.

23.523 Compression in Visual Short-term Memory: Using Statistical Regularities to Form More Efficient Memory Representations

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It is widely accepted that our visual systems are tuned to the statistics of input from the natural world, which suggests that our visual short-term memory may also take advantage of statistical regularities through efficient coding schemes. Previous work on VSTM capacity has typically used patches of color or simple features which are drawn from a uniform distribution, and estimated the capacity of VSTM for simple color patches to be ~ 4 items (Luck & Vogel, 1997), and even fewer for more complex objects (Alvarez & Cavanagh, 2004). Here, we introduce covariance information between colors, and ask if VSTM can take advantage of the shared statistics to form a more efficient representation of the displays.

We presented observers with displays of eight objects, presented in pairs around the fixation point, and then probed a single object in an eight-alternative forced-choice test. The displays were constructed so that each of the eight possible colors appeared in every display, but the color they were next to was not random – each color had a high probability pair (e.g. red appeared with green 80% of time). In information theoretic terms, the displays with statistical regularities have lower entropy compared with uniform displays, and thus require less information to encode. We found that observers could successfully remember 5.5 colors on these displays, significantly higher than the 3.5 colors remembered when the displays were changed to be uniformly distributed in the last block. These results show that capacity estimates, measured in number of objects, actually increased when the displays had some statistical regularities, and that VSTM capacity is not a fixed number of items. We suggest that quantifying capacity in number of objects fails to capture factors such as object complexity or statistical information, and that information theoretic measures are better suited to characterizing VSTM.

23.524 Metric-Dependent Repulsion Between Colors in Visual Working Memory

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There is general agreement that some form of sustained activation is the most plausible neuronal substrate for maintenance in working memory (WM). In the present study, we describe a dynamic neural field (DNF) model of WM that achieves a stable memory state through locally excitatory and laterally inhibitory interactions among feature-selective populations of neurons. This form of interaction allows self-sustained peaks of activation to be maintained in the absence of input (i.e., after the stimulus is removed). However, this can also give rise to metric-dependent interactions among peaks when more than one item is being held in WM. One consequence of such interactions, which we explore here, is that close peaks in WM (e.g., similar colors) will repel each other over delays. This arises as a result of shared lateral inhibition between nearby items in WM. Specifically, when two similar items are maintained, the lateral inhibition in-between them is greater than the inhibition on the “outside” of each peak, causing them to drift away from each other over the delay.

To test this prediction, participants completed a color estimation task probing WM for color. On each trial, participants were shown a memory display that contained two ‘close’ colors and one ‘far’ color. After a brief delay, a color wheel was presented at one of the three target locations, cueing the participant to estimate the color that was originally at that location. The DNF model predicts that estimates of the close colors should be biased away from each other across the delay, whereas estimates of the far color should be comparable to performance when only a single color was remembered. Results confirmed this prediction, suggesting that items in WM interact in a metric-dependent fashion. We discuss the implications of these findings for other models of working memory.

23.525 Directed Forgetting versus Directed Remembering in Visual Working Memory

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An individual’s ability to temporarily store information in visual working memory is extremely limited in capacity. Due to this extreme capacity limit, it would be advantageous to be able to selectively maintain the most relevant subset of information stored in visual working memory. In the present study, we examined the ability of subjects to make use of cues to either forget or remember a subset of the information stored in visual working memory during a retention interval in a change-detection task. On half of the trials, participants were cued to either forget or continue to maintain one of two sequentially presented arrays of colored squares. Contrary to previous work, we found that directed forgetting cues did aid change-detection performance for the information that was retained. However, we found that subjects benefited more from a cue to remember a subset of the information in visual working memory, suggesting that discarding information from visual working memory requires an additional cognitive operation compared to selectively maintaining subsets of information. Although, both low and high capacity individuals benefited from both types of cues, the results revealed an interaction between capacity and cue type. This would suggest that high capacity individuals differ from low capacity individuals in their use of the two types of cues. These findings are consistent with the idea that subjects can focus maintenance mechanisms on a set of information that is within their capacity, and are even capable of manipulating the maintenance process in order to better performance. Our results support the hypothesis that observers can selectively maintain certain objects in visual working memory based on cues to select or discard other objects from memory.

23.526 Heterogeneous object arrays increase working memory capacity in 7-month old infants

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Previous studies have shown that whereas 6.5 month-olds can represent only 1 object at a time (Kaldy & Leslie, 2003), 12 month-old infants, just like adults, can represent up to 3 or 4 identical objects within working memory (Feigenson & Carey, 2003; 2005, Luck & Vogel, 1997). However, nearly all studies measuring infants’ memory capacity have used identical objects. Evidence from adults suggests that visual working memory capacity may decrease as item complexity and similarity increase (Alvarez & Cavanagh, 2004), but capacity returns to 3-4 when using cross-category items (Awh, Barton & Vogel, 2007).

Can infants, too, store more objects in memory when those objects have distinct features? Recent work suggests that array heterogeneity can affect infants’ memory once they have already attained the adult-like capacity of 3 items (Zosh & Feigenson, submitted). However, it remains unknown whether array heterogeneity affects memory earlier in life, when capacity is still undergoing developmental change.

Here, we asked how heterogeneity affects memory capacity in younger infants. Seven-month-olds infants were shown 3 objects hidden sequentially behind 2 opaque screens (2 behind one screen and 1 behind the other). The screens were then lifted to reveal either the correct outcome of 3 total objects, or the incorrect outcome of 2. In Experiment 1, when the 3 objects were all identical, infants looked equally to both outcomes, thus failing to represent all 3 objects. However, in Experiment 2 when the 3 objects contained contrasting features, infants looked longer to the unexpected 2-object outcome, indicating an increased capacity limit that matches that of 12 month-olds.

These results serve as the first demonstration of infants younger than 12 months representing an array of 3 total objects. Additionally, the heterogeneity of features plays an important role in establishing infants’ memory representations for object arrays.

23.527 Visual Short Term Memory for Location: Does Objecthood Matter?

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VSTML has a high capacity.1 We further document its capacity while testing for object-based constraints on capacity.

Sample displays had 36 possible element locations (18 filled), followed by a 1 sec interval, and then a test display in which one element moved (a sample element offset and a new test element onset). Capacity was measured with Cowan’s K (most conservative, reported here), Pashler’s K, and a new K2 to be presented, adapted for the dual events of location-change.

Is VSTML capacity fixed by object? In Experiment 1, capacity was reliably higher for displays of one big, 36-location object (K=11.1 elements; 11.1 per object) than for displays of 3 12-location objects (K = 9.8, or 3.3 per object). Clearly, capacity was not fixed by object.

Are object representations independent from each other? If so, then capacity could depend on internal object structure but not on relations between objects. Displays were 3 12-location objects. In Experiment 2, element size was constant throughout a display or varied between objects in a display. Variation disrupted symmetry and alignment between objects, and caused capacity to be reduced reliably. In Experiment 3, element shape was constant or varied between objects; variation reduced symmetry, but did not reduce capacity. In Experiments 4 and 5 we also varied elements within object; internal object variation of size and shape reduced capacity more than between-object variation. K ranged from 10.8 to 6.4 elements in these experiments.

Object-based models are supported by the greater importance of within-object relative to between-object relations (Experiments 4 and 5) but wounded by flexibility of capacity (Experiment 1) and effects of size relations that span separate objects (Experiment 2).

1 eg Phillipsetal1974 long durations, SanockietalVSS2001, Alvarezetal2007a,b

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23.528 Strategic Control of Visual Short-term Memory during Scene Viewing

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During scene viewing, the eyes and attention are directed serially to objects of interest, and visual short-term memory (VSTM) is used retain information from recently attended objects. In the present study, we examined whether people can strategically control the contents of VSTM during scene viewing, retaining task-relevant objects in VSTM even as attention and the eyes are directed to subsequent objects. Stated more generally, is VSTM a passive storage system in which new objects automatically displace older objects, or can people strategically protect task-relevant objects from subsequent interference? Participants viewed a set of real-world objects presented serially within a 3-D rendered scene. One object in the sequence was cued by a tone as “to-be-remembered”. At the end of the sequence, memory for the visual form of one object was tested, with the cued object six times more likely to be tested than an uncued object. First, there was a general recency effect, with highest memory performance for the most recently attended objects. Second, objects at a particular serial position were retained more accurately when cued than when uncued, demonstrating that participants could indeed prioritize task-relevant objects for retention. Third, the advantage for a cued object was observed at the expense of memory for subsequent objects in the sequence, consistent with the strategic use of limited VSTM resources. Finally, cued objects early in a sequence were remembered less accurately than cued objects late a sequence, demonstrating some degree of interference. Thus, participants could prioritize task-relevant objects for retention in VSTM, but protection from subsequent interference was not perfect. Strategic maintenance of objects in VSTM could play an important role in real-world visual behavior, especially when object information must be maintained across shifts of attention and the eyes to other objects (such as when comparing two spatially separated objects).

23.529 Common capacity limit for visual perception and working memory

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Recent studies in working memory have suggested that our explicit visual representation is limited to a few objects. However, there are two possible explanations for this limited capacity. One possibility is that the explicit visual representations decay and a few object representations remain after a delay period (memory limit hypothesis). Another explanation is that we explicitly perceive only a fraction of visual objects from the beginning (perceptual limit hypothesis). We tested these two hypotheses by manipulating the delay interval. A sample display, containing six stimuli regularly spaced on an imaginary circle, was presented for 3 s. The stimulus was a bar with orientation of 0°, 45°, 90°, or 135°. A small circle was attached at either side of the bar, creating eight possible orientations of sample stimuli. After 0 or 1 second (perceptual or memory condition, respectively), a cue was presented at one of the sample stimulus locations. Observers pressed a key to indicate the orientation of the sample stimulus at the cued location. Capacity was estimated by using a formula [number of the sample stimuli × (% correct - 12.5) / 87.5]. The measured capacity was 3.2 items in both 0-s and 1-s delay conditions. The measured capacity varied substantially across individuals, ranging from 0.5 to 5.8. Yet, the capacity limits in the 0-s and 1-s delay conditions were highly consistent within individuals (r = 0.96). These results support the perceptual limit hypothesis. The strong correlation between perceptual and working memory capacity suggests that they may be originated from the same limitation.

23.530 No Iconic Memory Decay nor Visual Short-Term Memory Decay for Grating Contrast

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Lu, Williamson and Kaufman (Science, 258, 1668-1669, 1992) determined exponential decay constants (between 1-3 sec) for auditory echoic memory for loudness (around 85 dB) of pure sine tones. Their listeners’ echoic memories decayed to intermediate auditory memories of the context--the average loudness of all the tones presented in a session--in 2-6 sec, and were maintained for up to 12 sec. We explicitly followed Lu et al’s paradigm intending to measure the decay of iconic memory of the contrast amplitude of a visual windowed sinewave grating (a Gabor patch) and also to create (as did Lu et al, 1992) different intermediate-term memories by varying the composition of all the stimuli in the session (context). To a good approximation we found that observers’ judgments of relative contrast were as accurate for successive Gabor patches as for simultaneous stimuli, i.e., there was no iconic decay, nor was there any significant short-term memory decay over a delay period of up to 7 sec. This almost perfect memory of the encoded value of a Gabor patch’s contrast is indicated by both stable mean values of observers’ responses (point of subjective equality) and by stable variances of their responses. Experimental procedures: A broad-bandwidth Gabor patch of contrast 0.42 (in HIGH context condition) or 0.62 (in LOW context condition) was displayed for 267 msec, followed by a second Gabor patch whose contrast was randomly chosen between 0.36 and 0.68 which was displayed after a variable delay between 0 and 7.3 sec. Observers judge whether patch 2 has higher or lower contrast than patch 1. The session mean contrast is 0.47 in HIGH sessions and 0.57 in LOW sessions.

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23.531 Selective Effects of Emotion on Visual Short-Term Memory Consolidation

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An important factor determining visual short-term memory (VSTM) capacity is the efficiency with which people can avoid encoding irrelevant information (Vogel, McCollough, & Machizawa, 2005). We investigated the impact of emotion on VSTM and whether it depends on the degree to which selective attention is required at encoding. In two experiments, emotional distraction – induced via presentations of task-irrelevant emotional versus neutral pictures – impaired VSTM primarily when successful performance entailed the parsing of relevant from irrelevant information. This selective effect emerged even though emotional distractors were presented only after an encoding display had come and gone. In Experiment 1, participants performed a change detection task on three black shapes, which either appeared alone or were accompanied in the pre-change display by three gray non-targets (the post-change display contained only the black shapes). On each trial, the pre-change display appeared for 150-ms, followed by a 900-ms ISI and then the post-change display. On one-third of the trials, an emotional picture appeared briefly during the ISI, and on one-third a neutral picture appeared briefly. An emotion-induced VSTM impairment occurred only when participants had been required to ignore irrelevant non-targets. Experiment 2 controlled for the number of items presented in the two conditions: either two targets and two non-targets appeared in the encoding display or four targets appeared alone. Again, emotional distractors impaired VSTM primarily when non-targets had been present. These emotion-induced effects were strongest when the picture appeared sooner rather than later after the offset of the encoding array; thus, the impact of emotional distractors on VSTM depends both on the degree to which VSTM encoding requires selective attention and on when such distractors appear. The temporal dynamics suggest that emotional distraction may impede the selective discarding of irrelevant items during VSTM consolidation.

23.532 **Updating objects in visual short-term memory**

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Information in visual short-term memory is encoded as unified objects (Luck & Vogel, 1997). Does the updating of stored information also proceed in an object-based manner? If so, any effect of updating one feature of an object would spread to its non-updated feature. In the first experiment, participants were briefly presented with three objects with unique colors and orientations. After a delay, a color patch or white oriented bar appeared in the same location as one of the objects. Participants were instructed to update, that is selectively modify, their memory of either the color or orientation of the corresponding object. Finally, either the updated object or one of the two remaining non-updated objects appeared as a memory probe. The probed objects appeared either accurately or with a change applied to either the updated feature or the non-updated feature. When updated objects were probed, change detection accuracy for updated features (81%) was superior compared to non-updated features (57%), $t(10)=3.2$, $p<0.01$, showing a facilitative effect of updating. Importantly, change detection accuracy for the non-updated feature of updated objects did not differ from change detection accuracy for non-updated objects (59%), $t(10)=0.6$, ns. Two control experiments suggested that this did not result from effects of visual priming or a lack of object-based storage. These results show that features in memory can be selectively processed without affecting memory for other features of the same object. A future control experiment will examine whether this means the effect of updating one feature of an object did not spread to its non-updated features, or that memory for the updated feature was separate from the object. As viewed from object file theory (Kahneman, Treisman & Gibbs, 1992), these results could indicate that updating an object file may be done in the absence of a reviewing process that would integrate the old and new states of the object.

23.533 **Implicit Knowledge Biases Encoding into Visual Working Memory**

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It is known that subjects can exert voluntary control over what is encoded into working memory. Does implicit knowledge also influence what is encoded into this online workspace? To examine this question, we measured subjects' ability to detect changes in an array of colored squares, following a brief delay period that required the items to be maintained in working memory. Unbeknownst to subjects, one quadrant of the display (dominant quadrant) was more likely than the others (nondominant quadrants) to contain the changed item. Change detection accuracy was significantly higher in the dominant quadrant, suggesting that items from this quadrant were more likely to be encoded into working memory. Across four separate experiments, subjects were not significantly better than chance (6/52) at identifying the dominant quadrant. Moreover, those subjects that did identify the correct quadrant did not show a larger bias towards the dominant quadrant. This bias effect was not due to a reduction in the response threshold for indicating changes in the dominant quadrant (Experiment 2) or a speed-accuracy trade-off in the nondominant quadrants. In another experiment, we examined whether mnemonic resolution was also improved in the dominant quadrant (Experiment 3). We used a cross-category/within-category change detection paradigm that enables separate measures of the number and the resolution of the representations in working memory. This experiment also showed that a larger number of items were encoded from the dominant quadrant, but the resolution of these representations was unaffected. Thus, implicit knowledge influences which items are encoded into working memory, but not the clarity with which those items are represented. These results suggest that the encoding of items into working memory is influenced by implicit knowledge of which locations are likely to contain useful information.

23.534 **Sudden Death For Overtime Memories**

Weiwei Zhang[1] (wwzhang@ucdavis.edu), Steven Luck[1,2]; [1]Center for Mind & Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis

Although the brain has a system for storing some kinds of memories for a lifetime, it also maintains temporary, disposable, scratch-pad memories. Do these short-term memories simply fade away as they age? Or do they die a sudden death? For decades, researchers have concluded that visual short-term memories decay gradually, becoming less and less precise as they are retained for longer periods of time. However, results of this sort could alternatively result from a progressive increase in the probability that the memory has completely terminated.

In the present study, we used a short-term color recall paradigm in which subjects attempted to retain three sample items in short-term memory. After a delay of 1, 4, or 10 seconds, one of the three items was probed, and the observers attempted to report its color by clicking on a color wheel. The resulting data set consisted of a distribution of memory errors at each delay period. From this distribution, we used maximum likelihood estimation to extract the precision of the memory representation (which should decline over time if the memories decay) and the probability that any information at all remains in short-term memory (which should decline over time if the memories suddenly terminate). We found that visual short-term memories suffered no significant loss of strength or precision over a period of time. Instead, these memories suddenly terminated, disappearing without a trace. These results suggest that active maintenance in short-term memory is an all-or-none process, in which a representation is maintained over time with no loss of resolution until it is suddenly lost.

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23.535 **The Capacity for Spatial Updating in Visual Short-term Memory**

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In multiple object tracking studies, people can track the locations of 4-7 moving objects. Additionally, it has been hypothesized in the object-file literature that as an object moves, the association between object position and object surface features is automatically updated. However, people are often poor at recalling non-spatial features associated with tracked objects (Pylyshyn, 2004). In the present study, we sought to determine the capacity for updating the association between object location and surface features. In Experiment 1, participants saw four boxes and tracked either one, two, three, or four. Colors appeared in each box, the colors were removed, and the boxes moved to new locations. One of the tracked objects was cued, and the participant reported which of the four colors had been associated with that object before motion. Participants' updating capacity was approximately two color-position bindings. In Experiment 2, we replicated these results using a change detection task. Again we found that participants could update color-position binding for approximately two objects. This updating capacity was significantly lower than capacity for color in a standard VSTM task that did not require spatial updating. In Experiment 3, the stimuli to-be-updated contained two features. Colored shapes appeared in the boxes, and after motion, participants were asked to report color alone, shape alone, or either shape or color. Capacity for updating two features of an object was no lower than capacity for updating either feature alone, suggesting that spatial updating is constrained by the number of objects rather than the number of features, as found in standard VSTM tasks (Luck & Vogel, 1997). Together, these results indicate that VSTM is used to update the binding of surface features to locations in an object-based manner. However, this updating can be accomplished only for a subset of objects in VSTM.

23.536 **Activation in V4 predicts fragile or durable storage in visual working memory**

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Classic work on visual working memory shows that people robustly store about 4 objects for subsequent report (Luck & Vogel, 1997). Yet, when people are requested to shift attention to one item during retention by means of a retro-cue (Landman, Spekreijse & Lamme, 2003; Griffin & Nobre, 2003; Makovski & Jiang, 2007), people can report additional objects, up to 4 seconds after image off-set (Sligte, Lamme, Scholte, 2006). This suggests that some items are immediately stored in a robust form of memory, while additional items are represented in a more fragile memory store. To study the neural substrate of these different stores, we employed a similar visual working memory paradigm and concurrently measured BOLD fMRI in 8 retinotopic locations in V1 to V4. We sorted trials (correct vs. incorrect, cue during retention interval vs. match display) so that we could determine whether items at a particular retinotopic location were stored in durable (DWM) or fragile (FWM) visual working memory. We found that storage in FWM elicited selective retinotopic activation only in V4. This activation was enhanced when items were in DWM. We conclude that both storage in FWM and DWM depends on a selective and retinotopic neural representation that includes V4. Moreover, the activation level in V4 is indicative for the representational strength of the working memory representation.

23.537 **Linking Implicit Chunk Learning and the Capacity of Working Memory**

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Classical studies of the capacity of working memory have posited a fix limit for the maximum number of items human can store temporarily in their memory, such as 7±2 or 4±1. More recent results showed that when the stored items are viewed as complex multi-dimensional objects capacity can be increased and conversely, when distinctiveness of these items is minimized capacity is reduced. These results suggest a strong link between working memory and the nature of the representation of information based on the observer's long-term memory. To test this conjecture, we formalized the information content of a set of stimulus by its description length, which relates the "cost", the number of bits assigned to a particular stimulus, to its appearance likelihood given the representation the observer has. This formalism highlights that a high-complexity but familiar stimuli need less resource to encode and recall correctly than novel stimuli with lower complexity. Using this formalism, we developed a novel two-stage test to investigate the above conjecture. First, participants were trained in an unsupervised visual statistical learning task using multi-element scenes in which they are known to develop implicitly a chunked representation of the scenes. Next, they performed a change detection task using novel scenes that were composed from the same elements either with or without the chunk arrangements of the training session. Change detection results were significantly better with scenes that were composed of elements that retained the chunk arrangement. Thus the capacity of working memory determined by how easily the stimulus can be mapped onto the internal representation of the observer, and integrated object-based coding is a special case of this mapping.

Saturday, May 10, 2:30 - 4:00 pm
Talk Session, Vista Ballroom

Eye Movements and Perception

Moderator: Christopher Pack

2:30 pm

24.11 **Microsaccades counteract perceptual filling-in**

Susana Martinez-Conde[1] (smart@neuralcorrelate.com), Xoana Troncoso[1], Stephen Macknik[1]; [1]Barrow Neurological Institute, Phoenix, AZ

Our visual system contains a built-in contradiction: when we fixate our gaze on an object of interest, our eyes are never still. Instead we produce, several times a second, small fixational eye movements of which we are unaware. We recently showed that fixational microsaccades counteract Troxler fading and drive visibility during fixation (Martinez-Conde et al., Neuron 2006). Here we set out to determine whether microsaccades may also counteract the perceptual filling-in of artificial scotomas. Several studies have shown that artificial scotomas positioned within peripheral dynamic noise can fade from perception (that is, the surrounding dynamic noise appears to fill-in the scotoma). Because the dynamic noise is continuously refreshed, this filling-in effect cannot be explained by simple low-level adaptation mechanisms, such as those that may underlie classical Troxler fading. We asked subjects to indicate, via button press/release, whether an artificial scotoma presented on a dynamic noise background was visible or invisible at any given time. The subjects' eye movements were simultaneously measured with a high precision video system. No previous studies have established a direct correlation between eye-movement dynamics to the perception of filling-in, with tight timing. We found that increases in microsaccade production counteracted the perception of filling-in (and correlated to the visibility of the artificial scotoma), whereas decreased microsaccades allowed perceptual filling-in to take place. Our results show that microsaccades do not solely overcome low-level adaptation mechanisms but also contribute to maintaining second-order visibility during fixation.

Acknowledgement: This study was funded by Dana Foundation and Barrow Neurological Foundation . XGT is a Caja Madrid postdoctoral fellow.

URL: http://smc.neuralcorrelate.com/

2:45 pm

24.12 **Saccade adaptation in monkeys is object-specific**

Matthew Phillips[1,3] (mp2570@columbia.edu), Sara Steenrod[1,3], Michael Goldberg[1,2,3,4]; [1]Neuroscience, Columbia Univ., New York, NY, [2]Psychiatry, Columbia Univ., Columbia, NY, [3]Neurobiology and Behavior, New York State Psychiatric Inst., New York, NY, [4]Neurology, Columbia Univ,, New York, NY

Saccade adaptation (McLaughlin 1967) generally transfers from one similarly-sized object to another (Deubel 1995). However adaptation is also specific to a particular saccade vector, so that probes placed at locations orthogonal to the axis of adaptation, in particular, will elicit saccades that are only partially adapted (Straube, Fuchs, Usher & Robinson 1997). Thus we cannot infer from available data the extent of adaptation transfer to a probe object which lies partially in and partially out of the adaptation field of the primary target. We tested this by adapting the saccades of 2 S (macaca mulatta) to a small visual target at 20deg eccentricity. We interleaved two types of probe trials (approx. 15% total): 1) a long, thin orthogonally oriented bar centered on the axis of adaptation at the same eccentricity as the primary target, and 2) small squares with the same location as the ends of this bar. Using saccade adaptation we reduced the amplitude of saccades to the primary target; typically the resultant change in amplitude to the end probes along the axis of adaptation was much smaller. We compared populations of bar probe and primary target saccades with the same mean direction, and found that there was very little adaptation to the bar probe over and above the adaptation which transferred to the end probes. In a control task, we adapted an entire range of targets simultaneously which were arrayed orthogonally to the axis of adaptation so as to cover the extent of the bar probe, which was also presented on interleaved trials. In this condition transfer of adaptation from the primary targets to the bar probe was nearly complete. On the basis of this object-specific selective adaptation we conclude that information about the spatial extent of visual objects is available to the monkey oculomotor system.

Acknowledgement: National Eye Institute, Keck Foundation, Dana Foundation, Fight for Sight foundation

3:00 pm

24.13 **Fixation locations during three-dimensional object recognition are predicted by image segmentation points at concave surface intersections**

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Eye movements have been extensively studied in a variety of domains including reading, scene perception and visual search. Here we show how fixation patterns can also provide unique insights into how the human visual system accomplishes three-dimensional (3D) object recognition. Fixation patterns were recorded while observers memorised sets of novel surface rendered 3D objects and then performed a recognition memory task. Instead of pre-defining areas of interest (AOIs), analyses of fixation data were based on a new data-driven approach in which the fixation patterns themselves were used to define AOIs that are then subject to detailed analyses of shape information content. The analysis methodology contrasts fixation region overlap between the observed data patterns, a random distribution, and any number of predicted patterns derived from theoretical models of shape analysis. The results showed that the distributions of fixation regions are not random but structured and consistent across Ss: observers fixate the same image locations between the learning and test phases and track similar geometric shape features across changes in object viewpoint. We contrasted the locations of fixation regions from the recognition task against a random model of fixation region location, a visual saliency model, and against a model based on the localization of 3D segmentation points at negative minima of curvature at surface intersections. The visual saliency model did no better than the random distribution in accounting for fixation region overlap. In contrast, the fixation regions predicted by the 3D segmentation model accounted for significantly more than the random model. This suggests that, contrary to some current 2D image-based models of object recognition, relatively high-level local 3D shape properties defined by negative minima of curvature constrain fixation patterns during shape analyses for object recognition.

3:15 pm

24.14 Perceptual compression during head-free gaze shifts: visual and extraretinal contributions

Alby Richard[1] (alby.richard@mcgill.ca), Jan Churan[1], Daniel Guitton[1], Christopher Pack[1]; [1]Neurology and Neurosurgery, Montreal Neurological Institute, McGill University

Saccadic eye movements are accompanied by a transient distortion of perceptual space, traditionally attributed to errors in extraretinal mechanisms that preserve spatial constancy across eye movements. This perisaccadic mislocalization of visual space, so far studied in head-fixed subjects, comprises a compression of visual space towards the saccade target, along with a shift in the direction of the saccade (Ross et al., 1997) and a saccade-velocity dependence (Ostendorf et al., 2007). Here we asked whether these mechanisms occur when head motion contributes to a gaze shift. We used a head-unrestrained paradigm, in which both amplitude and velocity could be varied, and found a powerful compression of visual space that depended on both the gaze velocity and the time at which the localization target was presented relative to the onset of the gaze shift. Compression of visual space always occurred towards the intended gaze target, which was not necessarily the endpoint of the eye saccade component of a gaze movement. Furthermore, the magnitude and the latency of the peak perceptual compression increased as the amplitude of a gaze shift increased from 10 to 40 degrees. Across all conditions, there was also a strong correlation between the time of peak compression and the time of maximum gaze velocity. We also observed greater compression when the localization target was lower in contrast, and this effect became more pronounced for larger gaze shifts. The effect of reducing contrast was similar to that of increasing gaze shift velocity, suggesting that retinal events which reduce stimulus visibility increase perisaccadic compression. However, even when velocity and contrast were constant, perceptual compression increased with the amplitude of the gaze shift, indicating that extraretinal mechanisms contribute significantly to the perisaccadic perception of visual space.

Acknowledgement: National Science Foundation, Canadian Institutes of Health Research

URL: http://apps.mni.mcgill.ca/research/cpack/index.htm

3:30 pm

24.15 Improved visual sensitivity during smooth pursuit eye movements

Alexander C. Schütz[1] (alexander.c.schuetz@psychol.uni-giessen.de), Doris I. Braun[1], Dirk Kerzel[2], Karl R. Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen, [2]Faculté de Psychologie et des Sciences de l'Education, Université de Genève

Eye movements have various effects on visual perception. During saccadic eye movements, for example, suppression has been reported for visual stimuli being processed in the magnocellular system. Here, we explored the effects of smooth pursuit eye movements on visual sensitivity.

We compared sensitivity for briefly flashed color- and luminance-defined stimuli during pursuit and fixation. Subjects had to track a black target spot that was either stationary (fixation) or moved horizontally (pursuit) with a velocity of 10.57 deg/sec. Contrast sensitivity was measured by means of a blurred 0.3 deg wide horizontal line that appeared for 10 ms 2 deg above or below the pursuit trajectory. The line was defined by an increment or decrement in luminance or in isoluminant red-green color contrast. The results show that contrast sensitivity for luminance stimuli was slightly but significantly reduced during pursuit. However, for color stimuli instead of a decrease, a 15% increase in sensitivity was found during pursuit. The sensitivity enhancement for color was also present for a red pursuit target and a range of speeds (3-15 deg/sec) of the pursuit target.

To test if the increase in sensitivity is specific for a retino-thalamic pathway, we measured sensitivity for high spatial frequency luminance gratings of 14 cpd. Again sensitivity was increased during pursuit compared to fixation. Further we investigated the dynamics of this enhancement by flashing a red horizontal line at different points in time relative to the onset of a step-ramp target. The detection rate rises approximately 50 ms before the onset of pursuit, indicating that the enhancement is triggered by an extraretinal signal.

These findings indicate an active and selective sensitivity enhancement for the parvocellular pathway during pursuit. A facilitation of the parvocellular system may aim at improving object recognition and increasing sensitivity to small retinal speed errors while tracking objects.

Acknowledgement: This work was supported by the DFG Forschergruppe FOR 560 "Perception and Action" and the DFG Graduiertenkolleg GRK 885 "NeuroAct".

3:45 pm

24.16 Eye movements for shape and material perception

Lavanya Sharan[1,2] (l_sharan@mit.edu), Ruth Rosenholtz[1,2], Edward H. Adelson[1,2]; [1]Computer Science and Artificial Intelligence Lab, Massachusetts Institute of Technology, [2]Dept of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Human observers can perceive the shape and material properties of three dimensional objects, even from a single two dimensional image. What information in an image do they utilize to make these judgments? We conducted eye movement studies to pursue this question. Previous works have used the human figure, natural objects or silhouettes of abstract objects as stimuli in eye tracking setups to study shape perception (Van Doorn et al 2002, Renninger et al 2007). We are interested in shape and material perception for images of unfamiliar, three dimensional objects. We constructed shapes by adding randomized spherical harmonics and rendered these shapes using PBRT under different illuminations and viewing conditions (Pharr & Humphreys 2004). The surface reflectance properties – albedo and gloss – were varied, as were the spherical harmonic coefficients in order to generate different shapes. Based on psychophysical and computational results in shape perception, one might expect that some image regions (e.g. occluding boundaries, high contrast areas, corners etc.) are more useful than others for shape judgments. Recent work in material perception (Motoyoshi et al 2007) has shown that luminance contrast and skewness are predictive of albedo and gloss. Regions of higher contrast and skewness usually contain specular highlights and prominent edges. Therefore, it is plausible that observers look in different places during shape and material perception tasks. In our data, we found that observers' eye movements were a) non-random, b) correlated with each other and c) similar for both tasks. There seem to be regions in our objects that elicit eye movements during shape as well as material judgment tasks. These regions cannot be predicted by simple, low-level image measurements like mean luminance, local contrast, local skewness or local energy.

Acknowledgement: NTT, NSF

Saturday, May 10, 2:30 - 4:00 pm Talk Session, Royal Palm Ballroom 4-5

Multiple Object Tracking 1

Moderator: Yuhong Jiang

2:30 pm

24.21 A Neurophysiological Model of Multiple Object Tracking Derived From fMRI

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The multiple object tracking (MOT) paradigm is a powerful tool for studying dynamic attention and the nature of objects. However, surprisingly little is known about the neural systems underlying MOT performance. Here we present an improved method for identifying core brain areas involved in MOT, and introduce a novel analysis of effective connectivity among these areas. Previous fMRI studies of MOT employed a "passive viewing" baseline. This baseline is problematic, because it does not allow control of attentional load relative to tracking. We added an additional stationary baseline. Stimuli comprised eight identical disks, four moving and four stationary. Observers (N = 13) attended either to two moving disks (tracking), two stationary disks (stationary) or no disks (passive) while maintaining central fixation. Subtracting the stationary activity from tracking activity yielded a map of areas preferentially activated by MOT. This map comprised FEF, SPL, anterior IPS and MT+. Consistent with previous studies, using the passive baseline would have added posterior IPS and lateral postcentral sulcus. These last two areas are activated by attentional load, but not by tracking per se. Focusing on the first four areas, we employed a novel method to derive effective connectivity from their BOLD signal timecourses. We first determined the feed-forward connections between these areas by using prior anatomical information to constrain the Total

Conditioning algorithm (Pellet & Elisseef 2007). This method allowed us to derive causation from partial correlations, while making minimal assumptions. We then reversed the procedure to determine the feed-back connections. This analysis leads to an improved understanding of the relationship between neural activity and performance. For example, we found a surprising asymmetry between ipsilateral and contralateral connectivity patterns, which could explain why behavioral studies have found tracking in two hemifields to be superior to tracking in a single hemifield.

URL: http://search.bwh.harvard.edu/

2:45 pm

24.22 Attentional capacity is limited by the functional architecture of visual cortex: competition for representation impedes attention to multiple items

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We investigated whether competition among stimuli for representation in visual cortex may explain, in part, attention's limited capacity to act on multiple items. When multiple neighboring visual stimuli appear simultaneously, their representations interact in a mutually suppressive manner. Focusing attention on one of these stimuli reduces these suppressive effects, suggesting that attention may bias the competition for representation in favor of the attended item. If attention is divided among nearby stimuli, however, then once again, multiple, now attended, stimuli should be competing for representation. According to the theory, then, three attended items should be more vulnerable to competition than is one attended item. In two fMRI experiments, we presented participants with five complex visual stimuli. We manipulated whether attention was focused or divided by asking participants to detect the target in either one or three of the five locations. In Experiment 1, we manipulated the degree of inter-item competition by presenting items either sequentially or simultaneously. Competition could take place only among simultaneously presented stimuli. We assessed activation in V4 in each condition, and found an interaction between attentional and presentation conditions. Activation was significantly reduced during the attend-three condition relative to the attend-one condition, but only during simultaneous presentation. In Experiment 2, we manipulated the degree of inter-item competition by placing all three attended items within a single visual quadrant or by dividing them between the hemifields. Because representations in V4 are confined to contralateral space, only items presented within a single hemifield should compete. Preliminary data indicate that activation is less for the attend-three condition than the attend-one condition only when all attended items fall within a single hemifield. Together, these data indicate that attention is indeed less able to modulate competition when it must be divided among multiple items.

3:00 pm

24.23 Probing the Allocation of Attention during Multiple Object Tracking with ERPs

Andrew McCollough[1] (awm@darkwing.uoregon.edu), Trafton Drew[1], Todd Horowitz[2], Edward Vogel[1]; [1]Psychology, University of Oregon, [2]Ophthamology, Harvard Medical School

While most researchers would agree that multiple object tracking (MOT) is an attentionally demanding task, the specific function of attention during tracking is not yet fully understood. For example, it is unclear whether attention during tracking enhances the target representations, suppresses the distractor representations, or some combination of excitation and inhibition of both the targets and distractors. Currently, there is some evidence that distractors are actively inhibited during tracking, but that there is no enhancement of targets relative to static space (Pylyshyn et al., 2006). These and other results generally rely upon dual task paradigms in which subjects attempt to detect the presence of an occasional probe on targets, distractors or space while they simultaneously perform the tracking task. However, the fact that the probes are task-relevant could be problematic because it may significantly alter how subjects allocate attention to the tracking task.

In the present study, we used ERPs to examine the early visual evoked responses to task-irrelevant probes while subjects performed a standard MOT task in which they tracked a near capacity load of four targets. This gave us a unique opportunity to examine the allocation of spatial attention during tracking without requiring an additional detection task. Brief probes were flashed on either targets, distractors, or stationary objects. The results showed a significant enhancement of the anterior N1 component (150ms) for probes on targets relative to distractors and stationary objects. Furthermore, this enhancement correlated with the subjects' tracking ability; Good trackers showed larger differences between target and nontarget probe responses than did poor trackers. These results provide evidence that attention enhances the representations of tracked target items.

3:15 pm

24.24 How does attention operate during multiple object tracking?: Evidence from the 'slot-machine' task for parallel access to target features

Jonathan I. Flombaum[1] (jonathan.flombaum@yale.edu), Brian J. Scholl[1]; [1]Yale University

In multiple object tracking (MOT), observers track a subset of haphazardly moving and featurally-identical objects. The fact that MOT is possible in the first place is often taken as implicit evidence that the moving targets are all attended in parallel, but there has never been a direct experimental test of this critical hypothesis. We tested this possibility using novel combinations of MOT and probe detection. In the MultiProbe task, observers detected small simultaneous 80ms probes that appeared in the centers of targets once on each trial. In particular, observers determined whether there were as many probes as targets, or one fewer. Performance was well above chance when tracking multiple targets among an equal number of distractors -- an ability that would be impossible without simultaneous access to each of the targets. In the Slot-Machine task, observers tracked three targets among three distractors, but these objects were not identical. Instead, each object's color changed every 250ms, and each object possessed a distinct color throughout a trial (ensuring that tracking was still necessary for target identification). At one key moment in two thirds of trials, however, either two or three of the targets' colors momentarily matched -- as in the congruence of wheels on a slot-machine (jackpot!). Observers readily determined whether the match involved two, three, or none of the targets -- an ability that would not be possible without sustained parallel access to each of the targets' features. (This result is also striking due to the fact that observers generally have very poor access to objects' surface features during MOT.) This novel slot-machine method can also be used to directly explore the extent to which these parallel resources are divided between noncontiguous regions of the display. Overall, this work begins to reveal the underlying attentional dynamics that make MOT possible.

URL: http://www.yale.edu/perception/

3:30 pm

24.25 Object-based biased competition during covert spatial orienting

Ed Awh[1] (awh@uoregon.edu), Miranda Scolari[2], Jun Ishikawa[1]; [1]University of Oregon, [2]UC Irvine

Biased competition models assert that spatial attention facilitates perception by biasing the competition for resources between relevant and irrelevant aspects of the visual scene. This emphasis on competition predicts that the benefits of attention will be strongest in high interference displays, when there is significant competition to bias. In line with this view, psychophysical studies have shown larger benefits of covert spatial orienting when multiple distractors impede target processing. Thus, spatial attention resolves visual interference. The present work examined the boundary conditions of this interference resolution process. First, we replicated previous observations of larger spatial cueing effects when observers discriminated target digits that were embedded within distractor letters (noise displays) rather than alone in the visual field (clean displays). However, when the distractor letters were replaced by an equally challenging diffuse noise mask, spatial cueing effects were equivalent in the noise and clean displays. Because the letters and the diffuse noise mask generated equal levels of interference, these data suggest that attention is helpful in resolving a specific kind of competition between individuated object representations. To further test this hypothesis, we measured spatial cueing effects at larger eccentricities where targets and distractors representations are "pooled" because of amplified visual crowding. When crowding made targets and distractors less likely to be perceived as individuated objects, spatial cueing effects were again equivalent in noisy and clean displays. Finally, an analysis of individual differences in susceptibility to crowding showed that the same observers who exhibit weaker crowding effects – and who are more likely to perceive targets and distractors as individuated objects – are the subjects who show larger spatial cueing effects in crowded versus uncrowded displays. These data suggest that spatial attention does not relieve interference from all forms of visual interference. Instead spatial attention biases competition between individuated object representations.

3:45 pm

24.26 **Visual learning in multiple object tracking**

Yuhong V. Jiang[1, 2] (jiang166@umn.edu), Gustavo A. Vázquez[1, 3], Tal Makovski[1]; [1]Department of Psychology, University of Minnesota, [2]Center for Cognitive Sciences, University of Minnesota, [3]Department of Psychology, University of Santiago, Spain

Our ability to track a subset of moving objects with attention is severely limited and only a few objects can be tracked simultaneously. This ability, however, can be improved by learning, as tracking improves on displays involving repeated motion trajectories. In this study we examine the source of learning in multiple object tracking, its interaction with selective attention, and the role of temporal sequences in learning. Participants were asked to track 4 designated circles among a total of 8 moving circles. Several different tracking trials were generated and each trial was repeatedly presented 15 to 20 times during training. For each presentation of a tracking trial, the subset designated as the targets was constant during training but the motion started and ended at different moments to prevent participants from learning just the initial or ending positions. Accuracy improved as training progressed. To test whether the improvement was attributable to enhanced familiarity with the repeated displays, in Experiment 1 we tested participants in a transfer session where the same trajectories were used, but a different subset was designated as tracking targets. Results showed that relative to novel trials, tracking in old trials was enhanced only when the subset designated as targets was constant between training and transfer. Learning did not transfer when the same trajectories were used but the targets and nontargets switched roles or were mixed up. Experiment 2 showed, surprisingly, that temporal order of the motion sequence was not part of the learning, as learning fully transferred when the learned trajectories were played backwards. We conclude that visual learning in multiple-object tracking reflects learning of attended trajectories, and that learning is unaffected by prospective coding of motion temporal order.

Acknowledgement: This study was supported in part by NSF 0733764 and NIH MH 071788. The first and last authors claim equal contributions.

Saturday, May 10, 4:30 - 6:15 pm
Talk Session, Vista Ballroom

Cortical Processing

Moderator: Anna Roe

4:30 pm

25.11 **The role of cortico-cortical interactions during motion integration: a voltage-sensitive dye imaging study in V1 and V2 of the awake monkey**

Frederic Chavane[1] (chavane@incm.cnrs-mrs.fr), Alexandre Reynaud[1], Guillaume Masson[1]; [1]CNRS, Aix-Marseille Universtiy, Marseille

Lateral interactions are crucial mechanisms involved in contextual modulation of visual processing from which motion percept can emerge, such as in the case of apparent motion. Integration of a sequence of static stimuli could evoke motion signal in the visual system through spatio-temporal interactions originating from horizontal intra-cortical interactions or feedback from higher areas. However, horizontal and feedback interactions differ from their spatial and temporal properties, the first pathway being less extended and slower. Using voltage-sensitive dye imaging (VSDI) we investigated what are the cortico-cortical interactions that can shape the emergence of a motion signal in V1, in the awake monkey.

Using VSDI, we observe that local stimuli, containing or not motion information, activate a restricted cortical area followed by horizontal propagation of activity along the cortex at slow speed. In a sequence of two local static stimuli, 2 stroke apparent motion, two waves of activation, the horizontal propagation evoked by the first stimulus and the feedforward activation of the second stimulus, are interacting in V1. This interaction can lead to the emergence of a wave of propagating activity as was observed in the anesthetized cat (Jancke et al 2004). To identify the different roles of the various cortico-cortical interactions in the apparent motion integration, we therefore explored different spatio-temporal parameters of the 2 stroke apparent motion. The observed non-linear cortical interactions were then compared to the activity generated by real motion stimuli. Depending on stimulus characteristics, this cortico-cortical interplay develops a dynamical balance of facilitation and suppression. These non-linearities allow for the emergence of a gradual and smooth wave of normalized activity.

4:45 pm

25.12 **Functional subdivisions in macaque V4 revealed by optical imaging in the behaving Macaque monkey**

Hisashi Tanigawa[1] (h.tanig@vanderbilt.edu), Haidong Lu[1], Gang Chen[1], Anna Wang Roe[1]; [1]Department of Psychology, Vanderbilt University

In macaque V4, it has been proposed that there are several subdivisions based on patterns of connectivity and visual topography (Zeki, 1971; Maguire and Baizer, 1984). Zeki (1983) reported that color selective cells were more frequently found in the anterior bank of lunate sulcus (V4 proper), as compared with the cortex on the prelunate gyrus (V4A). However, this finding was based on qualitative observation and there has been no study to confirm this finding. Here, we studied the functional organization of V4 using intrinsic signal optical imaging in two alert macaque monkeys and examined whether there is any functional subdivision in V4 in relation to color, luminance, and orientation preferences. Intrinsic signals were obtained through a chronic chamber over the portion of V4 representing foveal and parafoveal visual space (<1.5° and 3-7° eccentricity, respectively). To reveal feature representation, a patch (0.25-8°) or full-screen stimulus filled with isoluminant color-varying or achromatic luminance-varying gratings was presented while the monkey was performing a fixation task.

Visual activations in V4 showed a stimulus-size dependence: small grating patches activated the cortex more strongly than the full-screen gratings, consistent with the presence of strong surround suppression. In the foveal V4, color/luminance and orientation mapped in the different cortical locations. Color and luminance-sensitive regions were located posteriorly, close to the lunate sulcus (within 2 mm), alternating with a band-like appearance (color/luminance domains). The width of these domains was approximately 0.5 mm. In a region anterior to these domains, orientation-sensitive regions were observed (orientation domains). These two types of domains were largely separated but with some overlap. Within the color/luminance domains, different colors activated separate sub-domains. This functional compartmentalization was also observed in the parafoveal V4. These results indicate that there are distinct functional subdivisions in V4, which appear to correspond to the subdivisions proposed previously (V4 proper/V4A).

Acknowledgement: NIH Grant EY11744, Vanderbilt VVRC, Vanderbilt CICN, Vanderbilt Discovery Grant

5:00 pm

25.13 **Processing of Orientation Discontinuities in Space and Time in V1 and V2**

Anita M. Schmid[1] (ams2031@med.cornell.edu), Ferenc Mechler[1], Ifije Ohiorhenuan[1], Keith P. Purpura[1], Jonathan D. Victor[1]; [1]Department of Neurology and Neuroscience, Weill Medical College of Cornell University, New York, NY

Neurons in primary visual cortex (V1) respond to luminance borders. Neurons in secondary visual cortex (V2) also respond to texture borders, but the extent of the differences between V2 and V1 and the ways in which new properties arise in V2 are as yet unclear.

To address these questions, we probed spatial and temporal nonlinearities in single neurons in V1 and V2 of anesthetized monkeys. The stimulus was a 4 by 5 grid of adjacent rectangular regions, covering the classical and non-classical receptive field. Each region contained sinusoidal gratings with one of two orthogonal orientations, controlled by an m-sequence. To disambiguate second-order interactions, we used a novel approach: on interleaved runs, regions were assigned differently-spaced “taps” into the m-sequence.

In response to this stimulus, first-order kernels of neurons in V1 are monophasic. In contrast, V2 neurons have temporally biphasic responses: first positive, then negative. That is, a higher firing rate is elicited by the preferred grating following an orthogonal grating than by continuous presentation of the preferred grating.

A second-order interaction driven by a change of orientation in time was present, but this signal was opposite in V1 and V2: in V1, responses were augmented when the same orientation was presented on successive frames, but in V2, responses were augmented when orientation changed. A spatial second-order interaction was also present: in V1, it was monophasic and corresponded to cross-orientation suppression; in V2, this component was present but in addition a later opposing component existed, indicating response augmentation by orientation differences.

Thus, V2 provides a signal for orientation discontinuities over time as well as space. Whereas all of the interactions in V1 can be explained by threshold nonlinearities, the opposing interaction components in V2 require a nonlinearity that follows a spatial and temporal differencing operation in orientation space.

Acknowledgement: Supported by NIH EY9314

5:15 pm

25.14 Spatial and Temporal Limits of Pattern Motion Analysis by MT Neurons

Romesh D. Kumbhani[1] (romesh.kumbhani@nyu.edu), Yasmine El-Shamayleh[1], J. Anthony Movshon[1]; [1]Center for Neural Science, New York University

Pattern-selective (PDS) neurons in macaque area MT signal the true direction of motion of plaids made by summing two component gratings drifting in different directions; component-selective (CDS) neurons respond independently to the two components. To learn more about the mechanisms responsible for this pattern motion computation, we studied the spatial and temporal limits over which signals from the two component gratings can be combined.

We recorded single units from area MT in opiate-anesthetized, paralyzed macaques. We estimated the temporal precision of the pattern computation by presenting the two component gratings in alternating time segments. We presented stimuli on a high-resolution monitor at a frame rate of 120 Hz, and varied alternation frequency from 7.5 Hz to 60 Hz. As expected, PDS neurons lost their pattern selectivity as we lowered the alternation frequency. The frequency at which PDS neurons lost pattern direction selectivity on average was between 20 and 30 Hz, corresponding to presentation durations of 16.7 - 25 ms. We made analogous measurements in the space domain by presenting the two drifting gratings in alternating spatial partitions. Consistent with previous results, when each partition covered half the receptive field, PDS neurons lost their pattern selectivity. As we increased the number of partitions to 4 or more within the receptive field, pattern selectivity returned. The scale of the partitions at the transition was roughly 1.5 times the neuron's optimal spatial period.

We conclude that the pattern motion computation in MT neurons occurs at a relatively fast time scale and small spatial scale; in other words, for pattern motion to be signaled, the component patterns must be closer to one another in space and time than the spatial and temporal scale of the receptive field itself.

Acknowledgement: This work was supported by NEI Grant EY07158-06.

5:30 pm

25.15 Representation of stimulus speed in prefrontal cortex during speed discrimination task

Cory Hussar[1] (Cory_Hussar@urmc.rochester.edu), Leo Lui[1], Tatiana Pasternak[1]; [1]Department of Neurobiology and Anatomy, University of Rochester, NY

When monkeys perform behavioral tasks requiring discrimination and retention of direction of visual motion, neurons in prefrontal cortex show direction selective activity reminiscent of responses in motion processing area MT (Zaksas and Pasternak, 2006). We now report that during a task requiring discrimination and retention of stimulus speed, over 60% of PFC neurons show a systematic modulation of activity by stimulus speed and that the nature of this modulation point to its bottom-up origin. Speed selective responses of these neurons fit classifications of low-pass, high-pass or band-pass tuning and were also direction selective, characteristics that disappeared when visual motion was not behaviorally relevant. During a subsequent memory delay, speed selectivity persisted, with many neurons showing activity that varied systematically with remembered speed. However, this activity was largely transient, occurring at different times in different cells, and rarely spanning the entire memory delay, resembling previously observed delay activity during the direction discrimination task. During the comparison phase of the task, when the current and remembered speed must be compared, responses were significantly enhanced when the two speeds matched. This enhancement was largely absent when the comparison speeds were similar and not distinguishable to the monkey, reflecting the nature of the comparison mechanism. Interestingly, while responses to the comparison stimulus were not predictive of the monkey's decision, activity immediately after stimulus offset, while the monkey was withholding the response, was predictive of the monkey's choice, suggesting involvement in the process leading to the motor response. These results demonstrate active participation of PFC neurons in the circuitry sub-serving tasks involving discrimination and retention of visual motion. The nature of the representation of direction and speed in PFC point to strong functional links with neurons in area

MT.

Supported by EY11749, T32 EY07125, P30 EY01319

5:45 pm

25.16 The Role of the Frontal Eye Fields in Velocity Compensation During Saccades to Moving Targets

Carlos Cassanello[1] (cc2391@columbia.edu), Abhay Nihalani[1], Vincent Ferrera[1]; [1]Departments of Neuroscience and Psychiatry, Columbia University, New York

Saccadic eye movements are programmed based on a position error signal that represents the difference between the current and desired eye position. Saccades based on position error alone should always undershoot a moving target. However, monkeys and humans make accurate saccades to moving targets, and there is good evidence that this accuracy results from the use of target velocity in saccade programming. The FEF receives input from visual motion-processing areas MT and MST, and sends output to oculomotor centers, and is therefore likely to be involved in saccade target velocity compensation. To decide whether neurons in the FEF code for position error (PE) or saccade amplitude (SA), and whether their responses are modulated by target velocity (TV), we recorded 96 neurons from awake-behaving rhesus monkeys making saccades to moving targets using a step-ramp paradigm. By comparing the neuronal responses preceding the onset of saccades to stationary targets to the responses to moving targets, we could determine whether firing rate is better correlated with PE or SA. We found that one third of the cells coded better for SA in saccades to moving targets, suggesting that they integrate velocity signals to compensate for the target displacement during the last 100 msec before the onset of the saccade. In addition, 55 (57%) cells showed significant modulation of firing rate by target velocity during an interval of 100 msec centered on saccade onset. The modulation in firing rate can be fitted well with a quasi-linear or a quadratic dependence on the variable SA-PE, which is in turn behaviorally linearly correlated to TV. This is different from the neuronal responses in the deeper layers of the superior colliculus that have been shown to encode PE alone. The results suggest a role for FEF in integrating target velocity to program accurate saccades to moving targets.

Acknowledgement: Support: NIMH MH59244

6:00 pm

25.17 Functional differentiation of macaque visual temporal cortical neurons using a parameterized action space

Joris Vangeneugden[1] (Joris.Vangeneugden@med.kuleuven.be), Frank Pollick[2], Rufin Vogels[1]; [1]Laboratorium voor Neuro- & Psychofysiologie, K.U. Leuven, Leuven, Belgium, [2]Dept. of Psychology, Univ. of Glasgow, United Kingdom

Neurons in the rostral superior temporal sulcus (STS) are responsive to visual displays of body movements (Puce and Perrett, 2003). We employed a parameterized action space to determine the representation of action similarity by visual temporal neurons and the contribution of form versus motion information to their responses. The action space consisted of whole body recordings of arm movements from an actor performing 3 different actions and 18 in-between blends of these 3 actions. We recorded from 240 responsive temporal neurons in fixating monkeys. Multidimensional scaling analysis showed that responses represented the similarity between the actions. Further tests indicated two classes of neurons: neurons responding as strongly to static presentations as to actions ("snapshot" neurons), and neurons not responding to static presentations, but responding to motion ("motion" neurons). Unlike many "snapshot" neurons, "motion" neurons still responded when presenting the arm or wrist-point in isolation. The "motion" and "snapshot" neurons were found predominantly in the upper bank/fundus and lower bank of the STS, respectively. Most "motion" neurons showed modulation of their response during the course of an action which correlated partially with the end-effector speed variations during an action. Further analysis of the responses of the "motion" neurons to temporally reversed action sequences showed that other kinematic factors beside speed must contribute to their action selectivity. The responses to the action sequences of most "snapshot" neurons correlated with their response selectivity for static snapshots. "Motion" neurons displayed an on average greater selectivity for these simple dynamic actions than "snapshot" neurons, and the former represented the parameteterized action configuration more faithfully than the latter. We speculate that the upper bank/fundus STS "motion" neurons code for visual kinematics and therefore contribute to coding of visual actions, while the lower bank STS (and IT) "snapshot" neurons can code for posture.

Acknowledgement: FWO, GSKE, DIRAC and EPSRC

Saturday, May 10, 4:30 - 6:15 pm
Talk Session, Royal Palm Ballroom 4-5

Attention: Divided Attention

Moderator: Alejandro Lleras

4:30 pm

25.21 Quantifying the effects of sleepiness on sustained visual attention

Todd Horowitz[1,2] (toddh@search.bwh.harvard.edu), Jeremy Wolfe[1,2], Daniel Cohen[1,2], Charles Czeisler[1,2], Elizabeth Klerman[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

Sleepiness impairs many aspects of performance, but little is known about the effects on visual attention. While typical vigilance tasks require the detection of discrete signals, many important visual behaviors are continuous and cognitive in nature. We measured continuous visual attention using the extended multiple object tracking task (xMOT, Wolfe, Place, & Horowitz, 2007, Psychonomic Bulletin & Review). Eight identical disks moved on independent random non-overlapping trajectories. Participants tracked a subset of four target disks continuously for 7 minutes. At exponentially-distributed intervals (mean = 3 s), participants indicated whether or not a randomly selected probe disk was a target. Sleepiness can arise from extended time awake, adverse circadian phase, or sleep restriction. We analyzed accuracy data from six healthy participants during the forced desynchrony (FD) segment of a 38-day inpatient protocol. The FD procedure allows independent analysis of the effects of time awake and circadian phase. During FD, participants were awake for 32.9 hours and asleep for 10.0 hours for 12 cycles (21 calendar days). This wake:sleep ratio, equivalent to 5.6 hours sleep per 24 hours, produces chronic sleep restriction. The xMOT was administered every 2 h while participants were awake. Results: 1) Accuracy was significantly modulated by circadian phase (based on data from four participants), with a minimum near the melatonin peak (23.7% decrease in accuracy at the middle of the subjective night); 2) Accuracy was constant over the first 10-12 hours of the waking day, then decreased with increasing time awake (18.1% decline); 3) Finally, chronic sleep restriction significantly reduced participants' ability to focus on the tracking task: accuracy declined by 15% over the course of the FD segment. Schedules that do not allow for adequate sleep at the appropriate time impair the ability to sustain attention to visual stimuli. The xMOT method can quantify that impairment.

Acknowledgement: AFOSR 05NL123

4:45 pm

25.22 An interface between language and vision: quantifier words and set-based processing

Justin Halberda[1] (Halberda@jhu.edu), Tim Hunter[2], Paul Pietroski[2], Jeffrey Lidz[2]; [1]Johns Hopkins University, [2]University of Maryland

While limits of visual processing are interesting in their own right, these limits take on a deeper meaning where vision integrates with other cognitive systems. It is at this point that limits within vision become limits that can affect the whole of cognition. We present one such case. Subjects viewed briefly flashed arrays of 2-6 colors. Arrays always contained some number of blue dots among other dots. Subjects evaluated the verbal statement, "most of the dots are blue". The concept MOST requires subjects to evaluate whether the number of blue dots is greater than the number of non-blue dots, but there are multiple ways to specify what counts as a 'non-blue dot': Hypothesis 1, these items are specified directly as the 'yellow, green and red dots'; Hypothesis 2, these items are specified via a negation of the 'blue dots' (i.e. 'non-blue dots' are computed as 'all dots' minus 'blue dots'). Hypothesis 2 is consistent with prevailing linguistic theory for the word 'most'. We found that subjects behaved in accord with Hypothesis 2, selecting the blue dots and the superset of all dots. Psychophysical modelling revealed that subjects performed two operations: first taking the difference of two Gaussian numerical representations to compute the cardinality of the remainder set (superset – blue set = non-blue set) then comparing this computed Gaussian and the focused set to evaluate 'most' (blue set > non-blue set). These two steps add error to the discrimination and the Weber Fraction for evaluating 'most' was twice as large as that for evaluating 'more' in a similar task. That is, which word subjects thought they were evaluating changed the observed Weber Fraction for this essentially visual discrimination. This difference highlights a case where non-visual cognition (lexical meanings) impacts vision and visual limits (tracking multiple sets) constrain later cognition.

URL: http://www.psy.jhu.edu/~halberda/visionandcognition.html

5:00 pm

25.23 Neural correlates of inhibition to individual members of complex visual categories that have been recently rejected as distracting

Alejandro Lleras[1] (alleras@uiuc.edu), JeeWon Ahn[1], Brian Levinthal[1], Diane Beck[1]; [1]Psychology Department, University of Illinois at Urbana-Champaign

Recent work on inter-trial effects has shown that experience with a target-absent display can strongly modulate attentional selection on an upcoming trial by virtue of inhibiting the visual feature that defined the absence of the target. For example, if participants are looking for a color-oddball target, experiencing a trial in which all items are green will lead participants to inhibit selection of green items on a subsequent trial. This effect is known as the Distractor Previewing Effect (DPE). Prior research has shown that this effect can occur not only at the level of basic visual features but with fairly complex visual discriminations, as for instance, when participants are asked to find the odd-gendered face on a display containing male and female faces. Here, we extend these previous findings to show that the DPE can modulate responses to all members of a category that has been recently rejected and tagged as "distractor" and we examine the neural correlates that accompany this category-wide inhibition of attention. Participants were asked to find the "category oddball" in a display containing faces and houses. We chose these categories because of the well-known and distinct neural regions responsible for processing these stimuli. Behaviorally, we showed that responding to an oddball "face" target was delayed by 96 ms when "faces" had been tagged as distractors on the previous trial (compared to trials on which "houses" had been the tagged as distractors on the previous trial). Similarly, RTs to oddball "house" targets were slowed by 69 ms when "houses" had been recently tagged as distractors. This attentional inhibition was observed even though specific faces and houses where never repeated in the experiment, suggesting generalized category-wide inhibition. Using fMRI, we examined the correlates of this inhibition in the FFA and PPA, as well as fronto-parietal attentional control regions.

5:15 pm

25.24 Unconsciously triggered inhibitory control is associated with frontal brain potentials

Simon van Gaal[1,2] (s.vangaal@uva.nl), K. Richard Ridderinkhof[2], Johannes J. Fahrenfort[1,2], Victor A. F. Lamme[1,3]; [1]University of Amsterdam, Cognitive Neuroscience Group, Department of Psychology, [2]University of Amsterdam, Amsterdam center for the study of adaptive control in brain and behavior, Department of Psychology, [3]Netherlands Institute for Neuroscience, part of the Royal Netherlands Academy of Arts and Sciences

To obtain an understanding of the function of awareness, we need to know which cognitive functions are linked to conscious experience and which are not. We studied whether an unconscious –invisible- stimulus could trigger inhibitory processes. Inhibition is a high-level cognitive control function, in part mediated by the frontal lobes and commonly associated with consciousness. We developed a masked Go/No-Go paradigm, in which participants had to respond as fast as possible to a Go signal, but were instructed to withhold their response when they perceived a No-Go signal, preceding the Go-signal. In our version of this paradigm, the Go signal also functioned as a metacontrast mask, leading to undetectable No-Go signals at short SOAs, and perfectly visible No-Go signals at longer SOAs. During this task, EEG was measured to track the fate of masked No-Go signals in the brain. Behaviorally, masked No-Go signals sometimes triggered response inhibition to the level of complete response termination, as well as yielded a slow-down in the speed of responses that were not inhibited. In addition, EEG responses showed that masked No-Go signals elicit activation at fronto-central electrode sites where previous Go/No-Go studies found the largest inhibition related effects. Also, the amount of slowdown in individual subjects strongly correlated with the strength of the fronto-central EEG activity. These findings show that inhibitory control can be initiated by unconscious events. This challenges traditional views concerning the proposed intimate relationship between awareness and cognitive control and extends the limits of unconscious information processing.

5:30 pm

25.25 Motion induced blindness: The more you attend the less you see

Olivia Carter[1] (ocarter@wjh.harvard.edu), Robert Luedeman[1], Stephen Mitroff[2], Ken Nakayama[1]; [1]Vision Sciences Laboratory, Harvard University, [2]Center for Cognitive Neuroscience, Duke University

During motion induced blindness (MIB), visually salient objects vanish from awareness when presented on a background of coherent motion. Here we investigate the influence of item-number, group-number and attentional demand on the perceptual disappearance of individual stimulus targets. In Experiment One, 1-4 square targets (varying in color and angular rotation) were each presented centered within one of the four visual quadrants. Disappearance of a single target presented alone averaged 23.4% of the 40 second trials. Surprisingly, the total proportion of disappearance increased only moderately to 28.7% when the maximum number of 4 targets was presented, while the disappearance of any individual target, reduced by more than half to an average of 11.4% of the trial. In Experiment Two, the effect of group number was considered. In every trial, all 4 target squares were presented within the same quadrant. Targets defined as "in-group," shared feature properties (color, texture, proximity and alignment of border contours), "out-group" targets differed in respect to all features. Despite only moderate effects of the grouping cues (i.e., simultaneous disappearance of all 4 targets only increased from 0.5% when targets formed 4 out-groups to 2% when targets formed a single group), an increase in group number lead to greater total disappearance without any associated increase in the disappearance of the individual targets. In Experiment Three, we selectively manipulated attentional load with a central detection task. Subjects reported less disappearance of a single target in high attention conditions relative to fixation and low attention conditions. In all experiments, a simulated MIB condition ruled out the effect of task difficulty or response inaccuracy. Together these results indicate a striking paradox: the more attention allocated towards a target object, the more it will be suppressed from awareness. A number of mechanisms are considered to explain this surprising effect.

5:45 pm

25.26 Adaptation-induced blindness

Isamu Motoyoshi[1] (motoyosi@apollo3.brl.ntt.co.jp), Sayuri Hayakawa[2]; [1]NTT Communication Science Laboratories, NTT, [2]Department of Psychology, Boston University

It is well known that adaptation to high-contrast stimuli elevates the detection threshold for subsequently presented stimuli by about ten times (e.g., Blakemore & Campbell, 1969). Here, we demonstrate that adaptation to dynamic stimuli causes blindness for sustained stimuli in the peripheral visual field (5.9 deg eccentricity). After adaptation to a drifting grating (8 Hz), static gratings often become invisible even at 100% contrast when presented within a gradual temporal window, and the contrast thresholds (~3% before adaptation) become immeasurable. This did not occur for test stimuli with high temporal-frequency components such as drifting gratings, or static gratings presented within a rectangular temporal window. The blindness effect was still evident even when the adapting and test stimuli were presented to different eyes, and was rather enhanced when both were presented to the same eye (the uniform background to the other eye). These seem to imply involvement of inter-ocular suppression in addition to simple sensory gain control. Importantly, the static grating, which was invisible after adaptation, became clearly visible again when it was accompanied by a transient presentation of a surrounding annulus. This indicates that early neural units respond to the stimulus even if it is not consciously perceived. We interpret these results as a new class of visual rivalry that occurs between the uniform field and the local pattern in the peripheral visual field, wherein the form information cannot reach awareness if transient signals are completely lost by adaptation. We will discuss the underlying mechanisms in relation to those of the other phenomena, including binocular rivalry, Troxler effect, motion-induced blindness, and the edge-adaptation effect (Shimojo & Kamitani, 2001, VSS).

6:00 pm

25.27 Attentional learning: The role of distractor expectancy

Todd Kelley[1] (t.kelley@ucl.ac.uk), Nilli Lavie[1]; [1]Dept. of Psychology, University College London

Previous studies have shown that practice in performing a selective attention task leads to improvement in ignoring task-irrelevant distractor stimuli (Kelley & Yantis, 2007). Performance in a color discrimination task was hindered by the presence (vs. absence) of irrelevant distractor stimuli (e.g. images of objects); these distractor interference effects were diminished with practice. Moreover these practice effects were shown to transfer to previously unseen distractor stimuli (e.g. new object categories), suggesting improvements in a general mechanism for ignoring distractors.

Here we report experiments testing the role of subjects' expectations regarding the probability of distractor presence, using Kelley and Yantis's color discrimination plus irrelevant distractor paradigm. Overall the results show that the practice effects were robust to a change in the probability of the distractor presence following practice. This indicates that improvements in ignoring distractors generalize not only across visual properties of the distractor items, but also across expectations about probability of distractor presence. This work provides a new demonstration of a general mechanism of attentional learning.

Acknowledgement: This work was supported by the Welcome Trust (grant WT080568MA).

Saturday, May 10, 2:30 - 6:30 pm
Poster Session, Royal Palm Ballroom 1-3

Binocular Rivalry and Integration 1
Faces: Other-race Effects
Spatial Vision: Mechanisms 1

Binocular Rivalry and Integration 1

26.301 The stabilization of a binocular percept during intermittent presentation

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PURPOSE: When rivalrous stimuli containing luminance contrast are presented continuously to each eye, the percept alternates over time. When the same stimuli are pulsed on intermittently, however, the percept is stable (Leopold et al. 2002). A basic question is whether the stable percept during intermittent presentation is due to persistence of the response from one eye (Chen & He, 2004; Pearson & Clifford, 2004) or persistence of the percept. This study examines a binocular percept resulting from rivalrous equiluminant chromatic gratings, which give rise to form rivalry between the two eyes but with the colors within the form from both eyes (perceptual misbinding of color to form; Hong & Shevell, 2006). Is the binocular, misbound percept stable with intermittent viewing?

METHOD: A 2 cpd square-wave vertical grating was presented to one eye and a tooth-shaped vertically oriented grating (top half of grating phase-shifted by one-half cycle relative to bottom half) to the other eye. Each eye's stimuli were equiluminant (e.g., purple/white in one eye, green/white in the other eye). Initially, the stimuli were presented for a fixed period (several seconds) and then extinguished. Then they were presented for 0.5 sec every 2.5 sec (0.5 sec on, 2 sec off) for 1 minute.

RESULTS: When a binocular, misbound percept (misbinding of color to form) was last seen during the initial viewing period, the misbound percept was stabilized. When an inhomogeneous, piecemeal percept was last seen, a piecemeal percept was stabilized. When a monocular percept was last seen, the monocular percept was stabilized to some extent but much less so than reported with stimuli having high luminance contrast (e.g. Chen & He, 2004).

CONCLUSION: For equiluminant stimuli, which often result in a misbound or a piecemeal binocular percept, stabilization occurs at the binocular perceptual level.

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26.302 **The importance of static phase-aligned, high spatial frequency components for continuous flash suppression**

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Purpose: A strong interocular suppression occur when counter-rich patterns continuously flash to one eye [Tsuchiya N., & Koch, C. (2005) Nature Neuroscience, 8 (8), 1096-1101]. This is called the continuous flash suppression. Here, we examined which aspects of these patterns are important for the continuous flash suppression.

Methods: Observers viewed dichoptic images through a mirror stereo scope. Gabor patterns were presented as targets to one eye. Spatially filtered fractal noise patterns or checker board patterns were presented to the other eye with a flickering rate of 0 (no flicker) or 10 Hz. We measured contrast discrimination thresholds for targets across a range of monocular pedestal contrasts, with and without the dichoptic stimuli.

Results and Discussion: Flicker by itself was not very effective in dichoptic suppression, neither were the low spatial frequency components of our fractal noise. The high spatial frequency components contributed the major suppressive effect even though its lowest component was at least 2 octaves from the signal frequency. To test for the importance of phase alignments at high frequencies we compared phase-aligned and phase-scrambled high-pass checkerboards and show the former to be more effective. These results suggest that phase alignment of the high spatial frequency components is critical for the continuous flash suppression.

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26.303 **Incompatible local features are unnecessary for binocular suppression**

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It is generally assumed that binocular suppression is induced when two half-images have incompatible local features (e.g., orthogonal gratings). We report here a new observation where binocular suppression could be induced by half-images with similar local features. Experiment 1 employed a stereo display whose one half-image had a 3cpd vertical grating (4.5x4.5deg) and the other half-image had a 1.5deg disc with vertical grating that was surrounded by a spatially phase-shifted vertical grating (4.5x4.5deg). The phase shift created a monocular boundary contour (MBC) around the disc, and led to the percept of a stable disc separated in depth from the surrounding grating. We measured the increment contrast threshold of a monocular Gaussian probe upon the vertical grating at varying contrast levels (0.8-1.6 log unit) (TvC function). We found the TvC function to be higher in the eye viewing the vertical grating alone than in the eye viewing the vertical grating with the MBC disc, indicating suppression of the former eye (despite the two half-images having similar local features). Corroborating this, Experiment 2 using a spatial frequency difference (3 vs. 3.5cpd) to create the monocular MBC disc with vertical grating, also showed suppression in the other eye viewing only the vertical grating. These findings suggest the interocular inhibitory and stereo processes together form a stable 3-D percept, in which the grating within the disc matches with the vertical grating in the other eye to obtain depth while suppressing it from visual awareness. Finally, confirming the co-existence of binocular suppression and depth perception, we demonstrated that a monocular green grating disc on a binocular red grating background is mostly perceived at a different depth in green, rather than in a red/green color mixture or color rivalry. We conclude that besides local features, boundary contour information can trigger binocular suppression while supporting depth.

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26.304 **Faces Are Privileged Stimuli: The Effect of Stimulus Characteristics on Continuous Flash Suppression**

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Continuous Flash Suppression (CFS) is a technique to render stimuli presented to one eye invisible for prolonged periods (Tsuchiya and Koch, 2005). A constant visual stimulus is presented to the non-dominant eye while the dominant eye is presented with random flashing color patterns at about 10 Hz. The color patterns dominate perception, blocking the constant stimulus from conscious awareness. As in binocular rivalry, however, these constant stimuli eventually become consciously available. In our study, we presented subjects with four categories of stimuli under CFS: faces, inverted faces, cars and sine-wave gratings. They indicated their visual percept on each five-second trial by holding one key while consciously perceiving only the random patterns and holding another key while perceiving a stimulus. We found that faces became consciously available for a significantly higher percentage of the presentation time than other stimuli of the same size, luminance, and contrast. Upright faces were visible significantly more of the time than inverted faces. Both upright and inverted faces were visible significantly more of the time than cars and sine-wave gratings. This result suggests that the effectiveness of the CFS paradigm is affected by high-level stimulus characteristics, which raises questions about the nature of CFS suppression. On the other hand, assuming low level blockage of visual information under CFS, our finding might suggest low-level cortical representation of face specific features or parts.

26.305 **Voluntary attention can modulate eye-specific neural signals prior to the site of interocular competition**

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Visual attention can enhance the neural activity to an attended stimulus in many cortical areas. A central question in understanding the top-down modulating mechanism of attention is how early in the processing hierarchy attentional effects can be seen. Exogenous attention has been shown to affect processing of monocular signals, but it remains unclear whether voluntary endogenous attention could also modulate monocular neural signals in an eye-specific fashion. In this study, a monocular stimulus competed against high contrast continuous flash suppression (CFS) noise presented to the opposing eye, both centered on a fixation cross. Two identical monocular stimuli, one in each eye, were presented to the left or to the right of the competing stimuli. Subjects did not know which lateral stimulus was presented to the left eye and which to the right eye, but they were instructed to attend to one of the peripheral stimuli and press a key as soon as the central suppressed target emerged from suppression. Results show that the central suppressed stimulus took less time to emerge from suppression when observers attended to the flanking stimulus presented in the same eye than in the opposing eye as the detection target. Also, there is no reduction in the strength of this ocular-specific attention effect when the intensity of the peripheral stimulus was considerably decreased, thus ruling out the possible contribution of stimulus-related suppression from the peripheral attended stimulus to the central competing stimulus in the fellow eye. These findings suggest that voluntary (endogenous) spatial attention can selectively modulate neural signals at the eye-specific level of visual information processing, prior to the site of interocular competition.

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26.306 **Misbinding of color to form in afterimages follows from a persisting binocular neural representation**

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PURPOSE: Rivalrous orthogonal chromatic gratings can cause perceptual misbinding of color to form. The rivalrous forms alternate but the color from both eyes is perceived within the dominant form. Further, an afterimage of the misbound percept follows the misbinding experienced during rivalrous viewing (St.Clair, Hong, Shevell, VSS 2007). Here, two alternative hypotheses are tested for the origin of the misbound afterimage: (i) rivalrous monocular afterimages are resolved to give misbinding (as during rivalrous viewing) or (ii) persistence of a response from a binocular neural representation for the misbound percept experienced during viewing.

METHOD: The frequency of misbound percepts was measured during and following the presentation of two equiluminant, chromatically rivalrous gratings presented dichoptically. In the first condition, the rivalrous gratings were pulsed on and off simultaneously; this resulted in misbound percepts during viewing. In the second condition, the left-eye grating and right-eye grating were presented in alternation (first to one eye and then to the other eye but not simultaneously to both eyes). Over the course of the viewing period, retinal stimulation was the same in both conditions.

RESULTS: When the stimuli to the two eyes were pulsed simultaneously, color misbinding was experienced during viewing and in the afterimage. When the grating to one eye alternated with the grating to the other eye, no misbound percept was experienced during viewing or in the afterimage.

DISCUSSION: The absence of misbound afterimage percepts following the alternating presentation of gratings indicates that rivalrous monocular afterimages are not resolved to give a misbound afterimage. Instead, the percept of a misbound afterimage follows from a persisting binocular neural representation formed during rivalrous viewing.

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26.307 **Suppression during binocular rivalry broadens orientation tuning**

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Introduction: During binocular rivalry suppression an ordinarily visible stimulus is erased from awareness, but how is the sensory representation of that stimulus affected? While it is well established that contrast sensitivity is attenuated during suppression, the influence of suppression on stimulus tuning profiles remains unknown. Here, we examine the influence of interocular suppression on the gain and bandwidth of orientation tuning curves inferred by noise masking.

Methods: Two competing stimuli were viewed dichoptically: a bullseye and a random noise patch whose orientation content was varied. To control rivalry state, we used the flash suppression technique. Following flash-induced dominance/suppression, a small, vertically oriented Gabor patch briefly appeared within the noise patch, above or below fixation, and observers reported the probe's location (2AFC). To obtain perceptual tuning functions, we used an orientation-bandpass noise masking procedure in which the noise and probe ranged from being identical in orientation, to the noise orientations being orthogonal to the Gabor. An adaptive procedure produced estimates of contrast thresholds for the probe embedded within varying orientation bandpass noise, yielding tuning curves for conditions when the noise and probe were presented during suppression and during dominance.

Results: Besides the expected overall increase in contrast thresholds for suppressed probe stimuli, we discovered significant broadening of the tuning curve bandwidth under suppression. To rule out the possibility that this broadening was attributable simply to a decrease in the noise patch's contrast representation under suppression, we decreased the contrast of the noise patch and measured tuning under monocular nonrivalry, but this led to no change in tuning bandwidth. These results indicate that the discriminability of a suppressed stimulus under rivalry is degraded not only by a general decrease in signal strength, but also by degradation of neural events promoting tuning sharpness which effectively increases the noisiness of the suppressed stimulus representation.

26.308 **Binocular rivalry between fast 'streaky' motions deeply suppresses static orientation probes: Evidence for motion streaks**

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Aim: Do fast translating motions leave neural 'streaks'? We test this by measuring sensitivity to static oriented probes while fast 'streaky' motions engage in binocular rivalry.

Methods: Rivalry stimuli were orthogonally translating fields of Gaussian blobs, each with 80 high contrast blobs (40 dark, 40 light). Blob size was 0.22° (defined as 4xSD). Fast and slow speeds were compared: 8.6°/s (4 dot-widths per 100ms, therefore 'streaky') and 2.15°/s (0.5 dot-widths per 100ms). To measure rivalry suppression depth, monocular probes were presented to the dominant or suppressed eye, using a temporal Gaussian profile to avoid transients (FWHM=60ms). Probes were noise patterns, either orientation-filtered (SD=7.5deg) or iso-oriented, and spatially low-pass filtered to match the motion stimuli. On each trial, the task was to indicate whether the randomly chosen probe was oriented or not. In separate blocks, the oriented probe was parallel to or orthogonal with the motion in the probed eye. Probe contrast was varied adaptively using Quest to find detection thresholds.

Results: For fast motion, suppression depth (one minus the ratio of dominance-to-suppression thresholds) was strongly orientation-dependent. Oriented probes aligned with the motion 'streaks' were significantly more deeply suppressed than were orthogonal probes. There was no orientation dependency at slow speeds. Overall, suppression depths for static oriented probes in motion rivalry were typical of other rivalry suppression studies (~0.5 log unit), except for the parallel probe in the fast condition, where suppression was twice as great (~1.0 log unit).

Conclusion: The high-speed orientation dependency suggests fast motions do leave behind neural steaks, due to temporal integration. Thus, the high-speed condition would have involved rivalry between orthogonal motions and orthogonal orientations. The extra suppression in the fast parallel condition is probably due to the combined effects of suppression across both dimensions. Thus, rivalry suppression appears to sum across orientation and motion domains.

26.309 **How emotional arousal and affect influence access to visual awareness**

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Emotional stimuli attract attention and potentiate the effect of attention on contrast sensitivity, a feature of early vision. The amygdala, a key structure in emotional processing, responds to emotional content prior to awareness and projects to visual cortex. In light of evidence that the primary visual cortex does not have direct access to awareness, we hypothesize that emotion can affect the processing of a visual stimulus even before awareness. Moreover, emotion varies along at least two dimensions: arousal and affect (valence). Dissociating their effects is important to understanding the link between emotion and perception.

We examined these effects in binocular rivalry. Pairs of images (54 total) were selected from a known database of natural images (IAPS). Pictures of a pair differed significantly along only one emotional dimension, creating two types – iso-valence and iso-arousal pairs. Pictures of a given pair were presented side by side in a rivalry setup for trials lasting 1 min. each. The duration for which each eye's image was dominant in a trial (dominant phase duration) was obtained from 12 observers. Our results showed:

–A main effect of arousal: The dominant phase durations for more arousing pictures of the iso-valence pairs were significantly longer than those for the less arousing pictures.

–No main effect of affect: The dominant phase durations of pleasant and unpleasant pictures of iso-arousal pairs did not differ significantly.

–An interaction between arousal and affect: For low arousal-level stimuli, the more pleasant image of the pair dominated significantly. In contrast, for high arousal-level stimuli, the more unpleasant image dominated significantly.

Our findings suggest that the limbic system acts on visual signals early in processing. While emotional arousal and valence interactively affect access to visual awareness, only arousal exerts an independent control of such access.

26.310 **Pupillary response to grating patterns during permanent suppression**

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[Purpose] By presenting a high-contrast grating to one eye, stable ocular dominance can be produced and a stimulus subsequently presented to the other eye would be phenomenally suppressed (permanent suppression). In the previous study, we showed that the pupillary responses to color and luminance changes were significantly attenuated during permanent suppression and suggested that the pupillary responses can be used as an objective index to evaluate interocular suppression (Kimura et al., VSS2007). The present study extended our previous work and investigated how the pupillary responses to grating patterns were affected during permanent suppression.

[Methods] The pupillary response was recorded under both permanent- and no-suppression condition. Permanent suppression was produced by presenting a 10° high-contrast vertical sinewave grating flickered in counterphase at 5 Hz to the right eye. During continuous dominance of the suppressing grating, a test grating of the same size and orientation was presented to the left eye for 400 ms. Spatial frequencies of the suppressing and test gratings were 0.5 or 2.8 c/deg. During the measurement, a 12° white background field of 4 cd/m2 was always presented to each eye. Under the no-suppression condition, only the test grating was presented to the left eye.

[Results and Discussion] The pupillary responses to grating patterns were largely suppressed during permanent suppression. The response amplitudes were reduced over a wide range of test contrast and the responses were generally delayed relative to those under the no-suppression condition. However, the magnitude of the suppressive effects did not clearly depend upon spatial frequency particularly when the test grating of 2.8 c/deg was used. In contrast, the sensitivity loss evaluated with psychophysical detection thresholds was highly selective to spatial frequency. These findings suggest that the visual mechanisms mediating the pupillary suppression are at least partially different from those underlying the perceptual suppression.

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26.311 **Integration of color and pattern investigated with visibility modulation of chromatic gratings**

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[Purpose] Visibility of rivalrous flashes can be modulated by presenting a preceding stimulus (visibility modulation, VM). Previously, we showed that the characteristics of VM were different for color and pattern stimuli and suggested that dominance and suppression of rivalrous binocular inputs are determined in distinct fashions for color and pattern (Abe et al., VSS2007). The present study investigated VM with chromatic gratings to explore how color and pattern are integrated in the visual processes mediating VM.

[Methods] The rivalrous test stimulus was composed of green/gray right-tilted and red/gray left-tilted square-wave gratings of 2 c/deg presented dichoptically on a black background (0.1 cd/m2). Mean luminance of the stimulus was 4 cd/m2 and luminance contrast was 90 or 0 %. The preceding stimulus was identical to one of the test stimulus in the same-combination condition, whereas color from one of the test stimulus was combined with pattern from the other in the different-combination condition.

[Results and Discussion] When luminance contrast was high, the color-pattern combination in the preceding stimulus strongly affected how VM occurred: Stimulus-based VM was observed under the same-combination condition (i.e., the test stimulus of the same attributes was phenomenally suppressed by the preceding stimulus), while eye-based VM was observed under the different-combination condition (i.e., the ipsilateral stimulus was suppressed). On the other hand, when the gratings were isoluminant and the test duration was long, the effect of the color-pattern combination was much reduced and the results could be mostly explained by color-based VM. Moreover, when the test duration was short, VM became eye-based and misbinding of color and pattern (e.g., red/green stripe) was also often observed. These findings suggest that VM for color, pattern, and the combination of the two can be determined in different fashions, which is consistent with the contribution of competition interactions at multiple neural sites.

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26.312 **Bi-stable perception and neural competition at equi-dominance and away from it**

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When a stimulus supports two distinct interpretations, perception alternates haphazardly between them. fMRI studies that revealed large concurrent changes in the activity of neural populations associated with the competing percepts used stimuli where each interpretation was dominant for roughly half the time ('equi-dominance'). Yet, parametric stimulus modifications can change the relative strength of the competing interpretations, and consequently the fraction of time observers spend in each. What are the neural correlates of such changes in the 'balance of powers'?

We recorded fMRI activity while observers viewed moving plaids - which produce alternations between the perception of a single moving surface ('coherency') and two gratings sliding over each other ('transparency') - and continually indicated their perception. By varying the angle between the directions of motion of the constituent gratings we controlled the relative strength of the two interpretations. Three different values yielded displays that gave rise to a 'transparent' percept 25%, 50%, and 75% of the time, in separate runs of 5 min each.

Similarly to findings in other bi-stability domains, at equi-dominance, marked anti-phase activity changes locked to perceptual alternations were found in early visual cortex: increases in the V1-V3 and KO during coherency and in the right LO during transparency. Surprisingly, away from equi-dominance (at 25% and 75% transparency) voxel-by-voxel analysis did not reveal activity changes in the same early visual areas during perceptual alternations; ROI analysis showed only modest changes. By contrast, more anterior cortical regions showed strong perceptually-related modulations in all cases. Away from equi-dominance, activity rose during perception of the weaker interpretation in the right STS and bilaterally around the IPS and PCS. At equi-dominance, activity rose in extensive regions in the anterior lef- and right-hemispheres during perception of the stronger and weaker interpretations, respectively. Neural correlates of perceptual competition therefore differ at equi-dominance and away from it.

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26.313 **Rotating walker: An ambiguous biological stimulus reveals biases in human vision**

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Ambiguous structure-from-motion stimuli have been used by vision scientists for many years in studying conscious visual awareness. We have recently developed an ambiguous, rotating, biological figure; the 'rotating walker' appears to randomly alternate between walking in clockwise and counter-clockwise directions (Jackson et al., 2007, Perception, 36, 74). As with other ambiguous figures, observers experience high rates of percept-reversal when the figure is viewed over long periods, and this 'multistability' disappears when blank intervals interrupt the trial period; observers consistently stabilise to one or other percept. What may be unique to the rotating walker is the fact that it represents a 'biological' form – when the walker is presented at right angles to the viewer at onset, the initial direction of rotation is often interpreted as that which is compatible with an 'approaching' or 'forward-moving' figure. Such an effect is consistent with perceptual biases previously found with standard biological motion stimuli (Vanrie et al., 2004), and may reflect the working of a fast-acting perceptual "life-detector" mechanism suggested to exist in the human visual system (Troje & Westhoff, 2006).

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26.314 **Pupil dynamics during bistable form/motion binding**

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Endogeneous modification of the perception of otherwise unchanging visual stimuli, so called perceptual bistability, provides a heuristic to uncovering the cerebral networks of consciousness and awareness. Searching for physiological correlates of bistable perception, we recorded pupil variations during perceptual reports of bistable moving stimuli. Our findings reveal a modulation of pupil diameter tightly witnessing perceptual changes and motor decisions. Pupil dilates ~300 ms before a button press signalling a flip from one perceptual state to another. Pupil dilation thus reflects a, yet unreported, change in phenomenal consciousness. Dissecting the perceptual, decisional, attentional and motor components of pupil activity in additional experiments, we found that the dynamics of pupil dilation is different with endogenously and exogenously driven alternations and has a strong motor component. Pupil diameter being controlled through sympathetic and parasympathetic antagonist activity, pupil dilation thus reveals the implication of subcortical structures during reports of bistable perception and opens a window to studying their activity. As changes in pupil size have the potential to activate retino-cortical pathways through changing retinal illumination, pupil dynamics should be taken into consideration when analysing cerebral activity recorded with imaging techniques, either to ensure that it is not the cause of the recorded signals, and/or to improve the signal-to-noise ratio.

26.315 The role of frontal areas in alternations during perceptual bistability

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When viewing ambiguous visual stimulation, observers may experience perceptual competition wherein mutually exclusive perceptual interpretations compete for dominance over time. When contrasted with 'replay' conditions, in which unambiguous stimuli evoking these perceptual interpretations are physically interchanged over time, ambiguous alternations lead to activation of a large network of occipital, parietal and frontal cortical regions. The brain, in other words, responds uniquely when invariant physical stimulation leads to perceptual fluctuations.

Using functional magnetic resonance imaging (fMRI), we investigated the roles of separate elements of this network of cortical regions using a bistable apparent motion stimulus, in which a sinusoidally counterphased spiral figure induces one of two distinct rotational motion percepts over time. Additionally, during the course of an extended observation period, transitions between motion percepts are occassioned by periods of non-directional flicker perception that cannot be realistically simulated in replay presentations; the incidence of these periods of indistinct motion increase with prolonged viewing, suggesting the involvement of neural adaptation.

During whole-brain fMRI scans performed at 3T, observers pressed buttons to indicate periods of clear motion perception and periods of flicker perception. Contrasting these two types of events, we could distinguish activity in various brain regions associated with perceptual transitions from one motion percept to the other, from motion to flicker and from flicker to motion. These contrasts revealed that frontal areas respond to the onset of flicker, whereas parietal regions respond preferentially to the onset of motion percepts.

These results shed new light on the different roles played by cortical areas previously implicated in perceptual rivalry. Specifically, we propose that the activity in frontal cortex is associated with periods of perceptual uncertainty that can occur during transitions between rival states.

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26.316 Can noises defeat will power in Necker cube reversals? Equating top-down influence with bottom-up bias with a noise paradigm

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Purpose. A recent study (Meng & Tong, 2004) indicated attention can selectively bias the intended percept for ambiguous figures (i.e. Necker cube) but not binocular rivalry displays. For Necker cubes, attentional control (or "top-down" influence) may operate by enhancing the desired representation, or suppressing the alternative representation. In addition, low-level cues (or "bottom-up" influence) such as eye fixation can also boost the desired percept by increasing the stimulus strength. However, the magnitudes of top-down vs. bottom-up influences on Necker cube reversals have rarely been compared in the past. Our present goal is to directly compare the magnitude of top-down vs. bottom-up influence with a random noise paradigm.

Methods. The Necker cube (width= 7°), with a red fixation crosshair (= 0.3°) in the center, was presented on a black background of Acer 17" LCD monitor. Experiment 1 measured bottom-up influences in 28 naïve observers with passive viewing. The strength of bottom-up cue was manipulated by adding 0%-99% random noises exclusively in the lower square (biasing the "top-view" percept) or the upper square (biasing the "bottom-view" percept). Observers received 27 trials in a mixed order (9 conditions × 3 repeats). Experiment 2 measured the extent of selective attentional control over the 0 % noise Necker cube in the same observers. Three instructions were given: (1) passive viewing; (2) perceive the cube from top; and (3) perceive the cube from bottom. In each 20-s trial, observers were instructed to maintain fixation while monitoring their perceptual state and reported perceptual switches by pressing one of two keys.

Results. First, the percentage of dominance duration of a percept increased reliably as a function of the noise density. Second, the attentional modulation was significant. Third, the magnitude of bottom-up cue was comparable to that of attentional modulation and was affected by the individual's initial bias.

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Faces: Other-race Effects

26.317 Face recognition algorithms and the "other-race" effect

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Human face recognition is more accurate for faces of one's own race than for faces of other races. The purpose of this study was to determine whether face recognition algorithms show an "other-race effect". We tested 13 algorithms from a recent international competition: eight from Western countries (France, Germany and the United States) and five from East Asian countries (China, Korea, and Japan). The algorithms were required to match facial identity in pairs of images (a controlled illumination image and an uncontrolled illumination image). We first assessed algorithm performance on Caucasian (n = 3,359,404) and East Asian (n = 205,114) face pairs at the low false alarm rates required for security applications. Algorithm performance was measured by fusing the East Asian algorithms and the Western algorithms separately. The Western fusion algorithm recognized Caucasian faces more accurately than East Asian faces and the East Asian fusion algorithm recognized East Asian faces more accurately than Caucasian faces. Next, we carried out a direct comparison between humans of Caucasian and East Asian descent and the face recognition algorithms. In this case, we used a manageable number of face pairs (40 East Asian and 40 Caucasian pairs) and employed a more general test that considered performance across the full range of false alarms. For humans, we found the standard other-race effect. However, both the East Asian and Western fusion algorithms performed better on Caucasian faces—the "majority" race in the database used in the competition. The performance advantage for Caucasian faces was substantially larger for the Western fusion algorithm than for the East Asian fusion algorithm. We discuss these results in the context of the short-term and long-term perceptual tuning (algorithm training) that may underlie the pattern of results. We conclude that algorithms can show the other-race effect under some conditions.

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26.318 Two faces of the other-race effect: Recognition and categorization of Caucasians and Chinese Faces

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The other-race effect is a collection of phenomena referring to the difference in processing faces from one's own race or other races. A plethora of research has found a disadvantage in recognition of other-race faces, which should be referred to more precisely as the other-race recognition effect (for a review, see Meissner & Brigham, 2001). Paradoxically, when categorized by the race other-race faces exhibit an advantage in reaction time, which should be referred to as the other-race categorization effect (e.g. Valentine & Endo, 1992; Levin, 1996, 2000). This mirror pattern for other-race faces processed in different tasks has only been investigated in separate studies, with significant differences in their participants, stimuli, and experimental designs. To address this question, in the present study we used a uniform, balanced design to examine the two other-race effects in Caucasian and Chinese subjects. Participants were asked to either recognize 32 learned faces mixed with 32 unlearned faces, or to make a race judgment to another 64 faces. The faces are selected from one face base, with equal chance to appear as learned or unlearned in the recognition or in the categorization task. The stimulus presentation and response are kept the same between tasks. In line with previous reports, in both groups other-race faces were less accurately and slower recognized whereas faster categorized by race. Furthermore, a significant positive correlation between the sizes of the two effects was found across participants with a hierarchical regression model, after controlling for the difference in overall reaction time. The present results suggest that the other-race recognition and categorization effects may share a similar underlying processing mechanism as suggested by Levin (1996). Also, both categorization and individuation are perhaps two integral processes involved in face processing, consistent with the view of the in-group/out-group model (Sporer, 2001).

26.319 **Potent features for the categorization of Caucasian, African American, and Asian faces in Caucasian observers**

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What is the information mediating race categorization? Here, we applied the Bubbles technique (Gosselin & Schyns, 2001) to reveal which areas of faces at five different spatial scales are efficient for race categorization in Caucasian participants. We asked 30 participants to categorize 700 "bubblized" faces selected randomly from sets of 100 male Caucasian faces, 100 male African American faces, and 100 male Asian faces. All face photos were normalized using SHINE, a new Matlab algorithm for luminance and power spectrum equalization (Willenbockel et al., in preparation). Separate multiple linear regressions between information samples and accuracy were performed for each race. The resulting classification images reveal the potent features for the categorization of Caucasian, African American, and Asian faces in Caucasian observers. For African American faces, the participants used mainly the nose and the mouth in the spatial frequency (SF) bands ranging from 10 to 42 cycles per face width. For Asian faces, they used the eyes in the SF bands ranging from 10 to 84 cycles per face width and the mouth in the SF band ranging from 5 to 10 cycles per face width. For Caucasian faces, they efficiently employed the eyes in the SF bands ranging from 5 to 21 cycles per face width as well as the mouth and the region between the eyes in the second highest SF band ranging from 21 to 42 cycles per face width. Interestingly, and congruently with the results of Smith et al. (2005), we observed almost no overlap between the information used for each stimulus category.

26.320 **Seeing beyond faces: the social significance of being an other-race expert**

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People show superior recognition memory for same-race (SR) as compared to other-race (OR) faces, an advantage termed the Other Race Effect (ORE) (Malpass & Kravitz 1969). Of course, faces carry a great deal of content beyond their identity, including both affective and social information. Using a combination of techniques, we investigated how the ORE interacts with social judgments of SR and OR faces. In this context, we consider the ORE to be an example of fine-grained perceptual expertise. That is, the differential perceptual response to SR and OR faces arises due the degree of personal exposure to these separable visual classes (Bar-Haim et al., 2006). Thus, we can ask more specifically whether perceptual experience with socially relevant stimuli modulates social processing. A two alternative force choice task measured recognition memory for SR and OR faces, revealing an own-race advantage for both African American and Caucasian subjects. This finding is supported by differences in the neural responses arising from SR as compared to OR faces. The social evaluation of SR and OR faces was assessed using an affective priming technique in which lexical decisions on positive and negative words were differentially primed depending upon the race of the face used as a prime. To further understand these biases in terms of visual expertise, we trained Caucasian subjects to expertly individuate OR faces. Along with affecting the recognition of OR faces, training interacted with social processing. This study reinforces the hypothesis that visual expertise accounts for the perceptual advantage for OR face recognition. Moreover, it suggests that the social information we extract from a face is influenced by these basic perceptual metrics. Critically, to the extent that these phenomena are malleable, we should be able to observe concurrent changes in neural structures underlying these perceptual and social mechanisms.

26.321 **Other-Race Faces: Limitations of Expert Face Processing**

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Adults' expert face recognition is better for the kinds of faces they encounter on a daily basis (typically upright human faces of the same race). Adults process own-race faces holistically (i.e., as a gestalt) and are sensitive to small differences among faces in the spacing of features and in the appearance of individual features. Various tasks are used to measure each of these components of face processing in the literature; for example, the composite face task and the part/whole task are used interchangeably as measures of holistic processing. To measure the specificity of adults' expertise we administered a battery of five tasks comprised of Caucasian and Chinese faces to two groups of participants: Caucasian adults (n=31) living in rural Pennsylvania and Chinese adults (n=32) living in Guangzhou who had minimal exposure to other-race faces. The battery included one measure of memory for faces, two measures of holistic processing (composite face task, part/whole task), and two measures of sensitivity to spatial and featural cues (Jane/Ling task, scrambled/blurred task). The race of face x race of participant interaction was significant in three conditions: the memory task, one measure of featural processing (Jane/Ling task) and one measure of spatial processing (blurred faces task), all ps<.02. There was no interaction in either measure of holistic processing (composite face task, part/whole task) or in the other measures of featural (scrambled faces task) and spatial (Jane/Ling task) processing, ps > .10. These results indicate that adults process both own- and other-race faces holistically, but are less sensitive to the spacing of features and the appearance of individual features in other-race faces, at least under some conditions. Surprisingly, individual scores on the three pairs of tasks designed to measure the same aspect of face processing were not correlated (ps>.20), indicating that they may be tapping different processes.

26.322 **It's more than just physical: The contribution of social category information to race-selective face aftereffects**

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Opposite changes in perception (perceptual aftereffects) can be simultaneously induced for faces from different social categories—for example, Chinese and Caucasian faces (Jaquet, Rhodes & Hayward, in press), or male and female faces (Jaquet & Rhodes in press; Little, DeBruine & Jones, 2005). We investigated whether these aftereffects are generated in high-level visual coding that is sensitive to the perceived face representation (or the social category) of the faces, or in earlier visual coding that is sensitive only to simple physical differences between faces. We created face continua ranging from SuperCaucasian faces (caricatured Caucasian faces) to SuperChinese faces (caricatured Chinese faces). Seventy-six Australian Caucasian participants and 72 Hong Kong Chinese participants were adapted to oppositely distorted (contracted or expanded) face sets that were a fixed physical distance apart on the morph continua. The adapted sets either crossed the race category boundary (Chinese and Caucasian faces) or did not (SuperCaucasian and Caucasian faces or SuperChinese and Chinese faces). Larger opposite aftereffects were found when the adapted sets crossed the race category boundary than when they did not. These results suggest that opposite aftereffects for Chinese and Caucasian faces reflect the recalibration of neurons tuned to high-level face information rather than simple physical face differences. An effect of expertise was also found. Opposite aftereffects could be induced for visually distinct sets within the participants own race (e.g., SuperCaucasian and Caucasian faces for Caucasian participants), but not for other-race face sets (e.g., SuperCaucasian and Caucasian faces for Chinese participants). We discuss the implications of these results for the representation of faces in face space.

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26.323 **Traditional facial tattoos disrupt face recognition processes**

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Presentation changes can potentially disrupt the ability to efficiently process faces. Specifically, inverting faces has long been known to disrupt configural processes leading to deterioration in recognition performance, as does scrambling, exploding, and misaligning face images. Unlike most changes in facial appearance (e.g. hairstyle), which involve feature changes, extensive facial tattoos are likely to involve configural changes as well. Here we show that the application of facial tattoos, in the form of curvilinear lines and spiral patterns (typically associated with the Maori tradition of Moko), disrupt face recognition to a similar extent as face inversion, with recognition accuracy little better than chance performance (2AFC). These results indicate that, unlike most other modes of altering our facial appearance, facial tattoos can severely disrupt our ability to recognise a face that previously did not have the pattern. This occurred for faces that were fully patterned and for those faces that were only partially patterned (i.e. forehead, nose, and chin). Given that there is a resurgence of interest in traditional facial markings and that tattoos continue to become increasingly more accepted in the West, these results raise issues as to how would-be wearers and their associates can best evaluate and prepare themselves for such a dramatic transformation!

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Spatial Vision: Mechanisms 1

26.324 **Thin films as spectacles and contact lenses for aberration-corrected vision via brain adaptation to contrast**

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Our aim was to develop special spectacles and contact lenses capable of solving common refractive errors such as myopia, hyperopia and regular and irregular astigmatism, as well as other accommodative insufficiency states (e.g., presbyopia), by exploiting brain's capability to adapt to contrast. Normally, these refractive errors are treated with adjusting a refractive correction. The method we used was adapting a special all-optical extended depth of focus concept taken from digital imagery. Special thin phase-only binary mask containing annular-like spatially large structures was developed to provide extension of the focus depth. This creates a "funnel" in the retina plane that is insensitive to defocus. The image is shown with no reduction of the spatial spectral content but with a reduction of the imaging contrast. Due to brain adaptation, the contrast reduction is corrected and brought into the normal (standard) range.

Here we present experimental bench results as well as preliminary clinical trials. The clinical testing included measuring the visual acuity under different illumination conditions (pupil size varied from 2 to 4 mm), as well as stereoscopy, color vision and contrast sensitivity. In the optical bench, the optical element showed an extension of 2.5 Diopters. In the clinical tests, we found an improvement of up to 3 Diopters in presbyopic subjects for pupil sizes of 2 to 4 mm and improvement of more than 2 Diopters for regular and irregular astigmatism.

The high-level performance of the proposed element, including the high contrasted quality vision is obtained due to the brain contrast adaptation capability since similar element in a digital imaging system exhibited visible reduction in contrast.

26.325 **The Visual Phantom Illusion Originates in "Higher" Cortical Areas, not V1**

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When two synchronized moving gratings are separated by a gap, and oriented along the axis connecting the gratings, faint bars are perceived in the gap (Tynan & Sekuler, 1975). One recent functional magnetic resonance imaging (fMRI) study reported that this visual phantom illusion emerges in early visual areas (i.e., V1 and V2) (Meng et al., 2005). However, it is possible that the visual phantom illusion emerges in higher visual areas (undetected by this recent study because of the larger point-spread function of these higher areas) with feedback as a potential explanation for the activation found in V1and V2. Here we used a simple psychophysical method to test this hypothesis. We predicted that if the visual phantom illusion originates in V1/V2, then no phantom should be perceived when one grating is presented in the left visual field and one in the right visual field. Our reasoning is as follows. First, note that in the absence of visual feedback, neither V1 representation can "know" about more than one of the gratings, because i) visual areas V1 and V2 in each hemisphere get bottom-up input only from the contralateral visual hemifield, and ii) no direct connections exist between the two hemispheres in V1 and V2, except for visual information presented approximately 2-3° around the vertical meridian. Second, a single grating is not sufficient to produce the illusion. We found that visual phantoms do, in fact, occur across hemifields. Furthermore, the across-hemifield phantoms are equally strong, and exhibit the same properties as documented in the literature. Thus, we conclude that the visual phantom illusion emerges in "higher" visual areas, and not V1. These findings suggest a critical role of the top-down processes in the constructive nature of visual perception.

26.326 **Two Contrast-Adaptation Processes: One Old, One New**

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We recently discovered an adaptable contrast comparison process (which we sometimes call "Buffy adaptation"). At each spatial position in a visual pattern, a contrast comparison level continually and rapidly (less than 1 sec) updates to equal the recent average contrast. The current contrast is then processed relative to that level, without regard to sign (in a second-order task such as ours). This process acts in concert with a previously known contrast-gain control of the normalization type.

The patterns in the current experiments are 2x2 grids of Gabor patches (windowed sinusoidal grating patches; approximately 2 cpd; presented at fixation). The adapt pattern – a grid of Gabors all at the same contrast – is shown for 1 sec, and then a test pattern is shown for 94 msec, and then the adapt pattern is shown again for 1 sec. The test pattern is horizontal (or vertical) contrast-defined stripes: the Gabors in the first row (or column) have contrast C1 and those in the second row (or column) have contrast C2. The task of the observer is to identify the orientation of these stripes.

The results curves have a "butterfly" shape (like an upside-down "W") when plotted as percent correct identification versus average test contrast (average of C1 and C2). When the average test contrast equals the adapt pattern's contrast, performance is poor (butterfly's center). If the average test contrast is increased or decreased while keeping the difference between the two test contrasts constant (e.g. |C2-C1|=10%), performance improves (butterfly's wing's inner edges) and then declines again (butterfly's wing's outer edges).

These results are an interaction of (1) the adaptable contrast comparison process, producing the poor performance at the butterfly's center, and (2) the normalization type process, producing the declines on the outside edges of the butterfly's wings.

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26.327 **Contrast Discrimination in Noise and Classification Images**

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Studies of the effects of noise have been useful in understanding pattern perception, but the form of TvC functions in noise is not established, and models do not account for all the facts (Pelli, 1985; Legge, Kersten & Burgess, 1987). We measured TvC functions for a small Gaussian spot and a narrow 4 c/deg Gabor pattern in 0, 0.44, and 1.77 microdeg2sec static noise. There were three observers. TvC functions decrease and then increase as pedestal contrast increases. Noise both increases thresholds and changes the form of the TvC function. As noise level increases the pedestal contrast at which the threshold is minimum increases causing the functions to come together and often cross at high contrast. So there is a range of high contrasts over which noise has essentially no effect or a facilitatory effect. These data are well described by an extension of a model designed to account for the effect of dissimilar pattern masks (Foley, 1994). In this model the noise not only adds variance to the visual signal, it also produces a divisive inhibitory input to the detecting mechanism resulting in a change in the form of the response function which steepens it and shifts the most sensitive part of its range to higher contrast, thus overcoming the masking effect of the noise. To further examine the effects of noise, we determined classification images for the Gaussian spot for Cped = 0, threshold, and 0.25. The classification images had a center –surround form and were essentially the same except for a difference between the stimulus present and stimulus absent images in the 0 pedestal case. These images are consistent with our model and inconsistent with models in which the pedestal produces an equivalent noise sufficient to make the stimulus noise negligible.

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26.328 **Perturbation Analysis of Perceptual Templates**

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Purpose. Classification images enable estimation of the linear component of the decision statistic (aka the perceptual template (PT)) used by observers in making a given type of judgment. However, this method is inefficient because the expected correlation of the PT with any given noise sample is low. We introduce a more powerful method. Method. Suppose (1) the task is to detect a target T and (2) the PT for this task seems likely to project strongly into the space P spanned by orthonormal images P1, P2,…, Pn (all orthogonal to T). In addition, Let X1, X2,…, Xm be a fixed set of orthonormal noise images spanning space X, orthogonalized with respect to T and all of the Pk’s. Let a be the threshold for detecting aT in a random linear combination of the Xk’s. Then for b small enough that perturbations are not noticeable, we measure performance at detecting each of aT+bPk and aT-bPk (in the same kind of noise). Performance in these 2n conditions is used to (1) estimate the projection of the PT into P (which should be large), (2) estimate the projection of the PT into X (which should be small), (3) test whether the PT accounts for performance, and if not (4) estimate a quadratic component of the decision statistic. We used this method to derive the projection into a 6-dimensional space of the PT for a task requiring the observer to detect a Gaussian blob in noise. Results. The PT deviated significantly from T; more interestingly, the linear model embodied by the PT was rejected; the decision statistic involved a significant quadratic component. Conclusions. Because the space of stimuli explored using perturbation analysis is only n+m+1 dimensional, this method enables stronger inferences than classification images given the same amount of data.

26.329 **Cross-talk between luminance-defined and contrast-defined detection processing revealed by asymmetric lateral spatial interactions**

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Lateral spatial interactions between stimuli defined by different characteristics can reveal independence or otherwise, of processing streams.

Foveal detection thresholds for luminance-defined and contrast-defined blobs in the presence of fixed modulation, laterally placed blobs (separations of 0 – 6 deg) were measured in 4 observers with normal vision. Blobs were constructed by adding or multiplying random-dot dynamic noise with a Gaussian (sd = 0.25 deg and 0.5 deg).

Detection thresholds measured for luminance-defined blobs placed between highly visible (~10x threshold) luminance-defined flankers (111) and for contrast-defined blobs placed between highly visible contrast-defined flankers (222) produces a similar pattern of lateral interaction effects. Threshold elevation occurs for overlapping blobs, however when they are completely separated by 1-3 deg (4-12 sd units) there is facilitation where thresholds are about 20-50% lower than when no flankers are present. The region of facilitation is not consistently matched by shallow psychometric function slopes.

Detection thresholds measured for luminance-defined blobs placed between highly visible contrast-defined flankers (212) are relatively raised for separations of 0.5 to 2 deg with otherwise minimal or facilitatory effects for all other separations. For detection thresholds measured for contrast-defined blobs placed between highly visible luminance-defined flankers (121), relative facilitation occurs in this region. However psychometric function slopes for both mixed conditions show similar patterns with steeper slopes in the 0.5-2 deg separation region ($\beta \sim 2.5$) compared to those found for thresholds measured without any flankers ($\beta \sim 1$-1.5).

These findings favour a model with two parallel processing streams for the detection of luminance-defined and contrast-defined targets, rather than a single stream. They also suggest that there is some cross-talk between these streams. Neural contributions must be considered, as uncertainty reduction due to the presence of visible flanking blobs, cannot consistently explain facilitation effects.

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26.330 **Detecting overlapping luminance-defined and contrast-defined stimuli: cue combination for better detection?**

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Dipper functions are valuable tools for investigating visual sensitivity to various stimulus combinations. Previous studies using luminance-defined and contrast-defined stimuli have measured dipper functions using interleaved static stimuli.

In this study, luminance-defined and contrast-defined noise blobs were constructed by adding or multiplying random-dot dynamic noise with a Gaussian (sd = 0.25 deg). Test and pedestal blob stimuli were combined on a single frame and the noise varied dynamically to randomise any luminance clumping cues. Thresholds obtained for these stimuli were compared to those combined neurally, i.e. where test and pedestal stimuli were placed on interleaving frames and presented dichoptically. Foveal detection thresholds for luminance-defined and contrast-defined blobs were measured in the presence of luminance-defined and contrast-defined pedestals.

When detecting a luminance-defined blob on a luminance-defined pedestal monocularly, a classical dipper shape of threshold versus pedestal visibility is obtained. Facilitation occurs for pedestals close to the detection threshold and masking, for higher pedestal amplitudes (exponent ~0.6). Thresholds for detecting a contrast-defined blob combined with a contrast-defined pedestal show masking effects of a similar magnitude. Thresholds for detecting a luminance-defined blob on a contrast-defined pedestal show facilitation (~30-50%) for pedestals around threshold and above (up to ~10x threshold). No masking is evident. Thresholds for detecting a contrast-defined blob on a luminance-defined pedestal sometimes show facilitation that reduces with increasing pedestal amplitude, or masking at the highest pedestal visibility. Preliminary results for dichoptic viewing reveal similar dipper functions with facilitation, although the masking effects for same-type stimuli are more pronounced (exponent ~1).

These results support parallel processing streams for detecting luminance and contrast modulations with some evidence of asymmetric crosstalk. It would appear that combining different cues for detection both monocularly and dichoptically, leads to improved target detectability rather than masking.

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26.331 **When noisy means cardinal: visual biases for cardinal orientations revealed by degrading stimulus identity**

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According to Bayesian theory, the influence of “a priori” biases on perception should be greatest when certainty about stimulus likelihood is least. These biases are thought to have evolved because certain types of stimulus are encountered more frequently than others. For example, our environment is particularly rich in perfectly horizontal and vertical things. Degrading information about stimulus orientation may shift perception toward a priori biases. We tested this hypothesis by asking observers to align a pointer with the average orientation of a briefly displayed array of Gabor patches. Unbeknownst to the observers, each patch’s orientation was drawn from a Gaussian distribution with near-horizontal (i.e. 0°±2° or 0°±14°) or near-vertical mean (i.e. 90°±2° or 90°±14°), and one of two possible standard deviations: $\sigma = 2^\circ$ or $\sigma = 14^\circ$. On average, responses elicited by the larger standard deviation were closer to the cardinal orientations. In particular, our results indicate a predisposition for seeing things as being perfectly horizontal or vertical. More generally, our results demonstrate that visual biases can be revealed by statistically degrading stimulus identity.

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26.332 **Getting the most out of classification images**

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The classification image technique is a method of estimating an observer's internal template on a detection or discrimination task. Originally used in the context of Vernier acuity (Ahumada 1996), this approach has recently been adapted to more complex tasks, including disparity processing (Neri et al. 1999), illusory contour completion (Gold et al. 2000) and face recognition (Sekular et al. 2004). The nature of the procedure limits the number of stimulus dimensions that can be probed, as well as the resolution. We therefore sought an analysis procedure that would maximize the efficiency of the classification image technique.

A widely-used approach to statistical testing of classification images is to apply a global threshold, along with a Bonferroni correction, to individual image components, a method which ignores correlations between adjacent image components. More efficient methods are available. For instance, hard thresholding of image components in overcomplete tight frames yields efficient image denoising (Yu et al. 1996). False discovery rate (FDR) testing has been shown to be as conservative as the Bonferroni correction in terms of global type I error, yet less prone to type II errors (Benjamini & Hochberg 1995). We adapted these two methods to the statistical testing of classification images. The hybrid FDR/tight frame method was applied to classification images from a simulated LAM observer, using a variety of idealized observer templates from previously published classification image experiments. The number of trials required to reach a desired Pearson's correlation (0.5) between estimated and true template was typically an order of magnitude lower with the hybrid technique than with Bonferroni thresholding. Improvements were greatest in templates with complex, oriented features, such as faces. These results suggest that the hybrid method improves the efficiency of classification image measurements, particularly in experiments with high-resolution or high-dimensional stimuli.

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26.333 **Dynamics of collinear facilitation: fast yet sustained**

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Purpose. 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 and this is termed collinear facilitation. Here the temporal properties in collinear facilitation were investigated in order to better the understanding of its underlying mechanism. Methods and Results. Collinear facilitation was measured at different onset times of the target (2 cpd, 1 octave bandwidth, 80ms presenting time) when the contrast of the flanks was modulated at 1 Hz (1 sec) and the results showed that facilitation occurred in the spatially out-of-phase condition, suggesting a long-lasting, sustained facilitatory effect. In experiment 2, the order between target and flanks in collinear facilitation was investigated by varying the ISI between target and flanks, both of which were presented for 50ms. Results were collected for 3 different target-flank distances (2, 3, 6 λ). The results showed that the amount of facilitation decreased with the time lag between target and flanks and the peak was shifted with the target-flanks distance. However, we also found the peak facilitatory effect occurred when the target preceded the flanks. The results showed that maximal facilitation occurs at or before (not after) flank presentation, suggesting fast dynamics. Conclusion. The dynamics of collinear facilitation are complex. Facilitation occurs rapidly (tens of milliseconds) lowering thresholds at and sometimes before flank presentation but its effects are sustained (hundreds of milliseconds).

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26.334 **Characterizing Joint Feature and Contrast Sensitivity of Human Observers**

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Perceptual sensitivity is usually measured either as a contrast threshold at a particular level of stimulus discriminability (e.g., Gabors of 45°±15°) or as a threshold feature difference for discrimination at a fixed stimulus contrast. The existing observer models assume that any single stimulus activates only one perceptual template. For example, in the perceptual template model (PTM), the observer is characterized by four parameters: a single gain to the signal stimulus β, exponent of the non-linear transducer function g, internal additive noise Nadd, and coefficient of the multiplicative internal noise Nmul (Lu & Dosher, 1999). These models are only applicable to contrast threshold tasks. Here, we attempted to elaborate the PTM to model both contrast and feature thresholds.

Using the method of constant stimuli, full contrast psychometric functions of three observers were measured in an orientation identification task at fovea with four orientation differences (±3°, ±6°, ±15°, and ±45° from vertical) across a wide range of external noise levels. Threshold versus external noise contrast functions at three performance criterion levels (65, 75, and 85% correct) were estimated in each orientation condition. In such two-alternative identification tasks, the performance of an observer can be modeled by gains of two templates; the gain of the better-matching template β and the gain of the less-well-matching template β´. The original PTM was developed for the cases where $\beta' = 0$. The simplest elaboration of the PTM model, with the same β, γ, Nadd, and Nmul but varying $\beta' > 0$ across all the orientation conditions, provided the best fit to all the data, accounting for 96-99% of the variance. The elaborated PTM provides a theoretical framework to characterize joint feature and contrast sensitivity of human observers.

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26.335 **Lateral facilitation is largely due to internal response enhancement**

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We studied the effect of high-contrast Gabor flankers on the contrast response function of a centrally placed Gabor patch (target). First, the lateral facilitation effect was reproduced - a two-fold decrease in target detection thresholds for the collinear configuration (target and flankers are aligned). Target and flanking Gabor patches were separated by 3 standard deviations of the Gaussian window. These results show that the ratio between the slope (gain) of the contrast response and internal noise is increased in the presence of collinear flankers. Thus the flankers effect can be explained by either increase in gain due to lateral interactions or by noise reduction. Here, we employed an identification task to obtain independent estimates of the actual response function and noise [Katkov, Tsodyks, Sagi, Vision Research (2007) p2855]. On each trial, the observer was randomly presented with either a collinear configuration or an orthogonal one (target is orthogonal to flankers). Observer reported which contrast out of four (randomly selected on each trial) the central grating had. To analyze the data we assumed a signal detection theory (SDT) based model where each stimulus evokes internal response normally distributed across trials, with category boundaries (criteria) set at the decision stage. Observer reports a particular category when the internal response falls between the corresponding boundaries. We further assumed that criteria are independent of the stimulus presented on a particular trial. The models fitted to the data show that the internal response is higher in the presence of collinear flankers as compared with the orthogonal ones (separated by at least one noise amplitude), whereas there are very small changes in the noise amplitudes. Since the noise amplitude in SDT represents uncertainty in the internal representation of stimulus, our results support the lateral interaction hypothesis, with a slight reduction of uncertainty for collinear configuration.

26.336 **The absence of a collinearity effect in second-order, contrast-modulation discrimination tasks**

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Second-order stimuli are stimuli that are not detectable by mechanisms sensitive to luminance or color changes. Second-order cues can be created by modulating local first-order cues. There is evidence to suggest that first- and second-order cues are processed via separate mechanisms (Ledgeway & Smith, 1994; Schofield & Georgeson, 1999). The present study was performed to investigate how similar these separate mechanisms may or may not be. The specific intent of this study was to look at the role of collinearity in surround suppression for contrast-modulated (CM), second-order stimuli. It has been shown previously that in first-order contrast discrimination tasks, the effect of a suppressive surround seems to lie largely in the collinear regions of the surround (Kramer & Olzak, 2007). We set up a similar experiment with second-order stimuli to see if the second-order mechanism showed a similarly strong collinearity effect. The task was a fine second-order contrast modulation discrimination of circular, sinusoidal patches of CM binary noise (while holding spatial frequency and orientation constant). Surrounds were also sinusoidal patches of CM binary noise abutting the circular target (with the contrast modulation level, m, for the surrounds centered between the m-values of the two central patches being discriminated while the orientation and spatial frequency of the surrounds were identical to the central patches). BOW-TIE stimuli (Cannon & Fullenkamp, 1991) were used to modulate surround size and location in order to create both collinear and non-collinear surrounds of varying sizes as used by Kramer and Olzak (2007). Discriminability was measured using a 6-point response scale from which d' values were calculated. Our results suggest that there is no effect of collinearity on surround suppression for this type of second-order stimulus.

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26.337 **The effect of sustained/transient temporal modulation on the horizontal effect of contrast masking**

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We have shown previously that contrast masking by broadband noise is greatest for horizontal orientations and least for vertical orientations (Kim, Haun and Essock, VSS 2007), which fits well with the earlier finding of greater salience and sensitivity for oblique content (and least salience for horizontal) in broadband patterns (Essock et al, Vis. Res., 2003). Here we examine this "horizontal effect" of broadband contrast masking with respect to sustained and transient temporal presentations. Contrast thresholds for sinewave gratings of either 1 or 8cpd were measured in the presence of oriented broadband (1/f) noise masks. The temporal presentation of the test grating and of the mask was either 'transient' or 'sustained' in nature. With no masking, threshold is poorest at oblique orientations and lowest at cardinal orientations (the "Class 1 oblique effect"). With a broadband mask present we find that when a brief (25ms squarewave pulse) or flickered (16Hz) test is combined with a brief or flickered mask, a horizontal effect of contrast sensitivity is obtained. When a sustained (560 ms, gradual ramp) test is combined with a sustained mask, we also obtain a horizontal effect. However, when test and mask have distinct temporal waveforms, an oblique effect is obtained along with a loss of masking. Since masking is typically accounted for in terms of a pooled response from other filters that is used to normalize output, these results suggest that there are separate normalization pools for the sustained and transient temporal conditions and that both are anisotropic (and in the pattern of a horizontal effect). It appears that in a divisive normalization model, only filters with temporal properties similar to that of the 'test' filter contribute to its normalization pool.

26.338 **Filling-in in the periphery indicates that the collinear facilitation is similar to the fovea**

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Collinear facilitation is a common phenomenon in the fovea, but it has been recently challenged in the human periphery. Using a new paradigm, Polat and Sagi (2007) have suggested that the feeling-in effect is induced by collinear facilitation in the fovea. Here, we used the same paradigm in the periphery to probe the facilitation using a Yes/No detection task by measuring the false-positive reports (false-alarm, Pfa) and hit-rate (Phit) for a low-contrast Gabor target (between two flankers) that appeared randomly in the fovea or at the periphery (2 deg) to the right or left side. We measured the facilitation effect in 3 experiments: 1) using different target-flanker separations, 2) comparing the collinear and orthogonal configurations and the target alone at 5λ, and 3) using different flanker orientations (0, 11, 22.5, 45, 90 deg.) at 5λ. The report for the target present was high (Phit, Pfa) for the collinear configuration and decreased with increasing target-flanker separation. The feeling-in effect for 5λ was similar to the results for 3λ in the fovea (Polat & Sagi, 2007). The sensitivity for the collinear configuration was significantly higher than the target and the orthogonal configurations for 5λ. The report for the target present was orientation specific; it was highest for the collinear configuration, but decreased with increasing differences in orientations between the target and flanker. However, the sensitivity of the collinear and the other configurations was similar, consistent with Polat & Sagi's results for mix-by-trial testing. The overall increase in the target-present responses only for the collinear configuration is consistent with excitatory interactions that induce filling-in in the periphery. The existence of a similar pattern of higher Phit and Pfa for the collinear configuration at the fovea and periphery suggests that collinear facilitation is a common phenomenon that exists in both the periphery and fovea.

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26.339 **The effect of curvature on the grid illusions: Influence of a homunculus?**

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The intersections of lighter alleys defining a grid of black squares display illusory effects (the Hermann grid and the scintillating grid). We have noted that a single light disk in an intersection at some remove from fixation is rendered less visible (the "vanishing disk"). Furthermore, contrast threshold for the vanishing disk becomes even higher when the alleys are curved instead of straight (Levine & McAnany, VSS 2006). We speculated that the effect of curvature is due to either an attention shift or inhibition from a "higher" center than the detection mechanism (Levine & McAnany, in press). If this is correct, one would expect a measurable latency for the onset of this influence.

To test for this temporal disparity, we presented vanishing disk stimuli in which half of each presentation featured straight alleys, and half featured curved alleys. That is, in the middle of a 250 msec presentation of a stimulus, straight alleys abruptly curved, or vice versa. Since these changes are equivalent, any difference in threshold for the disk between these conditions must be caused by the order of onset of curvature, and not be simply an effect of a transition.

Thresholds for light disks were significantly higher when moderately curved alleys straightened than when straight alleys became curved to the same degree. We infer that the earlier curvature has time to initiate whatever disrupts visibility even though the alleys are straight in the latter part of the presentation; curvature later did not have time to exert its influence before detection was effected. (Note that had the decision been based on visual short-term memory, the stimuli that concluded with straight alleys would have evinced lower thresholds, not higher.) These and related results indicate a higher-level effect of curvature (complexity) upon detection.

URL: http://tigger.uic.edu/~mikel/VSS/VSS2007_ML.pdf

26.340 **Second-order mechanisms do not process contrast-modulated orientation information optimally**

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There is considerable argument over whether second-order mechanisms (those responding to changes in textural contrast, grain, or orientation when mean luminance is contrast) constitute a single class of mechanism or whether different mechanisms underlie the processing of different types of second-order patterns. There is also argument as to the relative sensitivity of first order mechanisms (responding to luminance-defined patterns) vs. second-order mechanisms. Regan (2000) argues that the relative sensitivity of first and second order mechanisms is comparable for all hyperacuity tasks, although his measurements were confined to orientation-defined second-order patterns. We previously measured spatial frequency, contrast, and orientation discrimination thresholds for contrast-modulated second-order patterns. Our initial results indicated that while spatial frequency and contrast thresholds were comparable to those obtained with luminance-defined patterns, orientation judgments were much worse and observers refused to continue the experiment. We have now re-measured orientation discrimination thresholds and find them to be on the order of 10x values obtained with first-order stimuli. Our results imply that the mechanisms mediating contrast-modulated, second-order judgments are a) not well-suited to mediate judgments about orientation ; b) considerably less sensitive to orientation than first-order mechanisms; and c) different mechanisms than those mediating orientation-modulated judgments,. We conclude that an understanding of the second-order systems is by no means complete.

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26.341 **Fixational Eye Movements and Retinal Activity during a Single Visual Fixation**

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In the intervals between saccades, small saccades and drifts modulate the spatiotemporal stimulus on the retina. It has long been questioned whether the modulations of luminance resulting from fixational eye movements might encode spatial information in the temporal domain. Here, we examine the impact of fixational modulations of luminance on retinal activity *during a single fixation interval*. We have recently shown that fixational eye movements improve the discrimination of high spatial frequency gratings masked by low-frequency noise, but do not help in the discrimination of low-frequency gratings masked by high-frequency noise. In this study, we model retinal activity in the presence of the same visual input experienced by subjects in our experiments, i.e. the spatiotemporal signals resulting from viewing stimuli during eye movements. Spatiotemporal filters designed on the basis of neurophysiological data modeled the responses of parvocellular ganglion cells in the macaque's retina. We show that synchronous modulations in cell responses resulting from fixational instability are consistent with psychophysical results. During presentation of high-frequency gratings, oculomotor activity influenced the correlation between pairs of cells in a way that depended on the relative alignment of cell receptive fields. Cell responses were strongly correlated only when their receptive fields were aligned parallel to the grating's orientation. Such a dependence on receptive-field alignment was instead absent during viewing of low-frequency gratings. That is, in keeping with the subjects' reports, fixational eye movements synchronously modulated arrays of RGCs parallel to the grating's orientation during viewing of high-frequency gratings masked by low-frequency noise, but not during presentation of low-frequency gratings masked by high-frequency noise. Changes in the structure of correlated activity occurred without affecting average firing rates. Synchronous modulations resulting from fixational eye movements appear to be an important component of the way visual information is encoded in the early visual system.

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URL: http://aplab.bu.edu/

26.342 **Frequency-doubling in the early visual system underlies sensitivity to second-order stimuli**

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There are two primary visual cortical areas in the cat, each receiving a direct LGN projection. Area 17 neurons are described reasonably well by linear filters selective for the orientation and spatiotemporal frequencies of stimuli. Area 18 neurons are thought to be analogous except that they are selective for lower spatial and higher temporal frequencies. However, about half of Area 18 neurons possess a nonlinearity that makes them sensitive to beat frequencies and other second-order stimuli.

Because second-order responsive neurons are tuned for the orientation of the high spatial frequency carrier of a beat stimulus, it has been argued that this selectivity arises from a nonlinear combination of Area 17 inputs (Mareschal & Baker, 1998). Alternatively, this selectivity may originate from their LGN inputs, Y-cells. Consistent with this, Y-cells are responsive to low spatial frequencies but also show frequency-doubled responses to contrast-reversing stimuli at the high spatial frequencies used to construct second-order stimuli. Furthermore, the activity of retinal ganglion Y-cells modulates at the temporal frequency of second-order stimuli (Demb et al., 2001). To date however, it has been assumed, but not tested, that Y-cell tuning properties cannot account for the orientation selectivity of second-order responses in Area 18.

We asked if LGN responses to second-order stimuli can account for those in Area 18. Our results indicate that while X-cells are unresponsive to these stimuli, Y-cells behave similarly to Area 18 neurons. First, Y-cells show tuning for the orientation of the carrier of a beat stimulus. Second, the preferred temporal frequency and cut-off is greater for drifting sinusoidal gratings than for the envelope of a beat. Third, the temporal frequency tuning of the carrier resembles that of Area 18 neurons. Together, these findings suggest that the frequency-doubling nonlinearity of Y-cells is sufficient to account for second-order responses in cat Area 18.

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26.343 **Spatiotemporal dynamics of the perception of dot displays**

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Liss and Reeves (Perception, 1983) found that observers could often see only a subset of a group of discs which were masked after brief exposures. Subject numerosity judgments in this experiment provided evidence that this was due to the masks effectively interrupting the visual processing of the displays. An implication of their results is that the discs in their displays did not become available for conscious processing simultaneously. We sought to characterize the dynamics of this process.

In our experiments, we asked subjects to give location responses for all dots that were observed in displays masked at variable SOAs. The numerosity of responses confirmed the results of Liss and Reeves (1983). To go beyond those results, we assume that the pattern of location responses reveals the spatial distribution of the visual information that was made available to the observer during the brief exposure.

Subjects' location responses in our multi-dot displays indicate that the dots do not become available for conscious processing simultaneously. Dots near fixation are detected (and localized) first, followed by increasingly more peripheral dots. Additionally, at longer SOAs, dots closer the centroid of the dot distribution are more likely to be detected. However, dots presented alone seem to be detected nearly equally well centrally and peripherally. These three phenomena are encompassed in a quantitative model that describes the apparent rapid expansion of visual consciousness. The model provides a reasonable account of how the spatially distributed information is optimally processed within the limitations imposed by perceptual mechanisms.

Saturday, May 10, 2:30 - 6:30 pm
Poster Session, Royal Palm Ballroom 6-8

Lightness, Brightness and Luminance
Perception and Action: Reaching and Grasping
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Lightness, Brightness and Luminance

26.401 **Bayesian model of the staircase Gelb effect**

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Introduction: For perceived lightness to be a useful guide to object identity, it should correlate with physical surface reflectance across changes in viewing conditions. Most vision scientists agree that lightness perception involves the resolution of ambiguity inherent in the retinal image. There is less consensus about how to frame models of this process. We have found it clarifying to develop ideal observer models. These models estimate illuminant intensity and surface reflectance from the image data and link the estimates to psychophysical performance. Here we show that such a model can account for the staircase Gelb effect (Cataliotti & Gilchrist, 1995). This effect has been presented as a challenge for ideal observer models, because simple variants of these models to not predict it.

Methods: We simulated a world with a single row of eleven pixels. The retinal image was obtained as the pixel-by-pixel product of illuminant intensity and surface reflectance. The statistical ensembles of illuminants and surfaces were each modeled as a multivariate Gaussian distribution specified by the pixel mean, the pixel variance, and the correlation between neighboring pixels. We estimated illuminant intensity and surface reflectance at each pixel by maximizing the full posterior distribution (computed using Bayes' rule). Importantly, our implementation allowed both illuminant intensity and surface reflectance to vary over space.

Results: In the staircase Gelb effect experiment, a series of grayscale surfaces are illuminated by an intense spotlight. The data demonstrate range compression, since the actual reflectance range of the surfaces (~0.03-0.9) is far greater than the corresponding range of observed lightness matches (~0.3-0.8). For these conditions, range compression emerged naturally from our model: the estimated surface reflectances showed range compression similar to the experimentally observed matches.

Conclusion: Ideal observer models of lightness perception can account for the phenomenon of range compression.

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26.402 **Lightness perception has no anchor**

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One of the major theoretical views of lightness perception asserts that the highest luminance in an image serves as a standard that is assumed to be white (Gilchrist et al., 1999). We performed a number of experiments that challenge this view. In one set of experiments, five sets of paper Mondrians that spanned four ranges of reflectances (12%-3.1% at one end, and 27.2%-12% at the other) were presented in a black room. Observers matched the reflectance of the highest luminance to a set of standard papers in a separate room. Four separate experiments were run, using two different backgrounds for the matching papers (an articulated random-dot background, and a white background); and two different illumination levels. Although consistently overestimated, the highest luminance was never perceived as white: the highest luminance paper's reflectance could be perceived as low as 39%; the highest perceived value was 74.1%. Both chart type and illumination level had significant effects on perceived lightness: papers in higher illuminants were perceived as lighter, and matches using the white background match pattern was perceived as higher. This experiment was replicated using monitor displays that closely matched the luminance values of the paper Mondrians. We then conducted a more extensive study using monitor displays depicting a Mondrian with a (simulated) 4:1 reflectance ratio range under 13 different simulated illumination levels (ranging from .06-.0015 cd/m2, to 61.8 to 36.05 cd/m2). Lightness matches revealed that the highest luminance continuously increased as simulated illumination increased, exhibiting a compressive nonlinearity similar to Steven's Power law. These results demonstrate that the visual system does not treat the highest luminance as an anchor, but rather, that perceived lightness increases as a monotonic function of luminance.

26.403 **Spatial Filtering Versus Anchoring Accounts of Brightness in Staircase and Simultaneous Brightness Contrast Stimuli**

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Cataliotti and Gilchrist (1995) reported that the lightness of a black square in a luminance staircase was not altered by moving the position of a white square from a remote to an adjacent location. They argued that this result supported an anchoring model of lightness as opposed to a local contrast explanation. Economou, Zdravkovic and Gilchrist (2007) tested two more predictions of the anchoring model: 1) that the strength of simultaneous brightness contrast (SBC) should increase for darker targets and 2) that in a staircase SBC display only the decremental targets should appear to differ from one another. Economou et al. (2007) reported evidence to support both of these predictions and argued that contrast models and the ODOG model in particular could not account for these effects. The present study examined the matching behavior of subjects using stimuli similar to those in the aforementioned studies. The brightness of each of the five steps composing a luminance staircase (4-120 cd/m2) was measured for both a sequential staircase and for a disrupted staircase. Measurements were obtained for staircases surrounded by three different background luminances (5, 62 and 119 cd/m2). In a second experiment background luminance was held constant (62 cd/m2) and identical test patches were added to the centers of each step of the sequential staircase to produce a staircase SBC stimulus. The brightness of each of the test patches was measured for three test patch luminances: 24, 62 and 100 cd/m2. The matching data are compared directly to the predictions of the anchoring model (Gilchrist et al., 1999; Gilchrist, 2006) and the multiscale filtering model (the ODOG model) of Blakeslee and McCourt (1999).

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26.404 **The role of articulation and proximity in the effect of depth on lightness**

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We tested several competing predictions made by the coplanar ratio principle (Gilchrist, 1977) and the anchoring theory: one concerning the role of articulation and one concerning the proximity of the highest luminance to the target. (1) According to the anchoring theory, the depth effect reported originally by Gilchrist, although strong, would have been even stronger had the two differently illuminated planes been articulated (that is, had they contained more patches). One group of 20 observers viewed the dihedral planes display of Gilchrist (1977) with two equi-luminant target tabs, one attached to an illuminated white background and one attached to a shadowed black background. A second group of 20 observers viewed the same display except that both white and black backgrounds were replaced by Mondrian patterns consisting of 20 patches ranging from white to black. We did obtain a stronger depth effect using articulated planes. (2) According to the coplanar ratio principle proposed by Gilchrist, the lightness of a target surface depends on the luminance ratio between that target and its adjacent, coplanar neighbor. But according to the anchoring theory, target lightness depends on the ratio between the target and the highest coplanar luminance, even if the highest luminance is not adjacent. Twenty observers viewed the articulated display described above, in which the target, that was perceived to lie in the illuminated plane, was adjacent to a coplanar white surface. A separate group of 20 observers viewed a modified display in which the white surface in the illuminated plane was at least 3 patches away from the target, which was surrounded solely by gray shades between middle gray and black. The results support the prediction of the anchoring theory, showing that a target adjacent to a white surface does not appear darker than a target remote from the white surface.

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26.405 **Ilumination Frameworks, Selective Attention, and Edge Integration in Lightness Perception**

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The lightness of a target region is influenced not only by the contrast and contrast polarity of that region's border, but also by the contrasts and contrast polarities of other nearby borders. Recent studies have sought to model the process by which the effects of multiple edges that together influence the target lightness are combined spatially. Such models have typically assumed that the relative weights given to the target edge and other nearby edges are determined solely by low-level factors, such as the distance between the target and the inducing edge, and the edge contrast polarities. Here I show that the weights assigned to borders in perceptual edge integration can vary in predictable ways, depending on the particular lightness judgment that an observer is asked to perform, and on the particular information that the observer attends to in the stimulus. Subjects matched two incremental disk-and-ring stimuli in terms of their brightness (perceived luminance), lightness, or brightness contrast. Two lightness conditions were run in which changes in the luminance of the ring surrounding the target were viewed as either reflectance changes or as illumination changes on the target side of the display only. The matches made in the two lightness conditions differed in a manner consistent with a perceptual edge integration model in which the weights given to the various edges are adjusted in sensible ways depending on the observer's assumption about the nature of the illumination. I will argue that an edge integration theory that includes top-down control of the edge weights has the power to form a bridge between previous edge integration models and lightness anchoring theories based on the notion of illumination frameworks; and that a theory in which edges are selectively integrated under the influence of attention also provides novel and important insights into other lightness phenomena, including phenomena involving perceptual transparency.

26.406 **Spatial scale models of lightness illusions: contrast, anchoring, and tunable filters**

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Shapiro, Smith and Knight (2007) showed that most lightness illusions can be generated from the input images by removing their low spatial frequencies content. They suggested that the visual system eliminates spatial frequencies lower than the fundamental frequency of the area of interest. Here, we extend this account in three ways:

1. We show that removing the low spatial frequency energy is algebraically very similar to many existing contrast models (i.e., contrast computed over a region, followed by a two-branch non-linearity). With appropriate specifications, contrast models can account for many well-known lightness illusions, including Adelson's snake and checker-shadow illusions, the white shadow illusion, Anderson and Winawer illusions, Bressan's Dungeon illusion, gradient-gradient illusions, and test spots placed on natural images.

2. We present lightness demonstrations that cannot be explained by an anchoring rule that ascribes "White" to the highest global luminance, but can be explained by anchoring "White" to the maximum output of an array of contrast filters. The demonstrations are based on Adelson's checker-shadow illusion with the cylinder removed (see www.shapirolab.net). We show that when the luminance of the square in the shadow is increased, the square is perceived as white even when other lights in the global environment have higher luminance levels.

3. We present demonstrations that contain test areas of different spatial scales; a model based on a single cut-off spatial frequency cannot account for lightness variations at all spatial scales simultaneously.

We therefore propose a model with tunable high-pass cut-off or in which contrast is calculated over a tunable integration area. We discuss whether the filters adjust to local organizational factors (edges, grouping, scission and attention factors) or whether the model can be driven by a process that favors the spatial frequency channel that gives the maximum response within a local region (a winner-take-all model).

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URL: www.shapirolab.net

26.407 **Albedo perturbation detection under illumination transformations: A dynamic analogue of lightness constancy**

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Purpose. Everyday scenes are typically illuminated by multiple light sources (sun, sky). Changes in the position/intensity of neutral light sources can induce complex transformations of luminances associated with achromatic surfaces in the scene. Last year we presented evidence that observers can accurately discriminate the transformations induced by small changes in direction of a collimated source from transformations matched in edge-ratio information and global image statistics. This year we evaluate whether this ability aids in detection of simultaneous albedo perturbations, a dynamic analogue of lightness constancy. Methods. The stimuli were stereoscopically presented renderings of 8 concave or convex pyramids with random heights and facet albedo patterns. Two frames were presented in which the scene underwent a global luminance transformation induced by a change in collimated source position of 15 degrees (light change) or a matched, scrambled version of the same transformation (non-light change). From frame one to two, one pyramid facet might undergo an additional change: an albedo perturbation of ±20, ±30, ±40, or ±50%. Albedo changes occurred with 50% probability, with 400 trials total at each level for both global change types (3200 trials total). On each trial, observers judged whether an albedo change occurred. Feedback was not given. Analysis. We estimated d' estimates separately for light and non-light changes at each perturbation level. Results: Albedo perturbation detection was significantly more sensitive under light changes than under non-light changes ($t=10.74$; $p <0.0001$). The d' values for the light-change conditions were roughly double those for the matched non-light conditions. Conclusion: Observers can more accurately detect changes in surface albedo against a background of global change in surface luminance when the pattern of change of luminance is consistent with change of position of a collimated light source in the scene, a dynamic analogue of lightness constancy.

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26.408 **Seeing Through White Clouds: When Local Occlusion Cues Fail**

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Anderson & Winawer (2005, Nature) presented a dramatic lightness illusion, where identical texture patches appear either black or white depending on background properties. Albert (2007, VR) argues that simple well-known visual mechanisms detecting local occlusion account for the illusion, determining which stimulus areas are perceived in plain view.

Here, we present modeling and experimental evidence that a local occlusion explanation fails to account for the illusion (see also Poirier, submitted). Indeed, modeling shows that local occlusion theories predict a complete reversal of the effect at lower figure contrasts, even within the range used by Anderson & Winawer. However, this predicted reversal was absent in both the original data and in our replication (N=7). Moreover, repeating the experiment using thresholded textures (thus emphasizing local occlusion cues) did produce the expected reversal, thus providing evidence that our modeling did capture the essence of local occlusion. This further reinforces our conclusion that theories based on local occlusion cues fail to account for the Anderson-Winawer illusion.

We propose a simple model to account for these effects, as well as other related phenomena, e.g. the White effect (White, 1979, 1981, Perception), and simultaneous contrast (Heinemann, 1955, JEP; Horeman, 1963, VR).

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26.409 **Coming to Terms With Lightness and Brightness: Effects of Stimulus Configuration and Instructions on Brightness and Lightness Judgments**

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Depending on the experimental conditions, lightness (perceived reflectance) may refer to judgments that are identical to brightness judgments (perceived luminance), to local brightness-contrast judgments (the brightness difference between a target and its background), or that represent an independent dimension of achromatic experience (Arend & Spehar, 1993 a; b). This third dimension exists only when the illumination across regions of the display is visibly non-uniform and has been called "inferred-lightness" because it requires that the observer take account of the illuminant to make an inferential judgment of target reflectance (Blakeslee & McCourt, 2003). Because lightness judgments are based on different information under different conditions, lightness data generated in one condition may not be comparable to lightness data measured in another condition. We investigate this problem with regard to a history of data on simultaneous brightness/lightness contrast, by measuring brightness, brightness contrast and lightness in stimuli similar to those used in Gilchrist's early edge-substitution studies (Gilchrist, 1979; 1988; Gilchrist, Delman & Jacobsen, 1983). Our results clarify discrepancies in this literature which appear to stem from comparing different types of lightness judgments and from inadvertently using brightness as an index of lightness under conditions where inferred-lightness judgments are possible (Gilchrist, 1999; Gilchrist, 2006).

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26.410 **Brightness, Darkness and the Perception of Surface Material**

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A recent computational model of achromatic color perception proposes that gray shades are encoded in a two-dimensional space formed by brightness and darkness dimensions (Vladusich et al., 2007, PloS Comp Biol, 3: e179). This model predicts that achromatic colors should depend on higher-order image statistics, such as the variance, skewness and kurtosis of the luminance values in a scene. I provide perceptual evidence in support of this prediction and link the properties of the model to a recent demonstration that such image statistics play a key role in the perception of matte and glossy surface material (Motoyoshi et al., 2007, Nature, 447: 206-209). The model also makes the testable prediction that neural ON and OFF channels should provide inputs to a two-dimensional spatial map of achromatic colors analogous to the hue maps described recently in primate extra-striate cortex (Conway et al., 2007, Neuron, 56: 560-573).

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26.411 **Measuring brightness induction during brief stimulus displays**

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What is the time course of brightness induction? Rossi & Paradiso (1996) measured the strength of this illusion when the inducing region's luminance was sinusoidally modulated over time. The illusion decreased with increasing temporal frequency, eventually disappearing at between 2-4Hz. The higher the spatial frequency of the illusion, the higher the temporal frequency at which it could still be seen. From this, they theorized that brightness induction is due to a neural filling-in signal that propagates slowly. Here we introduce a new paradigm for investigating the timecourse of this illusion and find results inconsistent with slow filling-in.

METHOD: In our paradigm the stimulus was shown briefly (OnTime=58, 82, 117, or 1120ms, depending on condition), and then covered by a noise mask for 900ms. The display alternated between showing the noise mask and the stimulus while subjects adjusted the brightness of a constantly visible patch to match the perceived strength of brightness induction. Subjects typically took 30 to 60 seconds to find a satisfactory match.

RESULTS: We found the brightness induction illusion was visible when OnTime was just 58 ms. In addition, the illusion was actually stronger at short OnTimes, not weaker. Below 58ms subjects could not reliably see the whole stimuli, and thus could not make brightness matches at all. The same patterns of results were seen for high and low spatial frequency stimuli (0.5 cpd and 0.05 cpd, respectively), suggesting little difference in the speed of induction as a function of spatial frequency.

CONCLUSIONS: These results suggest that the brightness induction illusion develops much faster than previously thought. This suggests that filling-in may not be involved, or that if it is, filling-in is much faster than previously thought.

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URL: http://csclab.ucsd.edu/~alan/pub/

26.412 **The balance between transient and sustained temporal response varies across the V1 visual field map**

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Purpose: The temporal impulse response in V1 reflects multiple neural and hemodynamic components. We analyze these components by modeling the temporal response as a mixture of several terms and comparing the relative contributions of these terms across the cortical surface.

Methods: Functional MRI measurements were made using a 3T scanner (Siemens, Trio, Erlangen, Germany). We dilated subjects' pupils with mydriatics and placed semi-transparent, hemisphere-shaped diffusers on their eyes to eliminate spatial contrast (Ganzfeld). Subjects viewed spatially uniform brightness that alternated between a low and high luminance every 24 seconds (square wave). We modeled the temporal response as the sum of two terms. One corresponds to a signal at the luminance step (transient) and a second that corresponds to the mean illumination (sustained). Both regressors were convolved with the hemodynamic response function. We also measured the visual field eccentricity maps.

Results: The temporal responses varied as we measured from posterior to anterior calcarine sulcus. The responses spread far above 14 degrees isoeccentricity line which we could precisely determine from the eccentricity map. The sustained response decreased with visual field eccentricity, while the transient responses increased with increasing eccentricity. In the central representation, the ratio of the transient reponse to the sustained was 0.52 ± 0.18; in the periphery the ratio was 2.39 ± 0.26.

Discussion: The responses in central visual field representation depend more on the absolute luminance level (sustained) while in the periphery responses are influenced more by instantaneous luminance changes. This difference might reflect the differential weighting of cell types in these regions of V1.

26.413 **Effects of luminance contrast on visual responses in frontal eye field**

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The division of the early visual system into rapid, more sensitive magnocellular and slower, more selective parvocellular divisions is well established. Cells in the magnocellular division exhibit high contrast sensitivity while cells in the parvocellular division exhibit more graded responses to changes in contrast. How far this division extends in the visual pathway is unknown. One likely candidate for integration of the two processing streams is frontal eye field (FEF), a region of frontal cortex which plays a critical role in saccade target selection and eye movement initiation. Anatomical evidence confirms that FEF receives afferents converging from dorsal and ventral stream areas (Schall, Morel, King, & Bullier, 1995). We investigated the extent to which FEF visual neurons show the functional distinction between parvo- and magnocellular divisions. Single-units were recorded in FEF of two macaque monkeys performing a memory-guided saccade task with target stimuli of variable luminance contrast. Two populations of visual responses were observed: one population exhibited a strong modulation in onset latency with luminance contrast. The other population demonstrated very little modulation with contrast. The data suggest that FEF not only receives distinct input from different cortical streams, but maintains this distinction in its output. Supported by RO1-EY08890, P30-EY08126 and the Ingram Chair in Neuroscience

Perception and Action: Reaching and Grasping

26.414 **Identifying strategies for grasping objects with position uncertainty using empirical cost-to-go functions**

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Humans frequently and successfully reach to objects without precise information about their location. This success suggests humans have developed motor strategies that compensate for location uncertainty. To investigate this issue, we conducted experiments that involved grasping and lifting cylinders whose position was not precisely known. Position uncertainty was introduced by randomly moving the cylinder with a robotic arm over sequence of 5 positions sampled from a strongly oriented 2-D Gaussian distribution. Preceding the reach, vision of the object was removed using liquid crystal shutter glasses, and the robot moved the object one additional time. Participants reached and grasped the object while out of view. Finger trajectories were recorded for a set of covariance orientations. Preliminary results show that human grasping compensates for position uncertainty of objects. All subjects follow a similar strategy so that to maximize the probability of contact with the object: The approach angle increases almost linearly with the covariance angle, so that the fingers approach the cylinder in the direction of maximal cylinder uncertainty. Moreover, the finger and thumb slow down and become parallel as they approach the object. To interpret these results, we have analyzed the data using methods from reinforcement learning and optimal control. In particular we have used the experimental data to learn human policies and cost-to-go functions for grasping objects with position uncertainty. We will present a detailed comparison of human strategies with optimal policies to test the optimality of human compensation strategies. In addition, we investigated the effects of the 5equential cylinder's positions to the finger and thumb trajectory using regression analysis to address whether observers use information from the 5 movements to estimate the cylinder's position on each trial.

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26.415 **Visual uncertainty predicts grasping when monocular cues are removed but not when binocular cues are removed**

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Grasp apertures are typically wider under monocular than binocular viewing. Several researchers have proposed that this represents an added "margin of error", given increased uncertainty about object properties (see Melmoth & Grant, 2006). Consistent with this, it has recently been shown that increasing perceptual uncertainty, by presenting objects at eccentric retinal locations, produces systematic increases in grasp apertures (Schlicht & Schrater, 2007). We investigated whether the differences between monocularly- and binocularly-guided grasps are predicted by changes in uncertainty. The stimuli were rectangular objects on a horizontal surface. Grasps were visually open-loop. Experiment 1 measured the effects on grasp kinematics of selectively removing binocular or monocular cues. We varied distance to produce variations in uncertainty (cf. Hillis et al., 2004), which were measured psychophysically using size/distance discrimination. Experiment 2 measured grasps as a function of uncertainty per se, holding the depth cues available, and the required movement, constant. The stimulus was a random-dot-stereogram. We made the object transparent and increased dot density, making it difficult to discriminate the object from the surface. We again measured size/distance discrimination to assess uncertainty. We took measurements at each distance used in Experiment 1, to control for grasp effects due to increased movement variability at farther distances. In Experiment 2 grasp apertures increased systematically with increases in perceptual uncertainty. We used this relationship to generate predictions for the effects of removing binocular and monocular cues in Experiment 1. Grasp apertures increased when monocular cues were removed by a similar amount to that predicted by the change in perceptual uncertainty. The removal of binocular cues, however, resulted in an increase in grasp apertures considerably larger (by a factor of ~2) than predicted by changes in perceptual uncertainty alone. We conclude that the removal of binocular cues has effects on grasping over and above increasing uncertainty.

26.416 **Visually guided grasping and the Müller-Lyer illusion: As for pointing, the data look contradictory but in fact they are not**

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Some models of human vision propose a functional division of labor between vision-for-perception and vision-for-action (Milner & Goodale, 1995, The visual brain in action). This proposal is supported by neuropsychological, brain-imaging, and psychophysical studies. However, it has remained controversial in its prediction that actions are not affected by visual illusions. Here we re-analyze 16 studies on grasping the Müller-Lyer illusion (see Bruno, Bernardis & Gentilucci, in press, Neuroscience & Biobehavioral Reviews, for a similar meta-analysis on pointing). We find that median percent effects across studies are indeed slightly larger for perceptual than for grasping measures. However, all grasping effects are larger than zero and the two distributions show substantial overlap, with grasping effects showing a substantial variability. After detailed examination of methodological differences between and within the perceptual and grasping measures, we show that, as for pointing, critical roles in explaining such variability are played by the number of trials/condition (a learning-attentional effect), by the availability of visual feedback during movement, and by conditions at the programming phase of the action. We discuss to which degree these can explain differences between illusory effects on perception, grasping, and pointing, as well as their implications for the perception-action model.

26.417 **Gaze strategies while grasping: What are you looking at?!**

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Eye movements and visuomotor behaviour operate in sequence – we look at the objects with which we are going to interact. Although eye movements have been well documented during a variety of activities such as walking, sports, typing, reading, and driving, relatively few studies have investigated gaze strategies during object grasping. One that has suggests that gaze supports the planning and control of actions by marking key positions to which the fingertips are directed (Johansson et al., 2001). To date, however, the precise location of eye fixations while grasping objects of varying size and shape have not been well characterized. The purpose of this study was to investigate where people look, relative to where they grasp, when reaching out to pick up centrally placed symmetrical blocks.

Eye movement and grasping kinematic recordings were integrated into the same frame of reference via MotionMonitor software. Gaze position was reported at grasp-related kinematically defined time points: first fixation, maximum grip aperture (MGA), and object contact. Overall, fixations were found to be concentrated on the top half of the block, with the majority of fixations clustered along the object's midline. During first fixation, gaze points were clustered on the top central edge of the object, corresponding with the eventual index finger grasp point. At MGA, a significant shift in gaze position frequency was observed, with a greater concentration of gaze fixations around the object's center of mass. This monitoring of the object's center was also observed during object contact. These results suggest that during the planning of the grasp, prior to movement onset, eye gaze targets the grasp point for the index finger on the object. However, during the reach itself, the center of mass becomes more of a concentrated focus – as it is during perceptual tasks (Kowler et al., 1995).

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26.418 **Adaptive grasping: Corrective processes after perturbations of object size**

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When grasping an object the pre–shaping of the hand is a highly stable motor pattern which is largely pre–determined by object–related visual input (Jeannerod, 1984). If the object size changes during movement execution, the initially planned motor program has to be adjusted. How these adjustments are accomplished is still a matter of debate. We investigated the corrective responses using a size–perturbation paradigm. Participants grasped real objects of different sizes which were visually presented using a mirror setup. In 25% of the trials the visually presented object changed its size and became 1 cm larger or smaller, matching the size of the real object to be grasped. The perturbation could occur at two moments in time: (1) early: as soon as the hand left the starting position, (2) late: after 2/3 of the movement distance. In Experiment 1 participants could see their hand during grasping whereas in Experiment 2 vision of the hand was prevented. By combining the size perturbation paradigm with the presence or absence of visual information about the hand we were able to determine the relative contribution of feedback and feed–forward processes to on–line corrections of the grip. Results indicate that the availability of visual information about the hand influenced grasping kinematics (e.g., larger MGA if the hand was not seen) but had only little effect on the corrections to the new object size. In both experiments maximum grip aperture was perfectly adapted to the new object size after an early perturbation, whereas this correction was not accomplished after a late perturbation. The adaptation of the grip resulted from smooth changes in the aperture over time. These findings suggest that small changes in object size are corrected by a smooth amendment of the initially planned motor program using feed–forward mechanisms.

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26.419 **Calibration of grasp orientation (and 'wiggle-room' for errors in object orientation perception)**

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Background. Prehension movements are controlled on the basis of visual information regarding an object's distance, size and orientation. Accuracy is maintained through calibration processes that rely on visual and/or haptic information. It is known that reach distance and grasp magnitude can each be calibrated (Mon-Williams, Coats & Bingham, 2004; Mon-Williams & Bingham, 2007) but calibration of grasp orientation has not been explored.

Methods. We manipulated the felt orientation of a visually constant object to explore the role of haptic information in the calibration of grasp orientation. Participants reached-to-grasp a visible object using a pincer grip. Eighteen participants performed ten 'virtual' reaches before and after an adaptation stage (apparatus details in Mon-Williams & Bingham 2007). We monitored upper limb position using Optotrak markers attached to the index and thumb tip, index knuckle, inside and outside of wrist, elbow, shoulders and trunk. In the adaptation phase, three groups (n=6 per group) were subjected to distorted haptic feedback incrementally over fifty reaches (total perturbation=45°): the object's 'pitch' was perturbed for Group 1; 'yaw' for Group 2; 'roll' for Group 3.

Results. All participants successfully grasped the object across all trials in the adaptation phase. Nonetheless, the gain of the alteration in hand orientation as a function of object orientation was low (circa 25%). To grasp the objects without altering hand orientation, participants used: (i) the full extent of their middle and distal phalanges; and (ii) deformation of the thumb and index finger's fleshy pads. Small (gain circa 33%) but reliable changes in the appropriate direction were found in the 'virtual' reaches following adaptation.

Conclusions. Grasp orientation is subject to calibration, but with low gain. Resulting inaccuracies in object orientation perception will not lead to prehension failure: humans exploit the redundant degrees of freedom of the hand to minimise consequences of perceptual errors.

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26.420 **Visually guided grasping: using a small stimulus set can lead to overestimation of the effectiveness of depth cues**

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Studies examining the role of different depth cues in the control of grasping have typically presented three or fewer objects at three or fewer distances. This raises the possibility that participants learn the stimulus set. If so, even poor depth information could appear to support reliable grasping, provided that it was sufficient to identify which of the learned stimuli was presented, leading to an overestimate of the effectiveness of the cue. We examined this for the case of removing binocular information from the visual scene. The stimuli were rectangular objects, on a surface 400 mm below eye height. We measured kinematics of visually open-loop grasps made to stimuli defined by disparity and texture (binocular viewing), or texture alone (monocular viewing). There were two experiment designs: (i) a conventional "blocked" design, in which there were three distances (200, 350 and 500 mm) and three object sizes (30, 45 and 60 mm), and (ii) a "randomised" design in which the distances were randomised (uniform distribution) in the range 200 to 500 mm, and object sizes were randomly selected from the range 30 to 60 mm (in 5mm increments). Consistent with previous findings (see Melmoth and Grant, 2006), peak grip apertures were larger under monocular viewing than under binocular viewing, in both blocked and randomised experiments. However, removing binocular cues had a significantly larger effect in the randomised experiment. This suggests that learned information in the blocked condition improved performance when binocular cues were unavailable. Previous studies may therefore have underestimated the effect on grasping of removing binocular cues. These results demonstrate that using a small stimulus set in grasping studies can produce results that do not accurately reflect the depth information present in the stimulus itself.

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26.421 **No visual field advantage for visually-guided grasping movements made with the left hand**

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In a series of recent studies we compared the performance of the right and left hands when participants grasped targets embedded in illusory backgrounds. We found that compared to the right, the left hand displayed a much larger effect of the size illusions and this sensitivity was present in both right- and left-handers. The results led us to suggest that the left hemisphere is specialized for visuomotor actions. In the present work we expand this notion by showing a right-hand advantage for grasping outside the context of perceptual illusions. Participants either grasped or estimated the size of different target objects while fixating on one of 8 randomly-presented LEDs. The LEDs were arranged radially in four directions and at two eccentricities around the central target location. We replicated previous findings of a lower visual field advantage for prehension when participants used their right hand to grasp the different targets. When they used their left hand, however, no lower field advantage was detected. In other words, grasping movements made with the right hand to objects appearing in the lower visual field were less variable than similar movements made to objects appearing in the upper visual field. Left-hand movements were more variable overall than right-hand movements, and this high variability was the same in the upper and lower visual fields. No differences between the hands or across visual fields were detected when participants had to adjust their thumb and index finger to estimate the size of the targets. We see these results as new evidence supporting the notion of a left-hemisphere specialization for the visual control of skilled movements.

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26.422 **Visible surface area and prehension movement patterns**

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Visual information about an object's distance and size determines the reach-to-grasp movement pattern. If vision specifies that object A has a smaller grasp surface area than object B, then slower movements will be programmed to A. Smaller grasp surfaces afford slower movements because more on-line visual feedback corrections are required. But what happens if the thumb and index finger have different sized grasp surface areas? In experiment 1, participants (n=8) reached-to-grasp one of nine objects directly in front of their hand in the sagittal plane at one of three distances (10, 30, 50cm). Each object consisted of a block with a dowel attached so that the ends extended to either side. The objects were the same width (5cm) but made with three different dowel diameters (3, 2, 1cm). The dowel was either the same width on both sides, or one of the six possible asymmetric configurations (10 trials per condition, total=270). Duration was affected by the surface size (duration decreased linearly as size increased) but only as a function of the thumb's surface: the finger's surface had no effect. The position of the object provided a clear line-of-sight of the thumb's surface (but not the finger's). Thus, these results can be explained by: (i) the thumb and index finger's 'opposition vector' being controlled as a single coordinative structure; (ii) the opposition vector being maneuvered with respect to the visible (fixated) object surface. Experiment 2 directly tested this by manipulating the vertical height of conical frusta so that: (a) the upper surface was visible but not the lower surface; (b) the lower surface was visible but not the upper; (c) the upper and lower surfaces were equally visible. Our findings show the importance of considering the visible surface area as a critical task constraint when attempting to understand prehension movement patterns.

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26.423 **Pointing and bisection in open and closed loop reaching in patients with hemispatial neglect**

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It is well established that patients with hemispatial neglect present severe visuospatial impairments, but studies that have directly investigated the visuomotor control in these patients have revealed diverging results, some pointing to relatively spared visuomotor function. The present study compared the performance of 8 patients with hemispatial neglect and 10 without the disorder after right hemisphere stroke and 10 age-matched controls. Subjects were asked to point either directly towards targets or in the middle of two targets, both with and without visual feedback of the hand and target during movement. No specific impairments were observed for the neglect patients on either timing, speed and end-point accuracy measures for any of the conditions. Despite the failure of our neglect patients to react to stimuli on the contralesional side of space when assessed with paper and pencil tests, we did not find any specific deviations in their movements. Our results suggest that the perceptual distortions present in patients with neglect do not influence their performance on pointing tasks with or without visual feedback of their hand, supporting the view that such patients code spatial parameters for action veridically.

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26.424 **The weight to spatial memory in visually-guided reaching increases with retinal eccentricity**

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Purpose: When people pick up an object, they can use both the current retinal image of the object and spatial memory to plan the movement. Recent work has shown that people give a higher weight to memory in goal-directed movements when the retinal image is degraded by lower contrast (Brouwer & Knill, JOV, 7(5):6, p1-12). We asked how retinal eccentricity affects the relative contributions of visual and remembered information about object location. Methods: In a virtual environment, two objects appeared on the right side of the screen: a "weapon" and a circular "target" region. The weapon was simulated to be magnetic, so that it would attach itself to the fingertip when touched. Subjects had to move the weapon to the "loading station" on the left side, then move back to touch the circular target. In a third of the conditions, the position of the circular target shifted by one centimeter during the movement to bring the weapon to the loading station (when subjects were fixating the loading station). The screen flickered for 200 msec. to mask the target shift. The weapon / target configuration was located either 14 or 28 degrees of visual angle away form the loading station. Results: Although the final target region was visible in the periphery prior to moving back to touch the target, subjects were significantly biased toward the location where the target had originally appeared. The bias to use spatial memory was significantly more pronounced when the distance between the loading station and the target was 28 degrees than when it was 14 degrees of visual angle. Conclusion: When the target region is visually more eccentric, visual information about target location is degraded. Subjects appropriately weight remembered information about target location differently as a function of target eccentricity.

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26.425 **Differential spatial integration for perception and action revealed by perceptual and visuomotor crowding**

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While the spatial characteristics and perceptual effects of crowding are well documented, the influence of crowding on action, such as reaching and grasping, is largely unknown. Studies of saccades in a crowded visual search reveal that classic crowding manipulations (e.g. decreasing target-flanker distance & increasing target-flanker similarity) affect saccade size and duration (Vlaskamp & Hooge, Vision Research, 2006). This suggests that the mechanisms limiting perceptual resolution may similarly affect movement planning. The current study sought to directly compare perceptual and visuomotor effects of crowding in the upper and lower visual fields. A central target bar, flanked by randomly oriented distractor bars, was presented at an isoeccentric (30 deg) location in the upper, central, or lower visual field. Subjects discriminated the orientation of the target bar using a perceptual 3AFC key-press, or by reaching and grasping the target. An Optotrak tracking system recorded the angle of subjects' pincer grasp. The results demonstrated that the accuracy of perceptual and visuomotor judgments toward crowded targets were similar, with the lowest performance in the upper visual field, consistent with previous findings (He et al., Nature, 1996). Interestingly, while perceptual responses in highly crowded conditions were attracted to the mean or ensemble orientation (Parkes et al., Nature Neuro, 2001), the visuomotor responses displayed a repulsion or contrast effect relative to the mean flanker orientation (i.e. subjects tended to orient their grasp opposite the orientation of the average flanker orientation in all but the most crowded trials). The results suggest that while crowding may be an absolute bottleneck for both perceptual and visuomotor behavior, the spatial extent and/or weighting of visual space for perception and action are dissociable. A single antagonistic center-surround mechanism may account for this dissociation.

26.426 **Equivalent visuomotor adaptation for variable reach practice**

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Forming an internal model for adapted reaching movements to altered visual feedback requires a certain amount of practice. Numerous studies have shown the brain can quickly adapt to visual and force perturbations while performing reaching movements to both trained target and novel targets. But many of these studies have participants reach to only a small number of target locations repeatedly. Is learning comparable in the case where target locations are constantly different and participants only have a chance to reach once to each of them? We addressed this question by having subjects adapt their reaches to altered visual feedback of the hand either when repeatedly reaching to four targets (Repeated practice) or reaching only once to numerous target directions (Single practice). We also examined the extent to which this adaptation could transfer to untrained target locations. We found there is very little difference in learning rate between the two practice conditions. That is, participants were just as fast at learning a new visuomotor mapping when reaching once to each new target as they were when reaching over and over to the same targets. Likewise, we found that participants generalized to untrained targets similarly across exposure conditions. This suggests that the brain is as capable of deducing the required visuomotor adjustments following variable practice with unique targets as it is with repeated practice with the same targets.

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26.427 **Visually Guided Reaching Using Proportional Rate Control of Disparity Tau: Data and Model**

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Introduction: What information is used for modulating velocity during approach in targeted reaching? We propose a novel strategy for the visual guidance of reaching based on the use of disparity tau to control approach to matched disparity. We hypothesize that the rate of change of disparity tau is kept in proportion to disparity tau. Previous research using a slider apparatus to examine this question produced mixed results (Anderson & Bingham, 2007). Here, we used normal reaches at preferred rates to test alternative disparity tau-based strategies. In simulations, we found that maintaining a constant ratio of disparity tau to its rate of change produced reach-like trajectories. We isolated the use of binocular disparity in a distance matching reach task to test this hypothesis.

Methods: Eight participants were asked to match in darkness the distance of a point-light on their finger to a target point-light by reaching at preferred rates. Participants reached under conditions of visual guidance or no visual guidance and with or without a perturbed inter-pupillary distance. The latter rendered vergence information unreliable and inaccurate, thus requiring online use of disparity matching for successful reaches. Reach trajectories were recorded using a Mini-bird motion measurement system.

Results: Results show that participants used a constant ratio strategy beginning just before the decelerative portion of the reach and ending at contact. Statistical tests showed that disparity tau-dot decreased while the disparity tau/tau-dot ratio remained constant. These results replicated those from a concurrent study of walking-to-reach (Anderson & Bingham, submitted). Finally, the detailed forms of these reach trajectories were modeled using a mass-spring model of reaching driven by proportional rate disparity tau information.

Conclusion: The first dynamical model of online guidance of reaching complete with appropriate information variables was supported.

Search 1

26.428 **Monetary reward does not cure the prevalence effect in a baggage-screening task**

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In many important search tasks (e.g. medical and baggage screening) targets are rare. Previously, we have demonstrated that miss error rates are 2-3 times higher when targets are rare (1-2% target prevalence) than when common (50% prevalence; Wolfe et al, Nature, 2005). In signal detection terms, prevalence effects reflect shifts in criterion, rather than loss of sensitivity (Wolfe et al., JEP-General, 2007). At low prevalence, observers make more misses and fewer false alarms, and make faster correct rejection responses. In tasks where misses are much less desirable than false alarms, it would be advantageous to counteract the prevalence effect by coaxing observers into adopting the criterion characteristic of high prevalence at low prevalence. Can we shift criterion and "cure" the prevalence effect using a monetary payoff matrix (e.g. Navalpakkam et al, 2007)? Here, using a realistic x-ray baggage-screening task, we compared two payoff matrices. One was biased toward target-present responses: hits \$+0.32; false alarms \$-0.02; misses \$-

0.65; correct rejections $+0.01. The other was balanced: $+0.01 for any correct response; $-0.01 for any error. X-ray images of empty bags were "packed" with overlapping x-ray images of weapons and non-weapon objects. Bags contained 3, 6, 12, or 18 objects. Observers searched for guns and knives. The balanced payoff matrix produced the usual prevalence effect (29% misses at low prevalence, 18% at high). The payoff matrix favoring hits modestly shifted criterion toward target present responses and slowed correct target absent responses when targets were rare. However, the reduction in miss errors was disappointing. Observers still made 27% misses at low prevalence. Prevalence effects produced under these conditions remain stubbornly resistant to standard countermeasures.

26.429 **Why don't people use memory when repeatedly searching though an over-learned visual display?**

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Previous studies have shown that the efficiency of visual search does not improve when participants search through the same unchanging display for hundreds of trials ("Repeated Search"), even though participants have a clear memory of the search display. Why don't participants use memory? In earlier experiments, using a search for letters, search efficiency actually improved when we removed the visible stimuli, forcing participants to rely on memory. However, that manipulation might have changed the task. In repeated visual search, participants probably visually located the target on each target-present trial ("The K is right there"). For the repeated memory search, participants might have simply learned a 2AFC mapping of "target" letters to one response key and "non-target" letters to another key ("The K is a member of the target set", "The Z is not a member of the target set"). In the present work, we asked participants to use the computer mouse to click on the location of targets in repeated search for visible or remembered displays. Under these conditions, as before, visual search remained inefficient (39 msec/item) over hundreds of searches through the same, unchanging display. Interestingly, memory search was even more inefficient (81 msec/item). Like visual search, it failed to become more efficient over hundreds of repetitions. It seems clear that participants used visual search because it was a more efficient strategy. Can participants ever use memory? Yes, when targets were restricted to a subset of the visible letters, participants rapidly learned to use memory for that fact to restrict search to the relevant subset.

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26.430 **What does performance on one visual search task tell you about performance on another?**

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In visual search tasks, observers look for a target among some number of distractors. Civilization has created demanding and important search tasks like airport baggage screening and routine mammography. Can we use performance on laboratory search tasks to identify people who would be successful if employed in these critical real world tasks? In the current study, 20 observers (14 women) performed a battery of search tasks. The battery included one conjunction task (red vertical target among red horizontal and green vertical and horizontal distractors), two spatial configuration tasks (T among Ls and 2 among 5s), one search for arbitrary objects in photographs of indoor scenes, and a simulated x-ray baggage-screening task (two conditions: targets appear frequently or targets appear rarely). We used corrected reaction time (RT/d', Townsend & Ashby, 1983) as an index of performance. For a given search task, reliability was high. We conducted test-retest reliability for two of the 5 tasks: r = .76 on the T among Ls task, .55 on the rare target baggage-screening task, and .72 on the frequent target baggage task. Split-half reliability ranged from .83 on rare target baggage search to .94 on 2 among 5s. Rather surprisingly, however, correlations between performance on one task and performance on another were generally quite low. Only the conjunction task correlated with the frequent target version of the baggage-screening task ($r=.63$, $p<0.01$), while only the 2 among 5s task correlated significantly with the more ecologically valid rare target version ($r=.67$, $p<0.01$). The high reliability scores suggest that we had sufficient power to detect correlations if they were present. However, in general, performance on one task fails to predict performance on another for this set of tasks.

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26.431 **Videogamers excel at finding rare targets**

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Important real-world visual searches often operate with rarely present targets. For example, targets are seldom present in airport baggage X-ray screening, radiology, and aircraft inspection. Disturbingly, rare target searches can produce high miss rates when observers proceed too quickly. The low frequency of targets causes searchers to abort searches more and more rapidly, ultimately causing numerous motor errors and incomplete scanning of the display. Here we demonstrate that individuals with extensive videogame experience perform much more accurately on such rare target visual searches than individuals without any videogame experience. This significant accuracy benefit for videogame players (VGPs) over non-videogame players (NVGPs) derives largely from a top-down, strategic slowing of responses, countering the typical speed-up observed in rare target search. Although all participants were allowed as much time as desired for each search array, VGPs avoided the pitfall of responding too quickly in low frequency conditions, whereas NVGPs sped up and consequently yielded the typical speed-accuracy trade-off. Even under conditions of faster responding, VGPs continued to perform more accurately than NVGPs, potentially highlighting a bottom-up, response-based advantage. These findings demonstrate that videogame expertise accurately predicts higher performance on rare target search, suggesting important implications for real-world search tasks with similar low target probabilities.

26.432 **The Psychophysics of Chasing**

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The currency of visual experience consists not only of features such as color and shape, but also higher-level properties such as animacy. Psychologists have long been captivated by the fact that even simple moving geometric shapes may be perceived in animate, goal-directed terms. However, the study of such phenomena has been limited by two major challenges: (1) Previous research has had difficulty measuring animacy with quantitative precision, given the haphazard construction of typical stimuli. (2) Task demands have made it difficult to distinguish the perception of animacy from higher-level inferences, especially when using simple rating scales. Here we introduce two new converging methods that address both concerns. In the Search for Chasing task, subjects viewed many identical moving discs, and had to detect whether a chase was present: on half the trials, one disc (the 'wolf') pursued another disc (the 'sheep'). Across trials, we manipulated 'chasing subtlety' - the degree to which the wolf could deviate from a perfectly 'heat-seeking' trajectory. Detection accuracy revealed both a robust perception of chasing (with small subtlety values), and an ability to infer chasing without direct perception (with larger subtlety values). The Don't Get Caught! task was similar, but now subjects controlled the sheep's trajectory via the computer mouse, with the goal of avoiding contact with the wolf after identifying it. Performance was a U-shaped function of chasing subtlety. Subjects readily avoided being caught with both large deviations (when the chasing was highly inexact in the first place) and small deviations (when the wolf was easily identified and thus avoided). With intermediate deviations, however, performance was poor: the wolf essentially 'stalked' the sheep in a manner that was difficult to detect. These results collectively demonstrate how the perception of animacy can be measured with precision and can be distinguished from higher-level inferences.

URL: http://www.yale.edu/perception/

26.433 **More than Just Finding Color: Strategy in Global Visual Search is Shaped by Learned Target Probabilities**

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We investigated the relative contribution of bottom-up and top-down information to eye movements executed during a visual search. In two experiments, participants searched for a known target, a red (or blue) rotated T, among red and blue randomly rotated Ls. The stimuli were grouped into four 9-item clusters equidistant from a central initial fixation point. Bottom-up information was manipulated by varying the number of items in each cluster matching the target color (0, 2, 7, or 9 target-color items). Top-down information was manipulated by varying the likelihood that a particular type of cluster would have the target. In Experiment 1, the target was equally likely to appear in the 2, 7, or 9 (target-color) clusters, whereas in Experiment 2, every target-color element was equally likely to be the target. If search was simply guided bottom-up by the color composition of the clusters, then the search order though the cluster types would be the same in both experiments. Instead, initial fixations in Experiment 1 were directed to the 2, 7, and 9 clusters approximately equally, but in Experiment 2, clusters containing more target-color elements were more likely to be fixated sooner. In both experiments, the 0-cluster was rarely fixated and virtually never fixated after the initial fixation. Thus, other than avoiding clusters not containing the target color, the use of color was determined by the probability that the target would appear in a cluster of a certain color type. Once a cluster was fixated, however, the time spent within the cluster depended on the number of target-color items, consistent with a search of only those items. Thus, whereas within-cluster search was directly driven by color information in the cluster, between-cluster search was more indirectly influenced by color: only by color signaling the probability that the target was in a cluster.

26.434 **An effect of WM load on visual search guidance: Evidence from eye movements and functional brain imaging**

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We often have to search for multiple targets, and these searches often occur after substantial delays. These demands have implications for guidance from working memory (WM), and the brain mechanisms subserving search guidance. We conducted separate behavioral (eye movement) and fMRI investigations of the guidance process and mechanism. Our general method had subjects initially preview two objects (a butterfly and a house), presented sequentially. After 5000msec, this 2-object WM load was manipulated using 3 types of retro-cues (within-subjects variable): the letter "B" (only attend to the butterfly in WM), "H" (only attend to the house), or "E" (either the butterfly or house could be the target). Following a second 6000msec delay, a 9-object search display was presented and the subject's task was to indicate target presence/absence. Consistent with a WM load effect, errors were higher and RTs longer with an E cue compared to a B or H cue. Importantly, guidance was also affected by WM load, both in the number of distractors fixated before the target and in the proportion of initial target fixations. The identical experiment conducted in a 3 Tesla magnet revealed distinct posterior brain regions corresponding to the butterfly and house targets. Moreover, activation of these visual areas varied with the retro cue; one region showed higher sustained activation following the H cue, another region showed higher sustained activation following the B cue. Activation of both regions was observed following the E cue, but to a lesser degree. These fMRI analyses dovetail nicely with our behavioral evidence for guidance, suggesting that search guidance is mediated by WM representations in posterior visual areas. However, brain activation was also observed in prefrontal and parietal areas, suggesting the possibility of a larger network of systems contributing to the maintenance or reconstruction of the WM representations underlying search guidance.

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26.435 **Visual search guidance increases with a delay between target cue and search**

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Search studies typically present displays immediately following a target cue, but real world search often occurs after long delays between target designation and search. How does search guidance change with this delay? We hypothesized that guidance for pictorially previewed items may decrease over time as details fade from visual WM, while guidance for semantically-defined targets may increase with delay as subjects build a more detailed target representation. We presented either a picture or a semantically-defined target cue (e.g., a picture of a green apple or the text "Green Apple"), followed by a 0ms, 600ms, 3000ms, or 9000ms delay period, then a search display depicting 5 realistic objects. Consistent with previous work (Schmidt & Zelinsky, 2007), we found overall greater guidance to pictorial than semantically-defined targets. However, and unexpectedly, we found stronger guidance in the delay conditions (compared to no-delay conditions) for both pictorial and textually-defined targets. Specifically, subjects in the delay conditions fixated the target sooner (565ms vs. 609ms), required fewer fixations to reach the target (3.41 vs. 3.53) and made a greater percentage of their initial saccades to the target (46% vs. 38%). These initial targeting saccades also had a shorter latency (184ms vs. 216ms), suggesting a genuine benefit rather than a speed-accuracy tradeoff. We interpret our data as suggesting the need for a period to consolidate information in visual WM to mediate search guidance. For pictorial cues, this may involve extracting the most salient features from the pictorial description, thereby creating a more compact representation that can reside in visual WM. For semantically-defined targets, a visual WM representation would have to be constructed from information provided in the text cue. We speculate that both processes occur most efficiently in the absence of newly arriving visual information, explaining why a delay following target designation benefits search guidance.

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26.436 **Novice and Expert Performance on a Computerized Lifeguarding Task**

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The task of visual search is ubiquitous in everyday life. I present the case for studying one real-world search task - lifeguarding - in the laboratory. The lifeguard task encompasses a scanning component, a fixation component, and an evaluation component where the lifeguard determines whether a swimmer might need assistance. Research seems to indicate that lifeguards' scanning is continuous, so missed drownings may be due to faulty evaluation. Lifeguards are taught behaviors associated with drowning – bobbing vertical body with flailing arms and tilted head – but, more importantly, they must anticipate a drowning by closely examining weaker swimmers, who are most likely to drown. In my study, three groups of subjects saw 60 short video clips of varied swimming scenes while an eyetracker monitored their gaze position. The Naïve group was told to look at things that interested them. The Taught group was taught the behaviors above and told to act as a lifeguard and look for those behaviors. The Lifeguard group contained trained and certified lifeguards who monitored as if on the job. Two analyses were done – one on categorizing the target of fixations longer than one-third second and one on "critical events" (i.e., events in my clips identified as "important to monitor" by two persons who teach and research lifeguarding). So far in the analysis, Lifeguards spend more time scanning and less in fixation than Naïve subjects, and spend more time looking at weak swimmers (indicated by, e.g., slow speed). Lifeguards also fixate more critical events than Naïve subjects, although they are not perfect and even Naïve subjects fixate some of the critical events. The Taught subjects perform in between the other groups, and even though they look for the behaviors, they do less well at anticipating future problems and frequently saccade away from a critical event prematurely.

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26.437 **Don't distract the searcher: search performance for X-ray security screening images is reduced with the addition of a simple mental arithmetic task**

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Recent studies have demonstrated the important role of working memory in conducting effective visual search. The present study examined the role that the central executive plays in visual search, which is believed to be necessary for high-level control and coordination in search, as well as storing task- and target-related information. Performance was compared across three tasks: a visual search task, a simple mental arithmetic task, and a combined task, in which mental arithmetic and visual search were performed simultaneously. Adding the mental arithmetic task to the visual search task increased search response time while decreasing search response accuracy. There was also a decrease in search response accuracy when participants were asked to search for more than one target simultaneously (the dual-target cost). However, the dual-target cost was not amplified when the mental arithmetic and visual search tasks were combined. The results replicate previous findings regarding the highly limited capacity of the central executive and its importance to search. At a practical level, these results suggest that search performance may be impaired in real-world visual search applications in which the observer is open to potential distractions from their environment, and that performance may be improved by imposing measures to either reduce or prevent such distractions.

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26.438 Expected object position of two hundred fifty observers predicts first fixations of seventy seven separate observers during search

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Saccadic eye movements can be directed using ultra-rapid extraction of low-level information in images of natural scenes (Kirchner & Thorpe, 2005), and are also biased towards the expected location of objects (Torralba et al., 2006), allowing improved search performance in statistically structured scenes (Eckstein et al, 2006). Expected object locations can be objectively defined by the statistical properties of low level features across the scene (Torralba et al., 2006) but these methods have not captured more complex relationships such as the relative configuration of objects. To bypass this problem, we quantified expected object locations in scenes by asking two hundred fifty observers to report the position of where they would most expect a particular object to be located within each of twenty-four real world scenes (e.g. cup in kitchen). These distributions included a wide range of variances (1.36 – 7.92 deg) and multiple foci (1-3). We compared these distributions to first fixations of seventy seven different observers in two separate tasks: (1) detection, reporting the presence or absence of an object (N=48) and (2) localization, reporting either the position, or expected location of an object (N=29). In target-absent trials for each task, endpoints for first fixations were significantly closer to the average expected position than to an equidistant control location (detect: 6.67 deg vs 11.93 deg; localize: 6.39 deg vs. 11.62 deg). Expectation of object location also exerted influence on trials in which the target appeared at an unexpected position. Our results suggest that statistical knowledge of the relative configuration of objects is rapidly extracted from natural scenes, and that this knowledge is used to direct gaze in both detection and localization tasks. This pattern of behavior provides additional evidence for attentional mechanisms using sensory weighting based on expectations to guide eye movement behavior.

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26.439 The role of meaning in visual search

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The visual search paradigm is widely recognized as a means of assessing the salience of image features, and distinguishing properties that are processed pre-attentively. Recent research has used face stimuli to show high-level influences on putative pre-attentive processing (Hershler & Hochstein, 2005; Reddy, Wilken & Koch, 2004). Others have shown similar advantages with natural images (Rousselet et al., 2004; Li et al., 2002), however, with such complex stimuli it is often difficult to determine the basis of the effect.

Here we use meaningful, non-face, stimuli to evaluate high-level influences in a visual search task. Targets were black and white images of food and everyday objects; distractor stimuli were scrambled versions of the target items in which local features were re-positioned. The two classes of images and their distractors did not different in their low-level image properties (RMS contrast, frequency content). In a visual search experiment, observers indicated if a target was present in a set of distractors. Within a session all image types and distractor levels were randomly interleaved. Reaction times for non-food images increased with the number of distractors over the full range tested (n = 5-80). Reaction times for food images initially increased, but flattened at approximately 20 distractors. Further increases in the number of distractors had no effect on performance for this class of stimuli. This food specific pop-out effect is robust, and shows no effect of gender. Moreover, an image identification task shows that there is no difference in the discriminability of the two groups of images.

Our results show that so-called pre-attentive processing is not restricted to low-level image properties, but is clearly influenced by meaning. These data provide another piece of evidence against simple hierarchical models of visual information processing, and for more integrative models, like that proposed by Lee and Mumford (2003).

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26.440 Using gaze measures to diagnose what guides search in complex displays

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GIS maps are one kind of complex display in which people search for targets. Recent studies have shown that the choice of colour-scales when displaying these maps has important implications for people's strategies in searching these displays (Donnelly, Cave, Welland & Menneer, 2006). The current study follows up on this research. Observers searched for multiple targets in each display. Two targets were red and two were blue, and targets were not very salient. Observers searched until all targets were found. This often took several seconds and many fixations. The order in hich observers found targets suggested that they were more reliant on search for particular colours under some color-scales than under others. What will be presented here is a number of oculomotor measures used to explore how search was guided in the displays: the degree to which fixations clustered around targets, the image characteristics of regions of the display that were fixated, and goodness of fit to fixation distributions of Itti & Koch saliency maps, where the features used to compute saliency were varied. The goal was to see which measures would best pick up on differences in what guided search through complex displays.

26.441 Target overshoot when searching for a stationary target by moving a window or by moving a scene behind a stationary window

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When searching for a target with eye movements, saccades are planned and initiated while the visual information is still being processed, so that subjects often make saccades away from the target and then have to make an additional return saccade. We previously showed that increasing the cost of passing the target, by having subjects move a window through which they could see the visual scene with their hand did not prevent such overshooting. In that case the eyes and hand follow the same path. Here we compare that condition with one in which a scene is moved behind a stationary window. The task was to find an O amongst Cs. We ensured that the required movement of the hand was identical in both conditions, so that any difference could be attributed to the relationship between movements of the eye and of the hand. Subjects found the target faster when moving the window than when moving the scene behind the window at the expense of making more overshoots. The relationship between overshoot and movement speed when comparing the two conditions was the same as the relationship between these two when comparing targets of different contrasts or different window size. We conclude that the hand overshooting the target is not directly related to the eyes doing so, but rather that moving on before the information has been fully processed is a general principle of visuomotor control.

26.442 Visual Search in Air Traffic Control: Altitude Correlated Depth Cues Enhance Conflict Detection

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Air traffic controllers engage in a highly demanding attentional task that is vital for public safety. The amount of air traffic continues to increase on a yearly basis and the number of experienced controllers is dwindling due to a higher than expected retirement rate. Both of these factors point towards the need to improve air traffic control displays to make them easier to understand and use. Previous work (Palmer, Clausner & Kellman, in press) has shown that the altitude-correlated depth cues of size and contrast improve conflict detection and decrease search time in simulated air traffic control displays. Here, we address the question of whether the benefit is due to the mere presence of guiding features or whether there is an additional contribution from depth perception processes. Participants searched for aircraft conflicts (potential mid-air collisions) in simulated air traffic control displays. Observers were instructed to either imagine they were looking down on the scenario from above or up at the scenario from below. Aircraft icons were presented in different sizes and contrasts that correlated with their altitude. In the depth-consistent condition, aircraft icons obeyed the depth cues of relative size and aerial perspective. In the depth-inconsistent conditions, one or the other or both cues were opposite to the canonical depth ordering. Results indicate that depth-consistent graphical cues aid conflict detection, which suggests that guiding features are important, but guiding features that correlate with ecological depth ordering enjoy a privileged status in the visual system. There also appears to be a hierarchy of depth cue effectiveness, with size consistent conditions yielding better performance than contrast consistent conditions. We discuss the implications of these findings for air traffic control displays in particular and the graphical presentation of complex information in general.

26.443 Layout following and visual search for web labels

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Visual search within a web page depends of different strategies, based on semantic and spatial factors. Semantic aspects refer to the similarity between user's goal and label meaning; spatial aspects to label positions expected on the basis of scanning habits. We ran three visual search experiments to show that another strategy is involved; namely, layout following. Users exploit knowledge about web layout conventions and search for items in positions consistent with the categorization of their goals, expecting to find labels that refer to basic level categories in the navigation bar and labels that refer to subordinate level categories in the canvas.

In Experiment 1 observers searched for a basic/subordinate target word within either a standard (navigation bar on top and canvas on bottom) or non standard hierarchical page layout. In positive trials labels matching the target were displayed in one of 6 possible positions [3 in the navigation bar and 3 in the canvas]. In Experiment 2 the same visual search was performed in the absence of a web page layout [6 candidate labels on a white background]. In Experiment 3 target non-words were searched in the same standard hierarchical layout of Experiment 1.

Experiment 1 revealed a strong layout following effect that cannot be explained by either an independent or a conjoined estimation of the relevance of semantic and spatial labels. Searching within the navigation bar was faster for a basic target than for a subordinate target; while the opposite occurred when labels were displayed within the canvas, regardless of the type of web page layout. The effect was eliminated by removing the layout (Experiment 2) or the target meaning (Experiment 3). Results are consistent with a composite measure of label relevance, defined as the weighted linear combination of semantic, spatial, and layout following aspects.

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26.444 Applying models of visual search to map design

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At VSS 2005 we described how to use the Guided Search model of visual search to optimize colors on a simple mall directory. We now show how to apply a similar idea with a more general model and more complicated stimuli. The stimuli are similar to maps of parks, with various items of interest indicated by colored icons. We used the model to identify the optimal selection of colors and icon shapes that would promote fast search of the maps. The model analyzes the color, shape, and eccentricity of a target item relative to other display items on the map image and weights computational measures of these effects to predict search time. The model weights were parameterized to fit reaction time data from an experimental study where observers searched for a target in a map with different sets of icons. 45 observers in 3 groups each viewed 150 maps. The model did a good job (r=.67) fitting the average reaction times of the 450 total trials. We then used the model to explore optimization tasks that varied the color palette that could be used, the distribution of icon search frequencies, and the shapes of the icons. We also explored the generalizability of the model's parameterization by applying the model to a different map design task. This approach shows good promise for applying theories from visual perception to design tasks. The study highlights deficiencies in many current models of visual search that cannot be applied to this kind of project.

26.445 Two categories of glaucoma patients tell us the contribution of peripheral vision on visual search

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Peripheral vision is believed to play an important role in detecting object for guiding visual attention and foveation for achieving higher order visual analysis, e.g., part-whole integration, or small letter recognition. To test the contribution of peripheral vision on visual search for a letter under free viewing, we tested two categories of glaucoma patients; Bjerrum scotoma patients with partial peripheral vision, and concentric construction of the visual field patients with perfect loss of peripheral vision but unaffected central vision. Subjects searched for a letter. RT and error rate were collected. The causalities between these data and patients' visual factors and display factors were tested by SEM. Both groups did not show significant difference in behavioral data, whereas they showed a clear difference in causal analysis. For the concentric construction of visual field group, retinal letter distance was the chief factor that explained these data. In contrast, for Bjerrum scotoma group, all other factors but visual acuity explained RT. Visual acuity influenced error. Our initial hypothesis was that the contrasts between these two groups should suggest the contribution of the peripheral vision on the task. We analyzed the contrast and the following causalities were significantly different: age to visual acuity, visual acuity and % intact visual field to error rate, and retinal letter size to RT. Surprisingly, most causalities that showed a difference between the patient groups were related to the error rate and only one visual factor was related to RT or the search process per se. Contrary to the idea that the peripheral vision assists in guiding our attention and central vision, these results suggest that a large contribution of peripheral vision in visual search is availability of part-whole integration of letters for collective report and visibility, and that the search process itself is not such a large factor.

Acknowledgement: Supported by SCOPE to TY

Saturday, May 10, 2:30 - 6:30 pm
Poster Session, Orchid Ballroom

Scene Perception 1
Spatial Vision: Natural Images and Texture
Temporal Processing and Dynamics

Scene Perception 1

26.501 When two are one and one is two: Apparent motion, visible persistence, and scene organization

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Smooth apparent motion is often perceived between two stimuli when they are presented at appropriate temporal and spatial separations even when they differ substantially in appearance (for example in size). In contrast, when a moving stimulus undergoes an abrupt change in size, it is perceived as two simultaneously present objects, one of the changed size and one of the original size. This change-related persistence occurs, we have argued, because the change disrupts the original object representation causing the establishment of a second one to accommodate the change (Moore, Mordkoff, & Enns, 2007). Together these observations present a quandary with regard to inferring represented scene organization from phenomenological reports. For apparent motion, a two-stimulus event appears to be represented as a scene that is comprised of one object. In contrast, for change-related persistence, a one-stimulus event appears to be represented as a scene that is comprised of two objects. We created displays in which a single disc was displaced horizontally in 3° steps, for 80 ms at each location, separated by variable interstimulus intervals (ISI). The size of the disc in the second to last frame of the sequence varied from 10% to 100% the size of the original disc. Some observers reported whether they perceived smooth motion in the final two frames of the display or not. Other observers reported how many objects they perceived in the final two frames of the display, one or two. Good motion was reported at appropriate ISIs regardless of size change, suggesting a scene organization of one object. In contrast, two objects were reported more often with larger size changes, suggesting a change in scene organization from one object to two. Implications for the use of perceived motion as proxy for "represented as a single object" are explored.

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URL: www.psychology.uiowa.edu/labs/iapl

26.502 A distance principle of organization of the ventral visual stream

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Perceiving the distance of an object from the self is a fundamental feature of the visual system. Here we used fMRI to test the hypothesis that the ventral visual stream represents distance-related information in discrete cortical regions. In particular, object-related regions (Lateral Occipital Complex - LOC) are biased towards proximal stimuli, whereas scene-related regions (Parahipocampal Place Area - PPA) are biased towards distant stimuli. Participants were presented with Ponzo lines, which create an illusion of depth. In one condition, the stimuli (pictures of objects or houses) appeared in the perceived proximal position. In the second condition, the stimuli appeared in the perceived distal position. In addition, we ran a localizer, which included scenes, objects and scrambled images of objects. We defined for each subject the PPA (Scenes > Objects, p <10-4, uncorrected) and the LOC (Objects > Scrambled Objects, p < 10-4, uncorrected). Consistent with our hypothesis, we found a double dissociation such that object areas showed a higher response to perceived proximal stimuli than perceived distal stimuli, whereas scene-related regions showed a higher response to perceived distal objects than perceived proximal objects. Importantly, this effect was found for both objects and houses. This outcome suggests the plausibility of a distance principle of organization of the ventral visual stream.

26.503 Decoding of natural scene categories from transformed images using distributed patterns of fMRI activity

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Human observers are able to quickly and efficiently extract information, such as the "gist," from images of natural scenes (Potter & Levy, 1969). Previous studies have identified brain regions that respond selectively to images of natural scenes, including the parahippocampal place area (PPA; Epstein & Kanwisher, 1998) and retrosplenial cortex (RSC; O'Craven & Kanwisher, 2000). However, it is not known to what extent these place-selective regions participate in the categorization of natural scenes. As a means of testing for the presence of scene-category information in these regions, we used fMRI and statistical pattern recognition algorithms (Cox & Savoy, 2003) to identify distributed patterns of activity associated with natural scene categories (beaches, mountains, forests, tall buildings, highways, and industrial scenes). In our first experiment, fMRI data was aquired while subjects passively viewed 60 images from each of six categories, in 6 blocks of 10 images each of the same category, organized into 12 runs during which images were displayed upright or inverted on alternating runs. In a leave-one-run-out (LORO) cross-validation procedure, we found that statistical pattern recognition algorithms were able to predict the categories of the scene viewed by the participants at rates significantly above chance using voxels in retinotopic cortex or the PPA. Using a more sensitive classifier than reported last year, we found a significant inversion effect in both PPA and retinotopic cortex: i.e. training on upright and testing on inverted resulted in a decrement in performance relative to testing on new upright images. A subsequent experiment used a similar design, with alternating runs consisting of sequences of large and small images. Above-chance classification rates were obtained in the PPA, with a decrease in accuracy for small scene images vs. large images. These results suggest that the PPA is sensitive to changes in image size and orientation.

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26.504 Probability summation and phase spectrum are sufficient to support animal detection in multiple scenes

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Observers can detect animals in natural scenes rapidly and accurately. Rousselet et al. (Nat. Neurosci. 2002) briefly flashed (26 ms) 2 natural scenes, both in the periphery (centered at 3.6 deg). In these conditions, animal detection was slightly less accurate compared to when observers viewed a single scene. However, probability summation successfully predicted the decrement in d-prime for the double-scene condition compared to the single-scene condition. We retested the double- and single-scene conditions, and employed a novel condition where observers viewed 2 animal scenes. Three observers performed a rapid go/no-go animal/non-animal categorization task in all 3 experimental conditions: single-scene, target-plus-distractor, and double-target, with a total of 8,960 trials per observer. Probability summation was successful in accounting for the pattern of d-prime across the experimental conditions.

Consistent with previous modeling work, we found that an amplitude-only classifier could perform our task. If observers used amplitude spectra to perform our task, then resetting amplitude spectra to be the same across all images should lower d-prime. This is what we found. However, altering amplitude spectra introduces distortions that could even affect a phase-only observer. To test this hypothesis, amplitude spectra were swapped across images, but only within an image category. In these conditions, an amplitude-only observer should perform just as well as with the original images. Contrary to the amplitude-only hypothesis observers had lower d-primes for these amplitude-swapped images compared to normal images. Furthermore, this experiment led to the same low d-primes that were obtained in the amplitude-equalized experiment. This is consistent with the idea that the amplitude manipulations in both these experiments introduce distortions affecting our ability to extract phase information.

26.505 Preserved house discrimination in a patient with acquired object agnosia

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Is object discrimination a necessary precursor for discrimination houses, whose features might be considered to be objects? For instance, when we manipulate a house by inserting different windows, are the windows within the house an object or are they integrated into the house itself? We compared two different types of discrimination of two visual stimulus classes (houses and faces) in a patient with acquired brain damage to controls. Patient SB is a 38 yr old male who suffered damage to ventral visual areas including the right fusiform gyrus and inferior and middle occipital gyri from meningitis at the age of 4 years. This resulted in profound object agnosia and prosopagnosia but nevertheless SB has previously been shown to have intact scene categorization. Participants performed a same/different discrimination task with stimulus sets of house and face images designed to asses featural and configural processing across these two visual image classes. In the featural set, houses and faces differed only in the features (windows, doors or eyes, mouth). In the configural set, houses and faces differed only in the spacing of the features. Control participants could differentiate featural and configural differences on these two stimulus classes. Patient SB was unable to discriminate the feature spacing or the features of the face stimuli sets, reflecting his prosopagnosia. He also was unable to discriminate the feature spacing of the configural house test, which may be a floor effect. In contrast, SB was able to discriminate houses with different features despite his object agnosia. This implies that the features of the house are not processed as individual objects but rather as integrated components of a global scene. These results suggest that SB discriminates houses using his intact scene processing pathway and further suggests that object and scene processing are independent.

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26.506 Adaptation for individual places but not for place categories in scene-selective cortical regions

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An image of a real-world location can be identified in at least two ways: as a specific place in the world ("VanPelt Library"), or an exemplar of a more general place category ("library"). Previous fMRI studies (Epstein and Higgins 2007) indicate that scene-selective cortical regions such as the parahippocampal place area (PPA) and retrosplenial cortex (RSC) are sensitive to this distinction, responding much more strongly when subjects identify scenes as specific places than when they classify them into place categories. Although these results may indicate that the PPA/RSC are uninvolved in scene categorization, an alternative possibility is that information about scene category is encoded but using a submaximal response. Here we use fMRI adaptation to resolve this issue. In different blocks, subjects viewed images depicting: (1) prominent landmarks from a familiar college campus, (2) prominent landmarks from an unfamiliar college campus, (3) indoor scenes of various categories (e.g. kitchen, bedroom), (4) outdoor scenes of various categories (e.g. playground, beach). Within each block, the category or campus landmark was either fixed (different images of the same category/landmark) or varied (different categories/landmarks). Adaptation was indicated by reduced response in the fixed condition compared to the varied condition for each of the 4 stimulus classes. In RSC, adaptation was observed for familiar landmarks but not unfamiliar landmarks, indoor categories, or outdoor categories. No adaptation was observed in the PPA for any stimulus class. These results support the contention that the PPA/RSC encode representations useful for identification of specific places: a viewpoint-specific scene snapshot in the PPA, and a more viewpoint-invariant representation of familiar places in RSC. In contrast, neither PPA nor RSC appear to encode information about scene/place category.

26.507 Mean representation beyond a shadow of a doubt: summary statistical representation of shadows and lighting direction

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Shadows provide information about object motion and depth, but they must also be discounted to accurately recover surface properties and lightness. Our inability to accurately detect contradictory shadows in a scene suggests that shadow information is computed at an early, local scale, and that global factors such as lighting direction are not explicitly represented by the visual system. There is another possibility though. Several recent studies have shown that the visual system represents scenes with summary statistics. For example, observers perceive the average size of a group of randomly sized objects (Ariely, Psych Sci, 2001; Chong & Treisman, Vis Res, 2003), and the average identity of a group of faces (Haberman & Whitney, Curr Bio, 2007). Could shadow information across a scene be represented by summary statistics? To test this, we rendered a set physically realistic images of a simple three-dimensional object illuminated by a single light source from one of 50 different orientations. The resulting images contained a shaded object with a cast shadow (consistent with each of the 50 possible lighting directions). We created a second set of stimuli by converting those same 50 images into two-tone pictures that were not perceived as shadows, but rather as opaque paint. Subjects were presented with a heterogeneous group of either shadow or two-tone images, and asked to compare the mean shadow/lighting orientation to a test image. Mean discrimination thresholds for both the realistic shadows and the two-tone images were precise and surprisingly similar for both stimulus types, demonstrating that, at least for relatively simple scenes, observers can perceive the mean shadow orientation even when there is heterogeneity in the orientation of the shadows. Therefore, although we are insensitive to inconsistencies in shadows and lighting direction, the visual system seems to roughly model global lighting conditions in scenes using summary statistics.

26.508 The role of bias in human contour labeling

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In research presented at last year's VSS, it was demonstrated that when humans label image contours according to the type or physical cause of the contour, they are heavily influenced by the available vertex information. The present study was designed to refine our understanding of how vertices influence observer labeling; different vertices may be more or less informative in narrowing down possible labels. In addition, observers may be using prior experience to reduce possible interpretations to those that are most likely in the environment. A key test of this hypothesis is to gradually reveal image information: if observers are biased towards particular interpretations, these labels will be assigned to ambiguous stimuli that may then be made unambiguous by increasing available vertex information. The study therefore used computer generated images of simple scenes, beginning with a small, circular cutout centered on a particular contour and gradually increasing in size to reveal additional vertices one at a time. The range of sizes was designed to span completely ambiguous to completely unambiguous scenes in no more than 5 steps. Observers were asked to use mouse controlled sliders to indicate their confidence in assigning five different labels (reflectance, illumination, orientation, orientation occlusion, and smooth occlusion) to the single central contour. The results suggest that different vertices are in fact different in how informative they are about constituent edges, with some vertices being sufficient alone and others requiring multiple additional vertices to produce correct labeling. Observers also assigned high confidence incorrect labels to contours when stimuli were moderately ambiguous, later switching to high confidence correct answers when additional vertices were added. This suggests that observer bias does play a significant role in the use of vertex information.

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26.509 The effects of valence and attentional focus on the remembered size of objects in affective scenes

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Evidence suggests that motivational states might influence spatial judgments when viewing either real or virtual inclines 1. Recently, this finding has been extended to photographic stimuli 2. This study sought to determine whether the emotional aspects of a photographic stimulus would influence remembered size of both focal and non-focal objects contained therein. Participants were presented with arousing positively and negatively valenced photographs selected from the International Affective Picture System. To determine the contribution of attention, within each image objects were selected which were either more or less central to the affective scene. Following a 500 ms presentation of the original intact photograph and an unfilled 1s ISI, subjects were presented with a portion of the original image. This sub-section of the image, containing either a focal or non-focal object, was presented as either slightly larger or slightly smaller than it appeared within the original scene. Participants were instructed to manipulate the size of the image so that it matched the remembered size of the object in the original.

Participants sized the focal objects so that they accurately reflected their size in the original picture (.99 of original size) whereas non-focal objects were sized smaller than they appeared in the original picture (.95 of original size). There were no differences as a function of overall picture valence. Thus, attentional focus increased the relative remembered size of objects, but valence had no influence on remembered size.

1 Bhalla & Proffitt, 1999 2 Lindemann, 2006

Acknowledgement: Supported by USF Center for Pattern Recognition

URL: http://shell.cas.usf.edu/~sanocki/publicationspage.html

26.510 Exploring aesthetic principles of spatial composition through stock photography

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Past research in our laboratory (Palmer, Gardner & Wickens, in press; Palmer & Gardner, VSS 2007) has shown robust and systematic aesthetic preferences for the horizontal position and direction of a single object within a frame. In particular, people prefer the object to be laterally positioned near the center of the frame (the "center bias") and to face into, rather than out of, the frame (the "inward bias"). In the present research we extend these findings with experimentally manipulated images to the vertical dimension, where we find a strong "lower bias" for objects supported from below (e.g., a cup or bowl) and an "upper bias" for those supported from above (e.g., a ceiling light). We also investigated the extent to which these horizontal and vertical biases are manifest in aesthetically pleasing natural images outside the laboratory by analyzing images from the Corel database of stock photography. Observers viewed hundreds of images that they judged to contain just one or two focal objects and indicated where they perceived the center of the visible portions of these objects to be located. Using these data, we examined evidence for the center, inward, lower, and upper biases found in our previous laboratory research separately for one- and two-object pictures. We also tested models of people's judgments about the location of the center of the visible portion of an object (e.g. bounding-box, center of mass, geometrical center, etc.).

Spatial Vision: Natural Images and Texture

26.511 **Why do we see some surfaces as reflective?**

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Why do we see the surface of a polished car as a specular reflection of the surrounding environment rather than as a texture property of the car itself? In addition to highlights, other surface properties might contribute to perceived specularity. This study explores whether deformations of the reflected scene and the nature of the scene itself contribute to perceived specularity. Human observers viewed pairs of images of mirrored surfaces reflecting different surrounding environments and judged which image was more specular. We used a CAD package to render images of mirror-like objects reflecting a range of surrounding scenes. The objects were composed of shape primitives and the scenes were either real-world or synthetic environments (e.g., ellipses on the hemisphere). Surprisingly, objects reflecting artificial environments produced a much weaker impression of specularity than did those reflecting natural environments – reflected synthetic environments were more likely to be seen as the surface texture. Critically, the nature and magnitude of the deformation of the reflected environment was virtually identical across synthetic and natural scenes. Additional experiments showed that the phase component of the spectral decomposition of the scene plays an important role: reflections of a phase-randomized scene (using an algorithm based on RISE) weakened perceived specularity. Phase randomization weakens the spatial structure of scene, further suggesting that deformation cues based on reflected scene structure affect specularity perception. Yet reflections of phase randomized scenes were still seen as more specular than reflections of synthetic environments. All this suggests that the perception of specularity is strongly affected by the statistics of the surrounding environment - natural statistics yield a stronger impression of specularity. Thus, deformations acting on the reflected scene appear to be a necessary but not sufficient cue.

26.512 **Do colored highlights look like highlights?**

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How does chromatic information influence gloss perception? For glossy dielectric surfaces, pixel colors are linear combinations of the colors of specular and diffuse reflectance components. We generated images of glossy corrugated surfaces and independently changed the colors of the two components, while keeping the luminance profile fixed. We used a high-dynamic-range display to obtain sufficiently bright colored highlights. When diffuse and specular components shared the same color (e.g., white on white, or red on red), observers perceived normal glossy surfaces. When the specular component was white and the diffuse component was colored (e.g., white on red), the surface looked even more naturalistic. On the other hand, when we combined a colored specular component and a white diffuse components (e.g., red on white), the surface images looked somewhat strange. They looked less glossy, and more importantly, did not appear to have a uniform reflectance. Colored highlight regions appeared to be spatially segregated from the surrounding white-body regions, as if pieces of colored foil were attached to a white matte surface. Of the four color combinations, only the last one (color on white) contradicts our usual experience with dielectric surfaces. A white object under white light gives white on white; a white object under colored light gives color on color; a colored object under white light gives white on color, but in most circumstances we don't encounter color on white. Our observation suggests that the human visual system correctly takes into account a physical constraint of highlight color when it judges whether a given local luminance change is introduced by superposition of a highlight, or by other physical causes including reflectance changes. Thus white on red gives the best sense of gloss, and red on white gives the worst.

URL: http://www.brl.ntt.co.jp/people/nishida/Presentation/VSS2008/

26.513 **Is color patchy?**

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In many natural scenes shadows and shading, which are primarily luminance-defined features, proliferate. Hence one might expect that the chromatic layers of natural scenes, which more faithfully represent the layout of object surfaces, will contain relatively fewer and larger uniform regions than the luminance layers, i.e. will be more 'patchy'. This idea was tested using images of natural scenes that were decomposed into chromatic and luminance layers modeled as the 'red-green', 'blue-yellow' and 'luminance' channel responses of the human visual system. Patchiness was defined as the portion of pixels falling within a ± threshold in the band-pass filtered image, averaged across multiple filter scales. The red-green layers were found to be the most patchy, followed by the blue-yellow layers, with the luminance layers being the least patchy. The correlation of patchiness with the slope of the Fourier amplitude spectrum revealed a medium-sized negative correlation for the red-green layers (-0.48), and weaker negative correlations for the luminance and blue-yellow layers. We conclude that the chromatic layers of natural scenes contain larger uniform areas than the luminance layers, and that this is not predicted by the slope of the Fourier amplitude spectrum.

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26.514 **Finding meaningful patterns in visual images**

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It is widely acknowledged that the visual system summarizes complex scenes to extract meaningful features (see for example Barlow, 1959; Marr 1976; 1992). This primal sketch is based on primitives like edges, bars, for which specific neural mechanisms have been found (Hubel & Wiesel, 1962;1977; Maffei et al. 1979; Kulikowsky & Bishop 1983) and many computational models have been proposed (Marr & Hildreth, 1980; Watt & Morgan 1985; Morrone & Burr 1988). Several studies also suggest that neurons encode sensory input in an information-efficient way (Barlow, 1972; Atick, 1992), using a small number of active neurons at any given point in time ('sparse coding') (Olshausen & Field 1996;2004).

In this work we apply a novel pattern recognition model, derived from a principle of most efficient information coding within given computational limitations (Punzi & Del Viva VSS-2006).

Using sets of natural and artificial images, we show that this model, in spite of very few free parameters, processes images in a way that is strikingly similar to the human system, identifying edges, lines, and textural elements, and predicts a structure of visual filters closely resembling well-known receptive fields.

To evaluate the biological plausibility of the approach we compared the model performance to that of human observers, tested with psychophysical techniques.

These results lead us to argue that real-world limitations to an information processing system can do much more than simply limit its performance: they actually act as a strong constraint in defining what the system categorizes as relevant features in the input, that is, what the system ultimately perceives as meaningful.

26.515 **The Frozen Face Effect: Why Static Photographs Don't Do You Justice**

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When a television show or movie is paused, people who are frozen in mid-action typically look much less flattering than they do in natural motion. What causes this frozen face effect? Here we conducted two experiments to quantify the effect and determine its cause. In the first experiment, we presented 40, two-second video clips of people speaking in naturalistic settings (e.g., news programs, talk show interviews, etc). We also presented all of the static frames that comprised each video, interleaved in a random order within the same session. Using a 7-point Likert scale, subjects rated how flattering each stimulus was. Flattery ratings of the videos were significantly higher than average flattery ratings of static images derived from the videos. In the second experiment, we used an ABX discrimination task to measure recognition of the static faces that comprised each video. In each trial, a video was presented, followed immediately by two static images: a target image from the video, and a lure from another very similar video. Subjects were required to judge which static image was a member of the preceding video. Overall, there was a strong recency effect; subjects were more accurate at recognizing static images near the end of the video, despite the random order of presentation. More interestingly, subjects were more accurate at recognizing target images that had flattery ratings close to the source video's rating (Experiment 1). The results suggest that when viewing dynamic faces, the visual system selectively filters or suppresses outlying, unflattering faces.

Acknowledgement: NIH

26.516 **Temporal integration of high-level summary statistical representation**

Thomas Harp[1,2] (tdharp@ucdavis.edu), Jason Haberman[1,2], David Whitney[1,2]; [1]The Center for Mind and Brain, [2]Department of Psychology, University of California, Davis

We encounter sets of similar objects on a regular basis—a field of corn, a bin of apples, a parking lot of cars. When we perceive these sets, the visual system tends to favor a statistical summary of the group as a whole, while individual item information is often unavailable. This ensemble representation occurs not only for low-level features but also for high-level objects. For example, observers perceive the mean emotion or identity in a set of simultaneously presented faces. Here we investigated the timecourse of high-level ensemble representation of faces. Observers were shown sequentially presented faces of varying emotions. The number of faces, the duration per face, and inter-stimulus interval were manipulated. Observers were able to extract a mean emotion from the sequentially presented faces at even the shortest test durations (over 12 Hz), and even with the largest set sizes (20 faces). The results suggest that ensemble coding of high-level objects occurs rapidly with a brief minimum temporal integration.

26.517 **Classification images estimated by generalized additive models**

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Purpose. Classification images are typically estimated by a weighted combination of means of the noise profiles from response/signal categories in a psychophysical experiment in which the signal is embedded in noise on a fraction of the trials. This method can be characterized as a linear model (LM). The result is often subsequently smoothed by some arbitrary amount to yield a cleaner image. We describe how to estimate classification images with alternative statistical methods that incorporate smoothing in the estimation process and that result in more accurate estimates, described with fewer parameters. Methods. The classification image observer can be directly modeled trial-by-trial as a Generalized Linear Model (GLM). We describe how to extend the GLM by adding smooth basis terms to the model matrix, to produce a Generalized Additive Model (GAM). The GAM prediction is a smoothed template where the smoothing is chosen to minimize prediction error of the data. We compared the three methods on simulated data for experiments of 100 to 10000 trials and with a 2000-fold variation of noise added to the template. We also compared the methods on published data (Thomas & Knoblauch, 2005) for detection of a Gabor temporal luminance modulation. Results. For simulated data, the GAM method yielded a closer estimate to the underlying template than the other two in the presence of substantial amounts of noise. Interestingly, for the real data, the GAM estimate produced an image closer to the ideal template than the other two. In both cases, the GAM approach required about 1/3 to 1/2 fewer parameters to describe the data. Conclusion. A GAM approach to estimating classification images has the advantage of producing a more parsimonious estimate that is closer to the underlying template.

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26.518 **V1 responses to different types of luminance histogram contrast**

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It has been suggested that there exist neural mechanisms which are sensitive to luminance histogram skew, and that these mechanisms play a role in estimating surface properties (Motoyoshi, Nishida, Sharan & Adelson, 2007), or texture discrimination (Chubb, Landy, Econopouly, 2004). However, to the best of our knowledge, no systematic measurements of neural activity in early visual cortex in response to stimuli with skewed luminance histogram have been made to corroborate the existence of the postulated mechanisms.

Using fMRI, we measured BOLD signal in early visual cortex in response to noise images with either positive, negative or zero skewness of the luminance histogram.

Stimuli were circular (radius = 6.35 deg visual angle) random noise images whose histogram mean (M=128) and standard deviation (SD=43) were equated. Histogram contrast was manipulated by adjusting the third moment (skewness) of the luminance histogram to take on one of three values: positive (+1.4), negative (-1.4), or zero (0). Images were presented at a rate of 10Hz, in blocks of 24s separated by 24s presentation of a static image with uniform mean luminance (M=128, SD=0). The order of presentation during each scan (TR=2s) was: blank, positive skew, blank, negative skew, blank, zero skew. This sequence was repeated twice during each scan; there were a total of six scans per session. Observers fixated at the center of each stimulus, and performed a demanding fixation task during each scan.

The BOLD signal was analyzed within an independently determined ROI corresponding to an annulus located within the stimulus area (inner radius= 2 deg, outer radius 4 deg). On average V1 responses to noise images with positively and negatively skewed luminance histogram were significantly larger than those to images with zero skew. Furthermore, the V1 BOLD signal in response to images with negative contrast was larger than that to those with positive luminance histogram contrast.

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26.519 **The development of natural image contrast sensitivity**

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The present study verified the hypothesis that the development of contrast sensitivity to the spatial frequency content of natural images extends beyond the development of contrast sensitivity when tested with luminance modulated sine-wave gratings. In the same group of children and adults, we compared contrast sensitivity with a series of natural images for which a specific slice of spatial content was removed (a narrow range of α values) and we also tested contrast sensitivity with a series of sine-wave gratings varying in spatial frequency. Thresholds were measured with a temporal forced-choice task combined with a QUEST staircase procedure. Our data show that for children and adults, detection thresholds for natural images were increased by the removal of spatial content and the shift in threshold was dependent on the spatial frequencies removed. Indeed, thresholds were most elevated when the frequencies removed were those that the visual system is most sensitive to. This suggests a close relationship between spatial frequency processing and natural image perception. However, unlike grating contrast sensitivity, which becomes adult-like at each frequency tested by about 7 years of age, contrast sensitivity for natural images only becomes adult-like by about 10 years of age. Further, sensitivity matures less rapidly for lower frequency filtered natural images than for the higher frequency filtered natural images. Together, these results indicate that the mechanisms involved in the processing of the spatial frequency content of natural images mature less rapidly than specific mechanisms tuned to a single spatial frequency and orientation. Finally, because of the important developmental differences between traditional contrast sensitivity compared to natural image contrast sensitivity, the latter might be a more ecologically relevant way assess the limits of visual perception in children and in individuals with a visual pathology.

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26.520 **Local orientation and texture fixation statistics during free-viewing of natural scene images following brief adaptation**

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While the global structure of natural scene images is known to exhibit relatively stable biases across a large number of images with respect to the $1/f\alpha$ amplitude relationship and horizontal-vertical amplitude biases, the local structure within given images varies considerably as a function of distance. It has recently been shown that when macaque (Dragoi, Sharma, Miller, & Sur, Nat. Neurosci., 2002) or rhesus (Dragoi & Sur, J. Cog. Neurosci., 2006) monkeys free-view natural scene images, a largely orthogonal difference between the orientation statistics of sequential fixations was observed for long saccades. Dragoi and colleagues proposed that orientation-selective neurons in V1 have evolved to take advantage of such eye movement statistics with respect to orientation discrimination, and that adaptation in V1 was unlikely to contribute to fixation region selections. Here, we sought to extend this paradigm to human observers by examining the local orientation statistics or local amplitude spectrum slope of fixated natural or synthetic image regions during free-viewing following brief adaptation to narrow or broadband orientation patterns or isotropic visual noise patterns possessing different amplitude spectrum slopes. The data showed that while human observers tended to fixate image regions containing orientation statistics approximately orthogonal to the adapting patterns, this effect was dependent on global structural sparseness of the free-viewed images, with the strongest effects occurring for scenes possessing sparse structure. A similar effect was observed when the adapting pattern possessed a steep or shallow amplitude spectrum slope, only this effect was less dependent on the global structural sparseness of the free-viewed images. Taken together, these findings argue that when specific processing units of V1 are briefly adapted, the selection of content at subsequent fixation regions in natural images possessing sparse structure is influenced by adaptation.

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26.521 **Fixational Eye Movements and Retinal Activity across Multiple Visual Fixations**

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During natural viewing, saccades alternate with brief periods of fixational eye movements. It has long been questioned whether the modulations of luminance resulting from eye movements might encode spatial information in the temporal domain. Correlated cell responses might signal the presence of important features in the visual scene such as an edge or an object. In the presence of natural visual stimulation, however, the visual system needs to distinguish the input correlations caused by relevant visual features from the "uninteresting" correlations generally present in natural scenes. Here, we examine the impact of fixational modulations of luminance on retinal activity across multiple fixation periods. The responses of parvocellular (P) and magnocellular (M) ganglion cells in different regions of the visual field were modeled while their receptive fields scanned natural images following recorded traces of eye movements. Immediately after the onset of fixation, wide ensembles of coactive ganglion cells extended over several degrees of visual angle, both in the central and peripheral regions of the visual field. Following this initial pattern of activity, the covariance between the responses of pairs of P and M cells and the correlation between the responses of pairs of M cells dropped drastically during the course of fixation. Cell responses were completely uncorrelated by the end of a typical 300-ms fixation. This dynamic decorrelation of retinal activity is a robust phenomenon independent of the specifics of the model. We show that it originates from the interaction of three factors: the statistics of natural scenes, the small amplitudes of fixational eye movements, and the temporal sensitivities of ganglion cells. These results suggest that the correlations in retinal activity present during visual fixation represent salient features in the scene which cannot be predicted from the second-order statistics of natural images.

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26.522 **Contrast sensitivity in 1/f noise considered across spatial frequency band**

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We investigated anisotropic suppression of contrast sensitivity by broadband masks (strongest at horizontal: the "horizontal effect") as a function of spatial frequency to assess whether there was a differential contribution to this anisotropy of content at different spatial frequencies. Using isotropic, 1/f broadband noise as an contrast pedestal, we tested increment thresholds for six 1.0 octave (non-overlapping) bands centered at 0.28, 0.65, 1.5, 3.4, 7.9, and 18.2 cpd, and also for the full band from .2 to 25 cpd. We found that at a number of pedestal contrasts, contrast sensitivity for the first four (lowest) bands was a linear function of frequency (cf. Schofield and Georgeson, 2002 VR), with sensitivity to the 7.9 cpd band nearly enough to account for broadband increment sensitivity - the frequencies at which the sensitivity functions intersected full band sensitivity tended to fall around 8 cpd, indicating that a single channel in this vicinity of the frequency range is responsible for detection in the broadband condition. For oriented test bands we found that the horizontal effect typically seen in detection of broadband stimuli (Essock et al 2003 VR) would be anticipated given the sensitivity pattern to the peak frequency bands. Orientation effects were also apparent at other frequencies, perhaps contributing to the horizontal effect of perceived contrast of broadband oriented noise reported elsewhere (Hansen and Essock 2006 VR). Based on sensitivity across a number of background RMS contrasts, we develop a model of perceived broadband contrast structure in isotropic noise to account for earlier findings.

26.523 **Texture segmentation in natural images: Contribution of higher-order image statistics to psychophysical performance**

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Perceptual segmentation of a boundary between two textures is conventionally thought to be based upon differences in their Fourier energy, i.e. in their low-order texture statistics. Most evidence supporting (or contradicting) this idea has arisen from studies using various synthetic texture patterns. But what role, if any, do higher-order texture statistics play in segmenting natural images?

Here we extracted high resolution texture regions from monochrome photographs of natural scenes, rich in higher-order statistics. By phase-scrambling these textures, we could remove their high-order statistics, leaving mean luminance and RMS contrast unchanged. Using pairs of natural or phase-scrambled textures, we created RMS-balanced texture quilt boundaries in half-disc stimuli. We also created similar contrast boundaries from individual textures. Employing forced choice judgments of boundary orientation (left- vs. right-oblique), we measured modulation-depth thresholds for both contrast and texture boundaries. If only the low-order statistics are used, then phase-scrambling should have no effect on psychophysical performance.

Boundaries between these texture pairs could usually be segregated (thresholds: 35-70%), though in some cases even 100% modulation-depth did not produce reliable performance. In most instances, phase-scrambling made the task impossible. However in a minority of scrambled texture pairs, thresholds were measurable and in some, performance was improved. Contrast boundaries yielded lower modulation-depth thresholds (10-30%) which were impervious to or improved by phase-scrambling, particularly at lower texture contrasts. These results suggest that higher-order texture statistics contribute importantly to boundary segmentation in natural scenes.

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26.524 Knowing which channel is relevant does not improve performance in texture segmentation

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Variations in either the orientation, spatial frequency, or contrast (or a combination thereof) in a visual texture all involve contrast variations within narrow orientation/spatial frequency channels, even in the absence of a variation in overall contrast. Accumulating evidence indicates that such variations in image statistics are detected by so-called Filter-Rectify-Filter (FRF) mechanisms which detect contrast variations within narrow orientation and spatial frequency bands. Much research has concentrated on determining whether the visual system also has available FRF mechanisms which combine information across first-order channels. Here, textures are created which contain contrast variations in two orthogonal orientation channels. The textures either contain contrast only in the relevant (i.e., contrast-modulated) channels or contain contrast in irrelevant, unmodulated channels also. Performance in both conditions is described remarkably well by a model which assumes that performance is determined by probability summation between three mechanisms: two standard FRF mechanisms (each selective for one of the two modulated channels) and an FRF mechanism which linearly combines information across first-order channels. When the texture contains contrast only in the relevant channels, performance is dominated by the FRF mechanism which combines information across orientation channels. However, when contrast in irrelevant channels is present, a mechanism which combines information across all channels would be less efficient and performance is dominated by the standard FRF mechanisms. In a second experiment the relevant information was either contained consistently within the same orientation channels on each trial or varied randomly between orientation channels. Performance did not differ between these two conditions, suggesting that standard FRF mechanisms are not labeled with respect to the orientation of the first-order channel that serves as their front-end input.

26.525 Analyzing Band-Selective Preattentive Texture Mechanisms

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Purpose: To analyze preattentive mechanisms sensitive to variations in contrast in isotropic textures composed of narrow-band elements. Method: Textures were composed of small elements consisting of Difference of Gaussians (DoGs, aka Mexican Hats), all identical in spatial form but with eight different center contrasts varying from -1.0 (black center/light surround) to +1.0 (white center/dark surround). For all DoG elements, luminance averaged over the DoG was equal to the background luminance. Stimuli were scrambles (dense, spatially random arrays) of 2304 DoGs. In a 4AFC task, observers judged the location of a target scramble patch in a background scramble field. The difference d between contrast histograms of targets and backgrounds was experimentally varied. We assume that human vision has preattentive mechanisms differentially sensitive to different DoG-contrasts and that histogram differences d are discriminable only if the sensitivity function of at least one of these mechanisms has nonzero correlation with d. If we find a two-dimensional space of histograms in which some discriminations are possible but which also contains a maximum-amplitude difference dnull for which discrimination is at chance, then most likely only one mechanism is sensitive to differences in that space. Perturbation methods can then be used to measure the sensitivity of this mechanism to all 8 DoG contrasts. Results/Conclusions: We have been able to use this method to isolate and measure the sensitivity function of a previously unknown mechanism. This mechanism is highly sensitive to texture energy but also exhibits significant asymmetries in its sensitivity to positive vs. negative DoG contrasts. Human vision has other mechanisms sensitive to these DoG scrambles. For example, at least one additional mechanism sensitive to the sign of DoG contrast. By orthogonalizing the space of histograms to the sensitivity function of the mechanism we have found, we hope to isolate and characterize these other mechanisms.

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26.526 Adaptive spatial integration of orientation signals over time

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Psychophysical studies often claim, or implicitly assume, that the process of spatial integration is synonymous with averaging (or other statistical combinations) of local information contained within a visual image. We have recently shown that this is not the case for the spatial integration of local motion directions; physiologically plausible neuronal population decoders (maximum likelihood, winner takes-all) rather than image-based statistics accurately predicted human observers' perceived direction of global motion at extended stimulus durations. Here we ask which of these processes (image-based statistical estimates or neuronal population decoding) underpin the spatial integration of local orientation signals over different time frames. In a temporal two-alternative forced choice task, observers discriminated which of two sequentially presented texture patterns had a more clockwise surface (global) orientation. Texture patterns were composed of 500 oriented Gaussian lines (envelope SD, 0.16 x 0.33 deg) randomly positioned within a circular aperture (diameter, 10 deg), presented at a range of stimulus durations (0.05-3.33 sec). Lines in the standard texture had a common orientation, randomly assigned on each trial; the orientations in the comparison texture were chosen independently from a skewed (asymmetric) probability distribution with distinct measures of central tendency. We simulated observers' performance on this task on a trial-by-trial basis with a bank of orientation tuned neurons that respond to the stimulus distributions with a Gaussian sensitivity profile corrupted by Poisson noise. The perceived surface orientation of texture patterns was accurately predicted by an image-based statistic (vector average orientation) at short stimulus durations and by algorithms (winner takes-all, maximum likelihood) that decode the orientation tuned activity of the simulated population of neurons at longer stimulus durations. Our results suggest that the spatial integration of local orientation information is an adaptive process that uses different strategies as more sensory evidence is accumulated over time.

26.527 A view-point invariant texture descriptor

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A new texture descriptor based on fractal geometry, called the multi fractal spectrum (MFS) is introduced. The key quantity in the study of fractal geometry is the fractal dimension, which is a measure of how an object changes over scale. Consider the intensity of an image as a 3D surface and slice it at regular intervals at the dimension of height. For each interval we obtain a point set, for which we compute the fractal dimension. The vector composed of the fractal dimensions of all point sets is called the MFS of intensity. Replacing the intensity with other quantities, such as the density function, or the output of various filters (e.g. Laplacian, Gradient filters), different MFS descriptors are obtained.

The MFS is shown mathematically to be invariant under any smooth mapping (bi-Lipschitz maps), which includes view-point changes and non-rigid deformations of the surface as well as local affine illumination changes. Computational experiments on unstructured textures, such as landscapes and shelves in a supermarket, demonstrate the robustness of the MFS to environmental changes. On standard data sets the MFS performs comparable to the top texture descriptors in the task of classification. However, in contrast to other descriptors, it has extremely low dimension and can be computed very efficiently and robustly. Psychophysical demonstrate that humans can differentiate black and white textures on the basis of the fractal dimension.

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URL: http://www.cfar.umd.edu/users/fer/website-texture/texture.htm

Temporal Processing and Dynamics

26.528 The continuous Wagon Wheel Illusion and the 'When' pathway of the right parietal lobe: an rTMS study

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

26.529 Mislocalising flashes in time

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Flashed targets' positions are misjudged systematically under many circumstances. Often, misjudging the moment of the flash could be responsible for the error. For instance, flashes presented near the time of a saccade or during smooth pursuit may be mislocalised because they are considered to have taken place when the eyes had reached a later orientation. Similarly, flashes presented near a moving target may appear to lag behind the target because they are considered to have occurred when the target was further along its path. But why should flashes always appear to have occurred later? We propose that this is because it is impossible to distinguish between a short intense flash and a longer less intense flash. If people cannot reliably estimate the duration of the flash they cannot know that the experimenter used an extremely short one, so they are likely to overestimate flash duration and thereby the 'moment' of the flash. To show that this really occurs we conducted an experiment consisting of two parts. In the first part subjects synchronised and matched the luminance of two dark flashes of different durations that were presented on a white background (56 cd/m2). In the second part each pair was presented once, with the previously set parameters, and subjects indicated whether the two flashes were identical. The results indicate that flashes lasting up to 30ms look the same as ones lasting only one frame. Even considerably longer flashes were not always judged to be different. To appear simultaneous the flashes were synchronised at about a quarter of their duration. Thus unless subjects in experiments in which targets or the eyes move near the time of the flash (correctly) assume that the flashes are of extremely short duration, they will systematically misjudge the moment of the flash, resulting in systematic localisation errors.

26.530 How TMS and stimulus off/on signals modulate feature integration

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When a right offset vernier is immediately followed by a left offset vernier (or vice versa), only one vernier is perceived. Feature fusion has occurred. In feature fusion, observers cannot resolve the two verniers individually. Subjects perform at chance level, if asked whether the first or second vernier is offset to the right. The perceived offset of the fused vernier is a combination of the offsets of the two presented verniers. To our surprise, the perceived offset can be systematically modulated by transcranial magnetic stimulation (TMS) applied over the occipital cortex. For an astonishing long period of 400ms, TMS enhances the contribution of the first or second vernier depending when TMS is applied. Thus, TMS can modulate feature integration for a long time but does not render the individual verniers visible. However, when the two verniers are separated by an interstimulus interval (ISI) of only 10ms, the verniers do become visible as single entities. Observers can discriminate whether the first or second vernier is offset to the right. Hence, feature fusion is interrupted. We postulate that the transient off/on signals due to the ISI render the verniers visible individually. On the other hand, single TMS pulses modulate but do not interrupt feature fusion.

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26.531 A Cortical and a Sub-cortical Origin of Lateral Interactions in Perceived Temporal Variation

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PURPOSE: Perception of a temporally-varying light is strongly affected by temporal variation within a surrounding field. The neural mechanism mediating this perceived lateral interaction has been posited to be center-surround antagonism in the LGN (Kremers et al., 2004) or at a cortical level (D'Antona & Shevell, 2007). To determine the neural locus, this study examined the contribution of monocular and/or binocular components to lateral interactions mediating perceived temporal variation. METHODS: Observers haploscopically viewed a central test stimulus (1 deg diam) with luminance varying over time. This stimulus had a surround (6 deg diam) that also varied in luminance at the same frequency. Center and surround were separated by a thin dark gap (0.2 deg). The center and surrounding stimuli were either presented to the same eye (monocular condition) or to opposite eyes (dichoptic condition). The central test stimulus always had Michelson contrast 0.5; the surround's contrast could be either 0.25 or 0.5. Stimuli were presented at 3.125, 6.25, or 12.5 Hz. The relative phase between the center and surround was varied in each condition. Observers adjusted the modulation depth of a separate temporally-varying matching field to match the perceived modulation depth in the central test area. RESULTS&CONCLUSIONS: Perceived modulation depth depended strongly on the relative phase between the center and surround in both the monocular and dichoptic conditions. The monocular conditions showed a somewhat larger influence from the surround compared to the dichoptic conditions. The results revealed both a weak monocular (plausibly LGN) and large binocular (central) component of lateral interaction. The monocular component was relatively flat as a function of temporal frequency, while the binocular component showed low-pass temporal-frequency tuning. These findings are consistent with two separate neural sites (monocular and binocular) underlying perceived temporal variation in context, with each site having a distinct strength and temporal-frequency tuning.

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26.532 Color modulation of temporal response to oriented stimulation in macaque V2

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In daily vision, we use color and orientation to aid rapid identification of visual forms. Neurons in the second visual cortical area of the primate (V2) preferentially fire to signature colored and oriented stimulus combinations, but the modulation of temporal response to oriented stimuli by color, and its associated mechanisms, is still not well characterized.

To investigate these possible modulatory effects, we presented luminance-controlled colored and/or oriented stimuli to anesthetized macaque monkeys during single unit electrophysiological and intrinsic optical imaging recordings in V2. We have applied several quantification methods, including Surprise and spike density function (SDF) threshold, to objectively quantify the characteristics of neuronal temporal response. These methods provide estimates of response latency and allow quantification of the temporal evolution of response to presentations of oriented, color, and color/oriented stimuli.

Here, we show and contrast examples of temporal response of firing that were obtained following colored/oriented stimulation. With strong responses, Surprise and SDF measures showed comparable latency values, however sensitivity rapidly declined when responses were relatively weak. We found that latency reliability significantly improved when we controlled for mean post-stimulus spike firing. A broad distribution of response latencies were observed across the population of recorded V2 neurons (cf. Munk et al 1995; Schmolesky et al 1998). Therefore, color-induced temporal modulation of oriented response was optimally detected using a within-unit design. We observed significant advances in latency to oriented stimulus presentations, with supplementary specific color modulations. Interestingly, color inclusion was sometimes also associated with extended (rather than advancing) response latency, suggesting that color/orientation induced response in V2 may arise from a balance of excitatory and inhibitory neurophysiological mechanisms (cf. Anzai et al 2007). These data suggest that color inclusion produces identifiable temporal response modulations in V2 that may be important for efficient early visual processing and later perception.

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26.533 **Effects of context on visual temporal order judgments in RSVP**

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A combined rapid serial visual presentation (RSVP) and temporal order judgement paradigm was developed to study the role of task and context in visual temporal order perception. Participants had to identify an event specified by its order as well as another feature (report the first white symbol in a sequence).

The assumption that some additional information introduced into a context can change perception of temporal order was tested. Participants reported the first of two white digits following each other within an RSVP stream of black character distractors (100 ms per item). In some trials luminance of items was constant within each subset of items (black and white). On other trials a black item either preceding or following the white items was slightly brighter (less black) than the other distractors. Still other trials included a small difference in the luminance of the white digits. Trials of all types were intermixed.

The luminance manipulation significantly affected performance, although it remained unnoticed by the subjects. When the two white digits were of the same luminance, false reports of the second white digit were not significantly different from correct reports of the first digit. When either the first white digit or the preceding or following distractor was highlighted, more correct responses than false reports of the second item were observed. Highlighting of the second white item had no significant effect on temporal order performance. The fact that the following distractor produced the same effect (more accurate responses) as the preceding distractor rules out a processing speed benefit from a luminance/contrast change as the explanation of the context effect revealed in the present study. Other explanations will be discussed. More results obtained with temporal order judgement in the RSVP paradigm will also be presented.

26.534 **Perceptual latency of sound-induced visual bounce**

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Perceptual processing takes time, but the exact time course is unknown. The mystery is deepened by the fact that the perception of one event (target) is affected by another event (modulator) that occurs either before or after the event (prediction and postdiction). One might account for this flexibility by assuming that the processing of the target event waits for a constant period after the target appearance to register all the other potentially relevant inputs given before and after the target. A prediction of this conservative hypothesis is that the perceptual latency of the target event should be invariant against changes in the timing of modulator presentation. We tested this prediction by measuring the reaction time (RT) to judge an ambiguous motion event either as “bounce” or “stream” while changing the presentation timing of a modulatory sound. Subjects observed two black balls (0.4 deg in diameter) moving at 11.3 deg/s in opposite directions along the same path. A pip tone was presented through headphones at one of five SOAs (-140, -70, 0, +70 and +140 ms) from the balls' collision. Subjects had to report which event they saw by pressing one of two buttons as quickly and accurately as possible. The results show that, in comparison with the no-sound control, the sound increased the bounce response for SOAs between -140 and +70 ms. When subjects reported “stream”, no change in RT was observed between SOA conditions (~400 ms, average of 6 subjects). However, when subjects reported “bounce”, RT monotonically increased with SOA (~300 ms for -140 ms SOA; ~400 ms for +70 ms SOA). The result obviously contradicts the constant delay hypothesis. We consider that the processing of an event starts without delay and is flexibly updated by new relevant information.

26.535 **The Toelz Temporal Topography Study: Mapping the visual field of temporal processing across the life span**

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Visual function, especially with respect to its temporal characteristics, is believed to deteriorate over the life span. However, the time course, topographical patterns, and mechanisms of age-related loss of function are largely unknown. We examined the dynamic visual field properties of a large sample of normally sighted subjects to obtain normative data across the life span.

We mapped characteristics of visual function in 95 healthy subjects between 10 and 90 years of age. Topographical measures included: luminance thresholds (static perimetry), temporal resolution (double-pulse resolution, DPR), reaction times (RT), and contrast thresholds for character recognition (R_contrast). In addition, a variety of non-topographical visual and attentional functions were determined (e.g. saccadic exploration, alertness).

DPR thresholds increased slightly but significantly with eccentricity and age, and the periphery showed a more pronounced age-related increase than the center. RT increased only slightly and uniformly across the visual field with age. Luminance thresholds in perimetry increased in a pattern similar to that observed for DPR. Performance in one measure at a given visual-field position allowed no prediction on performance in another measure. Correlations between visual-field means of the topographical measures were partially mediated by age. Contrast thresholds, alertness, divided and spatial attention, and saccadic exploration showed age-related changes and complex correlation patterns with the main outcome variables.

An age-related performance decrease was confirmed, but age was mostly a poor predictor of functionality because of high inter-individual variability. Age is, however, an intervening variable for the correlation between visual-field means of different functions. Retinal and optic media properties alone cannot explain the decline, but maps are also shaped by higher visual and cognitive function. The low point-by-point (local) correlations between topographical measures suggest separate underlying mechanisms of RT, DPR, and perimetry. The dataset constitutes a normative basis for psychophysical and neuropsychological studies.

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26.536 **The Dynamics of Shape Coding for Glass Patterns**

Stéphane Rainville[1] (stephane.rainville@ndsu.edu), Aaron Clarke[1]; [1]Center for Visual Neuroscience, Department of Psychology, North Dakota State University

Introduction: Spatial Glass patterns are a class of stochastic stimuli whose global shape is defined by lawful positional relationships between local elements. Here, we investigated the dynamics of shape coding for concentric Glass stimuli.

Methods: Stimuli consisted of two populations of 256 dipoles that were randomly repositioned on each frame. Both populations alternated between structured (Glass) and unstructured (noise) patterns on each frame. In the ‘in-phase’ condition, Glass and noise patterns from one population coincided in time with their counterparts from the other population. In the ‘out-of-phase’ condition, Glass patterns from one population coincided with noise patterns from the other population. Observers judged the position (left vs. right) of the Glass center relative to the stimulus' aperture. Dipole orientation was jittered to find the 75%-correct point, and we assessed performance over a range of frame rates (~1 to 25 Hz).

Results: Observers performed significantly better (x2) in the in-phase than in the out-of-phase condition over the 1-to-5 Hz range. Performance above 5 Hz remained high but did not differ between in-phase and out-of-phase conditions.

Conclusions: Data show that shape coding for Glass patterns can exploit a temporal separation between signal and noise of up to 5 Hz (200 ms) – beyond 5 Hz, signal and noise become perceptually fused. Results suggest that the dynamics of shape coding can be approximated by linear lowpass filtering. We are investigating nonlinear aspects of shape-coding dynamics such as "object-locking" – a form of hysteresis whereby object capture is brisk but object release is sluggish.

Acknowledgement: Supported by NIH/NCRR Grant P20 RR020151

26.537 **Retinotopic adaptation can influence the apparent duration of a visual stimulus**

Aurelio Bruno[1] (a.bruno@ucl.ac.uk), İnci Ayhan[1], Alan Johnston[1]; [1]Department of Psychology, University College London

Adapting to a 20 Hz drifting grating compresses perceived duration for 10Hz stimuli displayed in the adapted location (Johnston, Arnold & Nishida, 2006, Current Biology, 16(5):472-9). However, Burr, Tozzi & Morrone (2007, Nature Neuroscience, 10(4): 423-5) described spatially selective duration effects after adaptation in both retinocentric and headcentric coordinates. They ascribed the retinotopic compression to a misrepresentation of speed. Here we investigated the effects of purely retinotopic adaptation on duration judgments. First we measured perceived speed after adaptation to an oscillating grating. The temporal frequency of the adapter was alternated between 5 and 20 Hz over time. For each subject, in different sessions, we determined the duty cycle that had no effect on perceived speed. We then used this stimulus to measure apparent duration. We adapted to an oscillating grating whose position changed continuously relative to the head, but remained constant relative to the eye. During the adaptation phase subjects tracked a fixation point that slowly oscillated across the screen. The adapter oscillated in a direction orthogonal to the eye movement. After adaptation the standard stimulus (600 ms) appeared in the last position occupied by the adapter followed by a comparison stimulus (300-1200ms) in the opposite position relative to the fixation spot. Subjects had to report which one appeared to last longer. The 50% point on the psychometric function provided a measure of the perceived duration. Continuous 5 Hz and 20 Hz adaptation conditions were also investigated. Perceived duration was reduced after adapting both to the mixed (5/20 Hz) and to the continuous 20 Hz adapter but only marginally after 5 Hz adaptation. Thus retinotopic adaptation reduces the perceived duration of a stimulus in the absence of craniotopic adaptation pointing to the existence of a retinocentric frame of reference for duration judgments.

26.538 **Apparent duration is influenced by the geometrical (perceptual) meaningfulness of the stimulus**

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

When we asked observers to perform a discrimination task with stimuli that were either geometrically organized in order to produce a subjective shape or disorganized in order to provide only local stimulus information, observers casually reported that the organized stimulus appeared to persist longer than the misaligned one.

Therefore in the current experiment we tested the question whether the apparent duration of a visual stimulus is affected by its geometrical, and hence perceptual, organization. Subjects (n=16) were presented with two test intervals, one containing the standard and the other the comparison stimulus, and had to decide which one persisted longer. Aligned and misaligned Varin stimuli were used as standards as well as comparisons. The standard was presented for a fixed duration of 150ms and was paired randomly with comparisons of 100, 133, 150, 166, 200ms durations. We found that a misaligned comparison had to be presented about 25ms longer than an aligned comparison in order to appear to be of equal duration as the aligned standard. An aligned comparison on the other hand could be about 13ms shorter than a misaligned comparison in order to be perceived as equally long as a misaligned standard. Hence systematic investigation confirmed the casual observation of longer persistence of a geometrically (perceptually) meaningful shape compared to identical but disorganized information. We conjecture that the greater persistence reflects the activation of a recurrent network in lateral occipital or more anterior cortex, driven by and feeding back to V1/V2.

Acknowledgement: We thank F. Geringswald for help with data collection. The work was supported by a TransCoop grant from the Humboldt foundation to MM and RS.

26.539 **A frequency sweep method for rapid estimation of visual delays**

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We have previously presented a technique for measuring the time course of visual processing, by introducing artificial delays in the visual feedback resulting from eye movements, and measuring the frequency of the resulting oscillations (Mulligan & Stevenson, VSS 2007). In our earlier work, we measured the frequency of oscillation during extended viewing with a fixed delay, and repeated this for a range of delays, slowly accumulating points on the period-vs-delay function. Here we introduce a sweep-delay method, in which the entire period-vs-delay function is acquired during a single measurement interval of less than a minute. The reduction in measurement time is key for measurements in which one or more stimulus parameters such as luminance or contrast must also be sampled. We have applied the technique to the determination of equiluminant null points of stimuli preferentially stimulating the S-cones.

Acknowledgement: Supported by the Integrated Intelligent Flight Deck Technologies project of NASA's Aviation Safety program, and

URL: http://vision.arc.nasa.gov/personnel/jbm/home/presentations/vss08/

26.540 **Poor temporal precision in judging the position of a moving object, imposed at a late stage of visual processing**

Alex Holcombe[1] (alexh@psych.usyd.edu.au), Daniel Linares[1]; [1]School of Psychology, University of Sydney, Australia

A luminance-defined blob orbits fixation. Observers judge the blob's position at the time of a change in color of the fixation point or an auditory tone. In addition to the "flash-lag" error, we find over a range of speeds that the standard deviation of position judgments corresponds to a ~100-ms portion of the blob's trajectory (Murakami 2001), which yields near-chance performance when blob speed reaches ~3 rps. Visual encoding at early stages is temporally very precise, and we seek to understand the source of the large variability in position judgments. The constant temporal variability suggests the positional uncertainty is imposed by a stage of low temporal resolution. To rule out low-level temporal smearing (Newton 1730), observers view two blobs, one orbiting fixation and the other orbiting a point in the periphery, and judge whether they move in phase or out of phase. Observers are nearly 100% accurate at revolution rates (3 rps) for which they are near chance judging position, inconsistent with the blur explanation. In the original task, if the number of blobs simultaneously sharing the orbit is increased, the blur theory predicts chance performance should occur at a lower speed, as a complete blur circle is reached at lower speed. However, we find that the limit is similar for 1, 2, and 4 blobs. Finally, as the radius of the orbit increases from 2 to 6 deg, a variety of low-level visual factors change, but again we find that temporal imprecision of judgments remains constant. Each result suggests that the low temporal resolution of position judgments is not imposed at early stages of visual processing. We speculate that the large temporal variability instead is mostly caused by the process of binding the temporal marker with the corresponding position of the moving object.

Acknowledgement: supported by Australian Research Council DP to AH

URL: http://www.psych.usyd.edu.au/staff/alexh/research/HolcombeLinaresVSS08/

26.541 **Reaction times and perceptual judgments are atypical in autism**

Natalie Dill[1] (nat@salk.edu), Richard Krauzlis[1]; [1]The Salk Institute for Biological Studies

Subjects with autism have greater difficulty than controls discriminating the direction of visual motion, suggesting the presence of abnormalities at early stages of visual processing. Alternatively, this difficulty could be attributed to differences in how perceptual judgments are formed. To test this possibility, we measured reaction times as well as choices in a motion discrimination task.

Subjects (ASD-diagnosed adolescents and typically developing controls) performed a 2AFC visual motion discrimination task. After subjects fixated a central spot, a stochastic motion patch (8° diameter, centered 8° above fixation) was presented along with two response dots placed 8° to the left and right of fixation. The direction of motion was equally likely to be rightward or leftward, and the strength of motion was randomly selected from 9 values between 0 and 40% coherence. Subjects were instructed to fixate until they could judge the direction of motion, and to indicate their choice by moving their eyes to the response dot in the same direction as the judged motion. Subjects received auditory feedback about their choice after each trial. We measured saccades on each trial to examine the subjects' reaction times as well as their choices.

As expected, autistic subjects showed higher motion coherence thresholds (15-32%) compared to control subjects (10-13%). However, the reaction times for autistic subjects were also much shorter (~250 ms) than for controls (~500 ms). In addition, the reaction times for the autistic subjects did not change as a function of signal strength, unlike the control subjects, who showed significantly shorter reaction times for stronger motion signals.

Our results confirm that autistic subjects have higher thresholds for discriminating motion direction, consistent with possible abnormalities in sensory processing. However, the unusual pattern of reaction times in the task suggests that the process of forming the perceptual choice is also atypical.

Acknowledgement: Supported by Cure Autism Now

26.542 **Visual processing oscillation fossils**

Caroline Blais[1] (caroline.blais@umontreal.ca), Martin Arguin[1], Frédéric Gosselin[1]; [1]Centre de Recherche en Neuropsychologie et en Cognition, Université de Montréal

When we look at the world surrounding us, we experience a continuous flow of information coming to our eyes. The most intuitive interpretation of this experience of continuity is that the visual system processes information in a continuous manner. In striking contrast with this intuition, a growing body of evidence suggests that we apprehend the world via discrete processing epochs (VanRullen, Reddy & Koch, 2005; 2006; Ward, 2003). However, the exact nature of these oscillations has been derived indirectly via modelization. Here, we investigated the nature of these oscillations using a classification image approach. We asked five subjects to determine if a stimulus, presented during 200 ms, was a face or a house. On every trial, the signal was either a house or a face that dissolved sinusoïdally into a white Gaussian noise field (phase relative to stimulus onset: 0, pi/6, pi/3, pi/2, 2*pi/3, and 5*pi/6; frequencies: 5, 10, 15, and 20 Hz). Performance was maintained at 75% correct by adjusting signal-to-noise ratio with QUEST (Watson & Pelli, 1983). We found a modulation of the performance as a function of the frequency and the phase relative to stimulus onset (peak-to-trough differences ranging from 11.9% and 18.7%, and from 5.9% and 19.0% for the frequency and the phase respectively), further supporting the hypothesis of discrete processing epochs. We have reconstructed the optimal stimulus in the least-mean-square sense for every participant by performing multiple regressions on the stimuli oscillations and performance. We typically found two oscillations in the classification images: one at 5 Hz and the other between 15 and 20 Hz. We believe that we have revealed fossilized oscillations at different stages of visual processing; the fastest oscillation could be the elusive "perceptual moments" and slower ones could be attention-related oscillations (see also VanRullen, Carlson, & Cavanagh, 2007).

26.543 **A model for temporal features of visual sensations evoked by a subretinal electrode array for restoration of vision**

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Purpose: Subretinal microphotodiode-arrays (MPDAs) have the potential to restore vision in patients suffering from degenerative retinal diseases such as Retinitis Pigmentosa. Experiments with patients taking part in clinical studies revealed the feasibility of electrically evoking visual sensations (phosphenes). Here we present results delivered by a model which reproduces implant-evoked activity distributions of retinal ganglion cells (RGC), considering activity spread in the retinal network as well as frequency dependent RGC-adaptation.

Methods: Input to the model was a movie-file representing two parallel rotating white bars. Width of the bars was 20x100 pixels with 20 pixels distance on a 100x100 pixels black background. Parameters for timing were set such that the output allowed recognizing form, number, speed and orientation of input stimuli. Retinal activity parameters from previous experiments were regarded in order to quantify spread of network activation in the retina and amplitude of RGC-activity. RGC-activity furthermore underwent frequency dependent adaptation.

Results: RGC activity patterns conveyed a satisfactory motion picture quality in this model when electrodes were activated with sufficiently high frequencies between 5Hz and 10Hz, assuming an input frame rate of 10-20 frames per second. High stimulation frequencies allowed continuous evaluation of position and speed of the stimuli, however visual sensations faded quickly within only few seconds after onset of the movie. RGC activity was not subject to adaptation if the stimulation frequency remained below 2Hz. Therefore slowly moving objects still were recognizable at low stimulation frequencies, but movement speed of the rotating bar – stimulus could no longer be realistically estimated.

Conclusions: Simulation of realistic approximations to visual sensations as evoked by subretinal MPDAs is subject to a number of assumptions made during model development. However model outputs sufficiently reproduced critical attributes of input stimuli. Also, disappearance of the sensations was in principal agreement with reports from clinical study patients carrying the subretinal MPDA.

Acknowledgement: This work was supported by the German Federal Research Council (BMBF)

Sunday Sessions

Sunday, May 11, 8:30 - 10:00 am
Talk Session, Vista Ballroom

Perception and Action: How Dissociated Are They?

Moderator: Melvyn Goodale

8:30 am

31.11 Preserved motion processing and visuomotor control in a patient with large bilateral lesions of occipitotemporal cortex

Melvyn A. Goodale[1] (mgoodale@uwo.ca), Marla E. Wolf[1], Robert L. Whitwell[1], Liana E. Brown[2], Jonathan S. Cant[1], Craig S. Chapman[1], Jessica K. Witt[3], Stephen R. Arnott[1], Sarah A. Khan[1], Philippe A. Chouinard[1], Jody C. Culham[1], Gordon N. Dutton[4]; [1]CIHR Group on Action and Perception, The University of Western Ontario, Canada, [2]Department of Psychology, Trent University, Peterborough, ON, Canada, [3]Department of Psychological Sciences, Purdue University, [4]Royal Hospital for Sick Children, Glasgow, UK

According to Goodale and Milner, visual perception is mediated by the ventral stream and the visual control of action by the dorsal stream of cortical visual projections. The initial neuropsychological evidence for this idea was based strongly on a single case, DF, who has impaired object recognition but spared visual control of grasping, consistent with lesions to lateral occipital (LO) cortex but intact dorsal-stream processing. Here we present data from a new patient, MC, a 38-year-old woman who shows very similar behaviour to DF despite much more extensive bilateral occipitotemporal lesions that encompass not only LO but most of early visual cortex in the occipital lobe, except for a small tag of tissue in the rostral calcarine cortex (Culham et al., VSS 2008). MC shows some preserved motion perception, but is unable to identify line drawings (or real exemplars) of common objects or discriminate colours or visual textures. Not surprisingly, MC cannot discriminate between rectangular objects with different dimensions; nor can she indicate their width manually. Remarkably, however, when she reaches out to grasp such objects, her in-flight grasp scales to the object's size. Similarly, even though MC cannot discriminate between objects of varying shape, she chooses stable grasp points on those objects when she reaches out to pick them up. The case of MC not only reinforces the conclusions about separate visual processing for perception and action drawn from DF, but also suggests that visuomotor mechanisms in the dorsal stream are capable of mediating the processing of object features such as size, shape, and orientation for the control of visually guided grasping even with highly impoverished (or perhaps entirely absent) input from the ventral stream and early visual areas.

Acknowledgement: Supported by grants from the Canadian Institutes of He alth Research to MG and JC. We are very grateful to the patient and her family for their generous participation.

8:45 am

31.12 Preserved processing of motion and dorsal stream functions in a patient with large bilateral lesions of occipitotemporal cortex

Jody C. Culham[1, 2] (jody.culham@gmail.com), Jessica K. Witt[3], Kenneth F. Valyear[2], Gordon N. Dutton[4], Melvyn A. Goodale[1, 2]; [1]Department of Psychology, The University of Western Ontario, Ontario, [2]Neuroscience Program, The University of Western Ontario, Ontario, [3]Department of Psychological Sciences, Purdue University, Indiana, [4]Royal Hospital for Sick Children, Glasgow, UK

We used anatomical and functional magnetic resonance imaging (fMRI) at 4 Tesla to examine the damaged and spared brain regions in Patient MC, a 38-year old woman with Riddoch phenomenon – awareness of moving but not static stimuli. Anatomical scans indicated extensive damage to occipitotemporal cortex bilaterally and right posterior parietal cortex. Within occipital cortex, the only spared and visually active region was a small portion of the anterior calcarine cortex bilaterally. The expected location of the lateral occipital complex in neurologically intact subjects fell within the lesion, consistent with MC's absence of object-selective activation for both static and moving stimuli. Similarly, no face-, place- or body-selective activation for static or moving stimuli was observed. In contrast to the severe damage to early visual areas and ventral stream areas, numerous areas within the dorsal stream remained intact and functional. Consistent with MC's awareness of motion, fMRI revealed motion-selective activation bilaterally in the MT+ complex, just ahead of the occipitotemporal damage. Consistent with the preserved accuracy of her hand actions, MC showed robust grasp-selective activation in the anterior intraparietal area bilaterally and reach-selective activation in the superior parieto-occipital cortex of the left hemipshere. When shown movie clips of hands acting with tools, activation was observed in areas implicated in tool processing (intraparietal sulcus/supramarginal gyrus, middle temporal gyrus) and action observation (superior temporal sulcus). These results suggest that MC's dorsal stream continues to receive input either from a very limited extent of visual cortex or, more likely, from extrageniculostriate projections, two possibilities currently under investigation with diffusion tensor imaging. In sum, the damaged and activated regions within MC's brain are highly consistent with her behavioral deficits (Goodale et al., VSS 2008) in ventral stream functions (recognition) and her preserved abilities for several dorsal stream functions (motion perception, reaching, grasping, and tool observation).

Acknowledgement: Funded by grants from the Canadian Institutes of Health Research to MG and JC

9:00 am

31.13 A medial parieto-occipital area coding all phases of prehension movements

Patrizia Fattori[1] (patrizia.fattori@unibo.it), Rossella Breveglieri[1], Nicoletta Marzocchi[1], Annalisa Bosco[1], Claudio Galletti[1]; [1]Human & General Physiology, University of Bologna, Bologna, Italy

In human and monkey posterior parietal cortex (PPC), area AIP is devoted to the guidance of grip formation to grasp an object, area MIP in planning reaching movements in the peripersonal space. Recent fMRI experiments in humans showed an activation of a medial parieto-occipital region for prehension actions. The aim of the present work was to study this region in the monkey brain during all phases of prehension movements.

Extracellular recordings were carried out in area V6A of PPC of 2 Macaca fascicularis, performing delayed reach-to-point movements directed to targets located in different positions in the periperonal space and reach-to-grasp movements directed to graspable objects located straight ahead.

One hundred V6A neurons were tested in both reach-to-point and reach-to-grasp tasks. We analyzed neural activity during the delay before movement execution, during transport and grasping phases of prehension, hand holding and return movements. About 75% of cells showed different activations in the 2 tasks (point versus grasp). The majority of them (about 60%) showed higher activity during reach-to-grasp rather than during reach-to-point. Of the 34 cells tested for directional tuning of reaching and grip formation, about 40% were able to code both components of prehension. In prehension of objects differently oriented, wrist orientation affected 45% of the neuronal population during planning, 48% during prehension execution, 44% during hand holding and 40% during return movements.

These data show that area V6A is involved in all aspects of prehension: in preparing prehension actions, in transporting the arm toward the spatial location of the visual target, in wrist orientation and grip formation till the accomplishement of hand-object interaction. These data suggest the existence in monkey PPC of an area where all aspects of prehension are represented and can address future experiments in the human brain.

Acknowledgement: Supported by EU FP6-IST-027574 -MATHESIS, MIUR, Fondazione del Monte di Bologna e Ravenna.

9:15 am

31.14 The Role of Monkey Frontal Eye Field in Visual Categorization

Vincent Ferrera[1,2] (vpf3@columbia.edu), Marianna Yanike[1], Carlos Cassanello[1]; [1]Dept. of Neuroscience, Columbia University, [2]Dept. of Psychiatry, Columbia University

The frontal eye field (FEF) is a region of prefrontal cortex that is involved in linking visual stimuli to motor responses. FEF is thought to select visual targets for eye movements. However, it is not known whether FEF is capable of playing a role in categorizing visual stimuli independently of a specific motor response. To investigate this, we developed a speed categorization task in which monkeys were presented with a random dot motion stimulus. They were required to make a saccadic eye movement to one of two targets to indicate whether the stimulus is “fast” or “slow”. The task was designed so that monkeys associated the speed categories with the colors of the response targets (“fast” = green, “slow” = red). The locations of the response targets were randomized. Hence, the categorical decision was independent of the motor response. The category boundary was determined arbitrarily by the computer and the monkeys learned it by trial and error. Once the monkeys had learned one boundary speed, the boundary was shifted to a new speed and the monkeys learned the new boundary. After learning, monkeys were able to shift rapidly between the two category boundaries. We recorded from 67 FEF neurons from two monkeys. Activity during stimulus presentation was significantly modulated by stimulus speed in 24 (36%) neurons. Activity changed significantly when the category changed in 28 (42%) cells (2-way ANOVA, $p < 0.05$). Some cells encoded both the physical speed of the stimulus and its category, which could be considered a categorical representation. Others simply showed enhanced firing to all stimuli of one category, but were not affected by stimulus speed. These results demonstrate that FEF activity is influenced by stimulus category and suggest a possible threshold model for categorical decision-making.

Acknowledgement: NIMH, Gatsby, NARSAD

9:30 am

31.15 Hand-centered visual representation of space: TMS evidence for early modulation of motor cortex excitability

Tamar R. Makin[1] (tamar.makin@mail.huji.ac.il), Nicholas P. Holmes[2,3], Claudio Brozzoli[3,4,5], Yves Rossetti[3,4,5], Alessandro Farnè[3,4,5]; [1]Neurobiology Department, Life Sciences Institute, Hebrew University of Jerusalem, Israel, [2]Psychology Department, Hebrew University of Jerusalem, Israel, [3]INSERM, U864, Espace et Action, Bron, France, [4]Université Lyon, Lyon 1, UMR-S 864, Lyon, France, [5]Hospices Civils de Lyon, Hôpital Neurologique, Mouvement et Handicap, Lyon, France

While avoidance movements might be rapid and relatively automatic (like Indiana Jones rolling under a closing barrier), target directed movements require planning (Jones grasping his hat at the last second). A wealth of studies has been devoted to reveal the neural basis of visuo-motor transformation in target-directed movements. However, less is known about the way in which rapidly approaching stimuli may be encoded and evoke reactive movements. Electrophysiological studies in the macaque premotor cortex have revealed visual receptive fields selective for 3D objects approaching the hand. In the present study, we explored hand-centered modulation of visual space in the human motor cortex. Subjects were engaged in a simple response task to a central go signal, and simultaneously presented with a (task-irrelevant) 3D ball, rapidly approaching a location either near to or far from their hand. Between 40-120ms after distractor ball appearance, a single TMS pulse was applied to the primary motor cortex contralateral to the responding finger, eliciting a motor evoked potential (MEP). At 80ms following ball appearance, the mean peak-to-peak MEP amplitude was significantly supressed when the ball approached the responding hand, as compared to far from it, regardless of hand position in space. Additional experiments showed that this hand-centered modulation of MEP amplitude was maintained irrespective of whether the subject’s eyes and overt endogenous attention were oriented towards or away from the location of the ball. Furthermore, manipulations of subjects’ covert exogenous visual attention had independent effects from the above hand-centered MEP modulations. Finally, when the distractor balls were replaced with stationary visual stimuli, no significant hand-centered modulation of MEP amplitude was observed. By demonstrating both early and selective modulation of motor cortex excitability, these findings constitute the first direct evidence that the human motor cortex represents visual peripersonal space in a hand-centered reference frame.

Acknowledgement: This study was supported by AVENIR grant #R05265CS

09:45

31.16 Evidence from visuo-motor adaptation for two partially independent visuo-motor systems

Lore Thaler[1] (thaler.11@osu.edu), James Todd[1]; [1]Department of Psychology, The Ohio State University

We can distinguish between two different kinds of visual information that subjects can use to guide their hand and fingers, and that impose different computational requirements on visuo-motor processes.

When we pick up objects, we can move our hands towards visually perceived target locations. Tasks like this can in principle be performed by establishing correspondences between target and hand locations in visual and motor space. Thus, it is sufficient if visuo-motor processes compute representations of target and hand locations in visual and motor space and correspondences between them. It is not necessary, however, that visuo-motor processes compute metric representations of target distances. In contrast, when we move our hands in the absence of a visual target location, for example when manually indicating the extent of an object, the task requires production of movements that match visually perceived distances. In this situation, visuo-motor processes have to compute metric representations of target distances.

The experiment reported here used an adaptation paradigm to test if observers rely on different visuo-motor systems in tasks that require the representation of metric distances and tasks that do not.

In an adaptation phase, observers were presented with distorted visual feedback on their hand movements. In a testing phase (no visual feedback), we measured how behavior changes in response to the distorted feedback. We used two tasks in testing and adaptation. One task required observers to move their hand to a visual target location. The other required observers to move their hand over a target distance in the absence of a visual target location. The results show, that behavioral changes are significantly larger when the same task is used during testing and adaptation, compared to when the task is switched.

The findings suggest that human observers have two partially independent visuo-motor systems with different computational principles.

Sunday, May 11, 8:30 - 10:00 am Talk Session, Royal Palm Ballroom 4-5

Search 2

Moderator: Greg Zelinsky

8:30 am

31.21 ERP correlates of inter-trial effects in visual search

Clayton Hickey[1] (c.hickey@psy.vu.nl), Jan Theeuwes[1]; [1]Vrije Universiteit Amsterdam

Visual search for a singleton target is slowed by the presence of a singleton distractor, and this interference effect is exacerbated when target and distractor identities are uncertain. For example, search for a uniquely shaped target is slowed more by the presence of a uniquely colored distractor when the defining characteristics of these objects change from trial to trial than when these characteristics remain the same over experimental blocks. This has been interpreted as evidence that endogenous attentional control can minimize the interference of salient-yet-irrelevant distractor stimuli. However, recent results have tied the cost of target and distractor uncertainty to inter-trial priming rather than top-down set. According to this perspective salient distractor stimuli capture attention when the characteristic that defines the distractor on trial n has changed from trial n-1. We used the event-related potential (ERP) technique to investigate the how target and distractor uncertainty affect visual search. The results were consistent with the idea that inter-trial priming underlies uncertainty effects in visual search. Furthermore, it appears that inter-trial priming has discrete influences on attentive and post-perceptual processing stages, but not on early sensory and perceptual activity. These results are consistent with models of selection and visual search in which stimulus-driven factors play an important role.

8:45 am

31.22 Configuration asymmetries in visual search

Justin Jungé[1] (justin.junge@yale.edu); [1]Yale University

Several new experiments demonstrate robust effects of stimulus composition on search time, equating stimulus parts and connectedness. Observers were instructed to search for an oddball target in an array of distractors (identical to each other, and different than a target). Both targets and distractors were composite objects, made of two parts. For example, in one trial, each distractor is a black square sitting directly above the top of a white square, and the target is a white square above a black square. An array of such stimuli can be collectively rotated 90, 180, or 270 degrees, preserving an oddball target. Other example stimuli include variations on one simple shape attached to another. The results are clear: observers are much faster to locate targets when the composites are vertically oriented, and when composites are mirror symmetrical across a vertical axis. Composite stimuli produce a number of interesting effects, including an initial statistical impression of irregularity present or absent, even before an oddball can be localized. The observed effects of part-configuration go beyond symmetry and complexity. These findings are discussed as possible evidence for mid-level configuration detectors.

9:00 am

31.23 A likelihood based metric to compare human and model eye movement fixations during visual search

Wade Schoonveld[1] (schoonveld@psych.ucsb.edu), Miguel P. Eckstein[1]; [1]University of California, Santa Barbara

When searching for a target among distractors humans often make saccadic eye movements every 200-300 ms. There have been many attempts to model these eye movements in a way that accurately reflects the observed human behavior (Najemnik & Geisler, 2005, Nature; Rao et al., 2002, Vision Research; Beutter et al., 2003; JOSA A). However, there are no standard methods to compare the eye movement fixations of human and models. Here, we propose a maximum likelihood metric that quantifies the probability of observing a human saccade or a sequence of saccades given that a model is driving the saccades. This probability is calculated by taking into account both the saccade noise inherent to the human brain as well as the error stemming from the particular eye tracking system used. We compare the likelihood metric to other common metrics including: a) the distance between the measured human and predicted model saccade endpoints (distance metric), b) a correlation metric between the human and model spatial cluster of fixations (cluster correlation metric), and c) the percentage of the trials in which the eye movements were directed towards the target for the models and human observers (percentage correct metric). We highlight theoretical situations when the distance, cluster-correlation, and percentage correct metrics fail to adequately distinguish between models. We finally apply the common metrics and the new likelihood metric to actual measured human saccades in a series of 400ms search tasks for a variety of targets with contrast noise (Gaussians: full width at half of maximum (FWHM) = 0.384 degrees, single frame (25ms) signal to noise ratio (SNR) = 2.58 or Gabors: FWHM of Gaussian envelope = 0.384 degrees, spatial frequency = 9.8 cycles/degree, single frame (25ms) SNR = 7.41).

Acknowledgement: National Science Foundation (BCS-0135118)

9:15 am

31.24 Eye can read your mind: Decoding eye movements to reveal the targets of categorical search tasks

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Theories of top-down search guidance typically assume that guidance to a distractor is proportional to the object's similarity to a target. This relationship, however, has been demonstrated only for simple patterns; it is less clear whether it holds for realistic objects. We report a novel method for quantifying guidance by reading the subject's mind, defined here as classifying the target of a categorical search task (either teddy-bears or butterflies) based on the distractors fixated on target-absent trials. The task was standard present/absent search. Half of the subjects searched for a teddy-bear target, the other half searched for a butterfly target. Except for the targets, search displays were identical between the two groups, meaning the same distractors in the same locations. All distractors were random real-world objects selected from the Hemera collection. To quantify target-distractor similarity we used a machine learning method (AdaBoost) and new target exemplars to train a teddy-bear/butterfly classifier. Target-absent trials were then combined across the teddy-bear and butterfly groups, and the distractors selected by gaze on these trials were identified and input to the classifier. The classifier evaluated these objects in terms of color, local texture, and global shape feature similarity to the teddy-bear and butterfly classes, then assigned each object to one of these target categories. Our joint behavioral-computational method correctly classified 76% of the actual butterfly target-absent searches and 66% of the teddy-bear target-absent searches, lower than the butterfly classification rate but still significantly better than chance (50%). These results definitively prove the existence of categorical search guidance to real-world distractors; in the absence of guidance above-chance classification would not have been possible. Our method also demonstrates that these guidance signals are expressed in fixation preferences, and are large enough to read a subject's mind to decipher the target category of target-absent searches.

Acknowledgement: This work was supported by NIH grant R01-MH63748

9:30 am

31.25 Eye movements and saliency in a natural search task: evidence from visual agnosia

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Models of eye movement control in natural scenes often distinguish between stimulus-driven processes (which guide the eyes to visually salient regions) and those based on task and object knowledge (which depend on expectations or identification of objects and scene gist). In the present investigation, the eye movements of a patient with visual agnosia were recorded during a real-world search task and compared with those made by healthy students and age-matched controls. The patient was unable to recognize 3D forms or line drawings, despite normal acuity and intact peripheral fields. We hypothesized that, with her deficit, there should be less top-down guidance in this task than with normal controls. If visual saliency is computed earlier than, or independent from, object recognition then saliency would be predicted to have an effect on eye movements. Furthermore, with reduced top-down biases, the eye movements produced might be closer to a raw saliency map than those made by normal controls.

The patient's deficit in object recognition was seen in poor search performance and inefficient scanning; she made longer fixations and smaller saccades than control participants. The low-level saliency of target objects had more of an effect in visual agnosia than in the control groups, and the most salient region in the scene was more likely to capture attention. Further analyses suggested that the relationship between fixation patterns and saliency in visual agnosia was stronger than that in the control subjects. These findings are discussed in relation to saliency-map models and the balance between high and low-level factors in eye-guidance.

09:45

31.26 PINK: the most colorful mystery in visual search

Yoana Kuzmova[1] (yoana@search.bwh.harvard.edu), Jeremy Wolfe[1, 2], Anina Rich[3], Angela Brown[4], Delwin Lindsey[4], Ester Reijnen[5]; [1]Brigham & Women's Hospital, [2]Harvard Medical School, [3]Macquarie Center for Cognitive Science, NSW, Australia, [4]Ohio State University, [5]U.Basel, Switzerland

Desaturated red is called "pink", a "Basic Color Term" (BCT, Berlin & Kay, 1969). In contrast desaturated blues and greens have names like "lilac" or "pale green" which are not BCTs in English. Does this distinct linguistic status reflect a special visual status? For example, we asked, would pink targets be comparatively easy to find in visual search?

Observers searched for a desaturated target (e.g., pink) among saturated (e.g., red) and achromatic (white) distractors. We picked saturated distractor hues at 9cd/m2, equidistant in CIELAB color space from the "white", 50cd/m2 Illuminant C distractors. Desaturated targets fell midway between the saturated and white distractors in CIELAB color space.

Search was much faster and somewhat more efficient when stimuli were in the reddish/pink range than in any other hue range. The magnitude of this advantage for pinkish targets was very large (hundreds of msec), and extended beyond categorical "pink" to include search for "peach" among orange and white. This suggests that the linguistic term, "pink", does not itself mediate the effect. We have replicated the result with colors chosen in a similar manner in other color spaces (CIExyY, RGB), and using equiluminant stimuli or heterogeneous distractor hues. In all cases, search for desaturated red and orange hues was significantly more efficient than search for any other desaturated target.

What are the sources of this robust effect, if not the linguistic status of "pink"? Perhaps the linguistic term imperfectly reflects an underlying specialization in visual selective attention that favors desaturated reds and oranges, but the basis of the specialization is not yet clear. Stimuli with large R-G signals are generally found faster than those with smaller R-G signals, whereas the relation between RT and Tritan signals is non-monotonic. More speculatively, it is interesting that preferred targets seem to be skin tones.

Acknowledgement: Supported by NIMH 56020 and AFOSR

URL: http://search.bwh.harvard.edu/new/participate.html

Sunday, May 11, 10:30 am - 12:15 pm Talk Session, Vista Ballroom

Motion Processing

Moderator: Duje Tadin

10:30 am

32.11 Human Ocular Following and Natural Scene Statistics

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It is commonly assumed that the visual system is optimized to process naturalistic inputs for both low and high level processing. Here we search for an advantageous effect of natural scene statistics when estimating speed.

Ocular following responses (OFRs) are reflexive eye movements known to reflect many properties of low-level motion processing. Using the scleral search coil technique, we recorded human OFRs to drifting sinusoidal gratings (1D) as well as narrow bandpass noise images (2D).

For sinusoidal gratings, it was previously shown that OFRs are best elicited with low spatial frequency stimuli (<1cpd) moving at optimal speed (20-40°/s). We were able to confirm this for 2D noise stimuli as well. However, we found a systematic difference in the acceleration profiles: OFRs to 2D noise stimuli consistently showed longer latencies, yet stronger overall responses than the 1D gratings. When combining two or more spatial frequencies, we found a gain in response strength mostly in the higher spatial frequency range. Also, we found evidence that stimuli consisting of the normalized sum of several spatial frequencies can create stronger OFRs than the normalized sum of the OFRs to the individual frequencies. When combining spatial frequencies, the weighting (mix ratio) of the individual frequencies influences the response gain. The optimum weighting with multiple bandpass noises appeared to be similar to the spectral shape of natural scenes (1/f).

These results show a systematic difference between OFRs evoked by 1D gratings and 2D noises, and provide a first behavioral evidence that speed is best estimated by combining information across different channels, with weighting based on natural scene statistics.

Acknowledgement: NATSTATS-ANR-2005-2009, FRM Grant FDT 20051206135

10:45 am

32.12 Predicting and computing 2D target motion for smooth-pursuit eye movements in macaque monkeys

Guillaume Masson[1] (guillaume.masson@incm.cnrs-mrs.fr), Jérome Fleuriet[1], Anna Montagnini[1], Pascal Mamassian[2]; [1]INCM, CNRS & Aix Marseille Université, [2]LPE, CNRS & Université René Descartes

Smooth pursuit eye movements in primates unveil the temporal dynamics of 2D motion integration. Tracking of single, tilted bars is always initiated in a direction close to the velocity orthogonal to the bar orientation. This initial bias is gradually reduced: 300ms after visual motion onset both target and eye movement directions are perfectly aligned. This time course is believed to reflect the temporal dynamics of the neural solution for the aperture problem in macaque area MT (Pack et al., 2001). We investigated how high-level cues can influence this temporal dynamics. Eye movements were recorded in macaque monkeys using the scleral search coil technique. Long (20°) bars were drifted along the horizontal direction (speed 10°/s) with different bar orientations (-45°, 0 and +45° relative to the vertical axis). We found no effect of a static presentation (500ms) prior setting target into motion with unpredictable directions. In a second set on experiments, we blocked both bar orientation and direction conditions so that 2D motion was fully predictable. We found strong anticipatory responses along the 2D motion trajectory. However, 100ms after target visual motion onset, strong pursuit biases were again observed suggesting that predicting target motion had no influence upon solving the aperture problem. In a final set of experiment, we briefly (200ms) blanked target motion during steady-state tracking (i.e. when pursuit and target directions were aligned). Blanking the image drastically reduced eye velocity and in many cases pursuit was stopped. At target reappearance, monkeys reinitiated pursuit responses along the orthogonal direction to bar orientation, albeit with a weaker direction bias. These results suggest that high-level prediction about incoming target motion cannot be used to solve the aperture problem. This demonstrates that low-level motion computation remains impenetrable to cognitive factors to preserve the ability to quickly react to new visual motion input.

11:00 am

32.13 Smooth pursuit eye movements generate spurious motion signals that create a motion after effect

Peter Tse[1] (Peter.U.Tse@dartmouth.edu), Po-jang Hsieh[1]; [1]Dartmouth College

Smooth pursuit eye-movements generate large magnitude spurious motion signals that generate a motion after-effect (MAE).

White bars of various orientations away from vertical (0,15,30,45,60,75,85,90 degrees) remained present on the screen on a black background, one orientation visible per trial. The fixation point swept from left to right smoothly for a variable duration and at a variable speed. Subjects smoothly pursued this moving point, after which the fixation spot stopped in the center. Subjects indicated when the MAE stopped. The duration of the MAE increased with increasing duration and speed of smooth pursuit. The strength of the MAE was effectively zero for vertical bars, even though this stimulus had the greatest image motion magnitude in the horizontal direction (the direction of smooth pursuit). This was presumably because there was no component of motion in the vertical direction for vertical bars. It was also zero for horizontally aligned bars, which had no motion component in the vertical direction. The MAE was strongest for bars oriented slightly away from horizontal at about 80 degrees from vertical.

We hypothesize that the motion processing system is able to discount component motion with less success for bars oriented at angles very close to the direction of smooth pursuit. We suggest that filters tuned to low spatial frequency components of motion determine a global direction of motion. To inhibit spurious motion signals due to the aperture problem, motion signals derived from contours oriented at an angle close to this global direction of motion receive inhibitory feedback such that perpendicular component motions from these contours are suppressed. However, the limits of angular acuity are reached at small angles (i.e. the angle between a contour and the global direction of motion across the retina), and inhibition of perpendicular component motion of these contours is correspondingly weaker.

11:15 am

32.14 **Tuning properties of local-motion pooling units**

Mark Edwards[1] (Mark.Edwards@anu.edu.au), Kunjam Vallam[1], Kanupriya Kalia[1]; [1]School of Psychology, Australian National University, Australia

The lack of a percept of motion transparency with locally-balanced dots moving in opposite directions indicates the existence of a local-motion-pooling (LMP) stage prior to global-motion (GM) pooling. We investigated the tuning properties of LMP units to luminance polarity, speed (temporal frequency) and multiple directions over time. It has previously been shown that luminance-polarity information (On and Off pathways) is kept independent at the local-motion stage, but is pooled at the GM stage. Whether polarity information is still independent at the LMP stage was investigated. Earlier studies have indicated that, while speed tuning occurs at the GM stage, it doesn't occur at the LMP stage. However, the speed combinations used in those studies would have driven common speed-tuned GM units. If speed tuning does occur at the LMP stage it would likely reflect the observed GM tuning. Consequently, LMP tuning was tested with speeds that drive independent GM units. Using locally-paired, orthogonally-moving dots, we showed that luminance polarity information is combined at the LMP stage and that independent, speed-tuned (TF) LMP units exist. Finally, it has been shown that adapting to a transparent-motion stimulus, in which the signals differ only in their direction of motion, results in an unidirectional MAE, opposite to the vector-average direction of the two adapting signals. It has been proposed that this MAE results from the integration of the different directions in each LMP unit over the course of adaptation, such that the net adaptation in each LMP unit is to the vector-average direction. This theory was tested with a multi-aperture stimulus in which a single motion direction was presented in each aperture. It was possible to generate a transparent MAE with this stimulus, supporting the theory.

Acknowledgement: ARC CE0561903

11:30 am

32.15 **Rapid generation of the motion after-effect by sub-threshold adapting stimuli**

Duje Tadin[1] (duje@cvs.rochester.edu), Davis M Glasser[1]; [1]Center for Visual Science, University of Rochester

The motion after-effect (MAE) is generally observed after prolonged inspection of a moving stimulus, typically requiring tens of seconds of adaptation. However, neurophysiological studies have reported adaptation effects following briefly presented adapting stimuli (e.g., Muller et al., 1999). The putative functional roles of this rapid neural adaptation are improved coding efficiency and increased stimulus discriminability. Here, we investigated whether psychophysical adaptation effects can be observed at the timescale of reported neurophysiological effects.

In the main experiment, observers viewed a large, high-contrast adapting grating presented for 67ms (1c/deg, 15deg/s, temporal sum of contrast was 0, precluding afterimage generation). As confirmed by control experiments, this exposure duration was below the motion discrimination threshold, likely because of suppressive center-surround interactions (Tadin et al., 2003). Nevertheless, when presented with a stationary test stimulus, observers reported perceiving illusory motion in the direction opposite to the sub-threshold adapting motion. This was observed for adaptor-test ISIs of 0ms, 150ms, 400ms, but not for 1000ms.

In other experiments, we showed that this rapid MAE exhibits partial interocular transfer and is low-pass tuned to the spatial frequency of the adaptor, with the strongest MAE when the adapter and test have the same spatial frequency. Interestingly, removing the test stimulus and shortening adaptor presentation to 50ms (in order to generate a negative afterimage) also yielded a strong MAE, i.e., the resulting afterimage appeared to move.

In summary, we found that adaptation to brief moving stimuli yields perceivable MAEs, even when the exposure duration is below that required for above chance motion discrimination. Evidently, the MAE is not merely a perceptual illusion that follows prolonged exposure to a moving stimulus, but rather a process that can occur essentially every time we experience motion.

11:45 am

32.16 **Psychophysical Measurements of Surround Suppression in 5-year-olds**

Terri Lewis[1] (lewistl@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour (PNB), McMaster University, Hamilton, ON, Canada

At low contrasts, increasing stimulus size can improve performance, a phenomenon known as spatial summation. At high contrasts, young adults show spatial suppression: worse direction discrimination as stimulus size increases (Anderson & Burr, 1991; Betts et al., 2005; Tadin et al., 2003). Such spatial suppression has been attributed to GABA mediated inhibitory connections among cortical cells (Jones et al., 2001). Recent results suggest that children may have decreased GABAergic inhibition (Boley et al., 2005); if so, they should show decreased spatial suppression. Methods. To assess changes in spatial suppression with age, we measured motion discrimination thresholds as a function of pattern contrast and size in 27 5-year-olds and 24 young adults. In 4 separate blocks, participants viewed small ($2\sigma = 0.7^{\circ}$) or big ($2\sigma = 5^{\circ}$) 1 cpd Gabor patterns of high (92%) or low (4%) contrast, moving at 8°/sec. Participants judged the direction of motion as leftward or rightward. Stimulus duration varied over trials to determine the minimum duration needed for accurate performance. Results. At low contrast, duration thresholds were 1.9 times longer for children than adults ($p < 0.001$), but the amount of spatial summation (threshold big/threshold small) was equivalent at the two ages ($p > 0.30$). At high contrast, thresholds were worse for big than small patterns ($p < 0.00001$) and worse for children than adults ($p = 0.03$). The amount of spatial suppression was smaller in children than adults ($p = 0.03$, 1-tailed) because children were worse than adults for small but not big patterns. Conclusion. In general, 5-year-olds require more time than young adults to process the direction of motion. Critically, at high contrasts, the suppression index is smaller in 5-year-olds than adults, consistent with the hypothesis that 5-year-olds, like the elderly (Betts et al., 2005), have weaker inhibitory surrounds than young adults.

Acknowledgement: Supported by the Canadian Institutes of Health Research (CIHR), Natural Science and Engineering Council of Canada (NSERC), and the Canada Research Chairs program.

12:00 pm

32.17 **Effects of onset-transients on the perception of visual motion**

Jan Churan[1] (jan.churan@gmail.com), Farhan Khawaja[1], James Tsui[1], Alby Richard[1], Christopher Pack[1]; [1]Dpt. of Neurology and Neurosurgery, Montreal Neurological Institute, McGill University

The sudden onset of a visual stimulus causes a short burst of activity in motion-sensitive areas of the brain. Because such onset-transients are by definition non-selective for motion direction, they are likely to disrupt motion perception during the period immediately following the appearance of a novel visual stimulus. We examined the effects of onset-transients on visual perception and on neuronal responses in MT.

Human subjects discriminated the direction of a single motion step for Gabor patches of varying sizes (5.3-18.5 degrees) and contrasts (98% or 1.5%). We also varied the time between the appearance of the stimulus and its motion (the motion onset delay). When the motion onset delay was short (35ms), subjects showed increasing discrimination thresholds for larger sizes of high-contrast gratings (similar to Tadin et al. 2003). However, for longer motion onset delays (>120ms), discrimination thresholds were lower and independent of stimulus size. When the motion onset delay period was interrupted by a short gap (12-188ms) which ended 35ms before the motion onset, the size-dependence of the thresholds returned.

To examine the neuronal basis for these findings, we recorded the responses of MT neurons to moving gratings of different size, contrast and motion onset delay. In general the sudden onset of a moving stimulus caused a short period (~30ms) of non-direction-selective activity that was strongest for large, high-contrast gratings. These onset-transients effectively masked the earliest portions of the directional MT responses. When the motion onset delay was increased, the early MT responses were again direction-selective.

Our results suggest that onset-transients temporarily disrupt motion processing. This may help to explain psychophysical phenomena such as the flash-lag illusion, the Frohlich effect, and the surprising decrease in motion sensitivity for large high-contrast stimuli reported recently by others (Tadin et al. 2003).

Acknowledgement: Supported by NSERC and CIHR. Thanks to Irfan Khawaja for help with data acquisition.

Sunday, May 11, 10:30 am - 12:15 pm Talk Session, Royal Palm Ballroom 4-5

Attention: Neural Mechanisms and Models

Moderator: Geoff Woodman

10:30 am

32.21 Inactivation of superior colliculus causes visual extinction

Lee Lovejoy[1,2] (lovejoy@salk.edu), Richard Krauzlis[1]; [1]Systems Neurobiology Laboratory, Salk Institute for Biological Studies, [2]Graduate Program in Neurosciences, UCSD

Although the primate superior colliculus (SC) has a well documented role in the generation of saccadic eye movements, it may also be involved in the control of spatial attention. We have used reversible inactivation to directly test the role of the SC in the allocation of spatial attention.

We performed focal inactivations with muscimol, a GABA agonist, in the SC of a rhesus macaque trained in an attentionally demanding motion discrimination task. After the monkey initially fixated a central dot, four stochastic motion patches were presented in each quadrant of the visual field. One of the four patches was momentarily cued, and after a variable delay, a brief pulse of motion appeared in the cued location. At the same time, a pulse appeared in the diametrically opposite location; the direction of this foil signal was never the same as that of the cued signal. The monkey was rewarded for reporting the direction of the cued signal with a saccade in the same direction as the motion. The direction of the saccade was thus dissociated from the locus of attention.

Focal inactivation in the SC map caused the monkey to preferentially attend to stimuli in the unaffected portion of the visual field. When the monkey was cued to attend into the affected region, he was unable to report the direction of that signal. Instead, he reported the direction of the foil signal despite the fact that this response was never rewarded. In contrast, when the signal appeared in the affected region in the absence of distracters, motion discrimination thresholds were only marginally increased (12% to 17% coherent motion). Therefore inactivation of the SC caused the monkey to neglect visual stimuli in the affected region but only in the presence of distracters (i.e. visual extinction).

Acknowledgement: Aginsky Estate, Institute for Neural Computation, UCSD (NIH Grant MH20002)

10:45 am

32.22 Timing of target selection between visual cortex and frontal eye field

Jeremiah Y. Cohen[1,2] (jeremiah.y.cohen@vanderbilt.edu), Richard P. Heitz[2,3], Jeffrey D. Schall[1,2,3,4], Geoffrey F. Woodman[2,3,4]; [1]Vanderbilt Brain Institute, [2]Dept. of Psychology, Vanderbilt Univ., [3]Center for Integrative and Cognitive Neuroscience, Vanderbilt Univ., [4]Vanderbilt Vision Research Center

A substantial body of work implicates a frontoparietal network as the source of top-down attention in humans. Studies in monkeys have shown that the frontal eye field (FEF) participates in target selection during visual search and top-down attention. Recently, we discovered a monkey homologue of the human N2pc (Woodman GF, Kang M-S, Rossi AF & Schall JD (2007) Nonhuman primate event-related potentials indexing covert shifts of attention. Proc Natl Acad Sci 38, 15111-15116), an ERP component that indexes attention. We now bridge the two bodies of literature by testing the hypothesis that the FEF is a source of top-down attention for visual cortex. We recorded event-related potentials (ERPs) over visual cortex (approximating human 10/20 locations T5 and T6) while simultaneously recording local field potentials (LFPs) and single neuron activity in the FEF of monkeys performing a T/L visual search. Target selection, measured using a common criterion, occurred earliest in the visual cortex ERPs (mean = 165.4 ms), next in the FEF LFPs (182.5 ms), and latest in the 24 FEF neurons (190.9 ms) across sessions. Thus, the FEF appears not to be the source of the monkey homologue of the N2pc.

Acknowledgement: Supported by NEI R01-EY08890, P30-EY08126 and Ingram Chair of Neuroscience.

11:00 am

32.23 Effects of Frontal Eye Field Inactivation on Visual Responses of Area V4 Neurons

Behrad Noudoost[1] (behrad@stanford.edu), Tirin Moore[1]; [1]Neurobiology Department, Stanford University

Recent work has shown that electrical microstimulation of the frontal eye field (FEF) alters the visually-driven responses of neurons within visual cortex. Although these observations suggest that FEF neurons exert a top-down influence on visual cortical representations, it has not yet been demonstrated. We investigated the effects of reversible FEF inactivation on the visual responses of area V4 neurons in alert monkeys. Using a custom-designed recording/microstimulation/microinfusion cannula, we delivered small volumes (100 – 800 nL) of drugs to select sites within the FEF. At different FEF sites, we first determined the location to which saccades could be evoked by microstimulation (current <50 uA). As in previous microstimulation studies, we then located FEF sites at which the evoked saccade shifted the monkey's gaze to a location within the receptive field (RF) of a V4 neuron being recording from simultaneously. Next, we infused GABA agonists (muscimol or GABA) into the FEF site and the measured the behavioral effects of the inactivation using a memory-guided saccade task. In most cases, within ~45 minutes, the monkey showed a spatially-selective deficit on the task, and at the location of the V4 RF. We then studied the visual responses of V4 neurons to stimuli presented within the FEF scotoma using both passive fixation and saccade tasks. In the saccade task, the monkey made visually-guided saccades to RF stimuli or to targets presented at non-RF locations after a delay. We could therefore measure the effects of FEF inactivation both on the visual guidance of saccades to RF stimuli and on the pre-saccadic visual activity of V4 neurons. Thus far, we have found that inactivation of the FEF not only increases the scatter of visually-guided saccades to visual targets in the scotoma, but that it alters the visually-selective responses of V4 neurons with RFs at the same location.

11:15 am

32.24 Border ownership representation in human early visual cortex and its modulation by attention

Fang Fang[1] (ffang@pku.edu.cn), Huseyin Boyaci[2], Daniel Kersten[2]; [1]Department of Psychology, Peking University, Beijing, China, [2]Department of Psychology, University of Minnesota

Natural images are usually cluttered because objects occlude one another. A critical step in visual object recognition is to identify the borders between image regions that belong to different objects. Single-unit studies have suggested that a representation of border ownership may form as early as V2. We used fMRI adaptation to investigate sensitivity to border ownership in human early visual cortex. Two stimuli were generated by modifying a black/white square-wave radial grating. In one stimulus, the white stripes were slightly longer than the black stripes in the radial direction. This provided contextual information that caused the borders between the white and the black stripes to appear to belong to the white stripes. In the other stimulus, the black stripes were slightly longer than the white stripes, which caused the borders to appear to belong to the black stripes. Subjects adapted to one of these two stimuli and were then tested with both stimuli. Their attention was directed either to a central fixation point or to the borders. Regions of interest in the early visual cortex were confined to areas corresponding to an annular interior part of the radial grating. This part was locally identical across the two stimuli, but as a consequence of the difference in the contextual information, the borders between the white and the black stripes were perceived to belong to either the white or the black stripes. When subjects attended to the border, we found a strong adaptation effect in V2 consistent across four subjects, but a weak effect in V1. However, when subjects attended to the fixation, the adaptation effect was largely abolished in both V1 and V2. Our data suggest that V2 is a critical area for the processing of border ownership and that this processing depends on feedback from higher-level visual areas.

Acknowledgement: This work is supported by NIH grant EY015261. The 3T scanner at the University of Minnesota, Center for Magnetic Resonance Research is supported by NCRR P41 008079 and by the MIND Institute.

11:30 am

32.25 Reflexive and Preparatory Selection and Suppression of Salient Information in the Right and Left Posterior Parietal Cortex

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Attentional cues can trigger activity in the parietal cortex in anticipation of visual displays, and this activity may in turn induce changes in other areas of the visual cortex, hence implementing attentional selection. In a recent TMS study (Mevorach, Humphreys & Shalev, 2006) it was shown that the parietal cortex can utilize the relative saliency (a non-spatial property) of a target and distractor to bias visual selection. Furthermore, selection was lateralised so that the right PPC is engaged when salient information must be selected and the left PPC when the salient information must be ignored. However, it is not clear how PPC implements these complementary forms of selection. Here we used online triple-pulse TMS over the right or left PPC prior to or after the onset of Global/Local displays. When delivered after the onset of the display, TMS to right PPC disrupted the selection of the more salient aspect of the hierarchical letter. In contrast, left PPC activity delivered prior to the onset of the stimulus disrupted responses to the lower saliency stimulus. These findings suggest that selection and suppression of saliency, rather than being 'two sides of the same coin' are fundamentally different processes. Selection of saliency seems to operate reflexively whereas suppression of saliency relies on a preparatory phase that 'sets-up' the system in order to effectively ignore saliency.

11:45 am

32.26 Parallel architectures in visual search within an eye movement

Barbara Dosher[1] (bdosher@uci.edu), Zhong-Lin Lu[2], Songmei Han[1]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Psychology, University of Southern California

Finding a target object in a complex visual scene requires search across the visual field. Although early visual processing is characteristically parallel, difficult visual search tasks with significant set size effects on search time are often associated with time-limited serial operations of the attention system. However, the typical measures of the set size effects (increased average response time and decreased error rates for larger displays) could be consistent with either a serial or a parallel architecture. A full time-course analysis of visual search is necessary. We measured target detection accuracy at search times from 0.1 to 2.3 s for several difficult and error prone searches for different display sizes. Using computational models with probabilistic responses (Dosher, Han, & Lu, 2004) corresponding with independent information accumulation across objects within a single epoch of information acquisition, we distinguish unlimited capacity parallel versus serial search mechanisms. Rather than invoking serial, time-limited deployment of covert attention, a range of difficult searches, including search asymmetries, heterogeneous distractor effects, and some conjunction searches, instead exhibited nearly identical search dynamics regardless of the size of the display [although accuracies differ] -- information-limited, not time-limited processes. Slightly slowed dynamics in large displays reflects the impact of classification errors on the early dynamics of probabilistic parallel search. These observations are related to but go beyond unlimited capacity statistical models of asymptotic accuracy of search (e.g., Palmer, Verghese, Pavel, 2000; Eckstein, Thomas, Palmer, Shimozaki, 2001) and relate directly to results in multi-target visual search (Thornton & Gilden, 2007). These time-course dynamics also support the assumptions of recent models of parallel information acquisition across the field in Bayesian prediction and analysis of eye movement selection (Najeminik & Geisler, 2005). The visual and item-comparison systems operate as an unlimited-capacity parallel analysis over the visual field within a single eye fixation.

Acknowledgement: Funded by AFOSR, NSF, NEI

12:00 pm

32.27 Computational Model of the Spatial Resolution of Visual Attention

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The resolution limits of visual attention are conceptualized as being determined by an attention spread function. The parameters of the attention spread function are derived from a search experiment. Subjects search attended areas of a 12x12 array for a single target disk (a large disk) among 133 distracters (small disks) and 12 false targets (large disks in unattended areas) that force subjects to confine attention to the to-be-attended locations. To derive the parameters of the attention spread function, to-be-attended locations are defined as rows or columns interleaved with to-be-unattended rows or columns, analogous to spatial frequency gratings. Two model parameters characterize the width and shape of the attention spread function. One parameter characterizes task difficulty (how discriminable targets are from distracters), three parameters describe the asymmetric decline of spatial acuity with eccentricity. Once these 6 parameters have been determined from experiments with attention confined to rows or columns, the model makes predictions (with no new measurements) for all of the 1.5*1042 possible ways of requesting subjects to attend to 72 of 144 locations. To test the model, the 12x12 stimulus was conceptually divided into 16 3x3 blocks. Eight blocks were arbitrarily chosen to define to-be-attended areas. In a still more complicated task, subjects were required to attend to an arbitrarily chosen 18/36 blocks. The model made 288 good a priori predictions for one subject (not merely fits to data) when attending both 8/16 blocks and 18/36 blocks. However, the other subject, despite extensive practice, could attend to only slightly more than half of the to-be-attended blocks in these complex arrays; predictions within the attended subset were in accordance with the model. Conclusion: A simple spread function adequately describes the resolution of spatial attention but, when extremely complex distributions of attention are requested, complexity itself becomes a limiting factor.

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Sunday, May 11, 8:30 am - 12:30 pm
Poster Session, Royal Palm Ballroom 1-3

Faces: Neural Mechanisms 1
Perceptual Development Across the Lifespan
Spatial Vision: Crowding and Eccentricity 1

Faces: Neural Mechanisms 1

33.301 The Magnetoencephalography M170 Response to Degraded Images

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The M170 is a peak in scalp magnetoencephalography (MEG) that manifests roughly 170 milliseconds after image onset, and is believed to be face-specific. In this study, we explored the influence of image blur on M170 latency and amplitude. In separate behavioral experiments (Cherian et al., VSS 2008), we found an increase in reaction time on subordinate but not basic-level categorization tasks correlated with the level of degradation. With increasing blur, face identification accuracy decreased and latency increased, on the order of 100 milliseconds for no to highest blur used in the our study. We sought to determine whether changes in the latency and amplitude of the M170 reflect these behavioral findings.

MEG signals across the entire scalp were recorded while participants viewed famous and non-famous face and building images, degraded to varying extents, and performed a one-back task. We found that as blur was increased, the M170 amplitude decreased, and the latency increased for all image types (on the order of 20 milliseconds from no to highest blur). The M170 amplitudes for celebrity and non-celebrity images were identical to each other, and greater than those for building images, for every blur level. For celebrity and non-celebrity images, the M170 latencies were identical, and larger than those for building images, at the different blur levels.

Our data showed that the behaviorally manifested delay in face recognition could not be fully accounted for by the observed delay in the M170. This, coupled with the finding that celebrity and non-celebrity M170s were identical, suggests that the M170 is unlikely to reflect subordinate face identification. Additionally, the finding that blurring non-face images affects the corresponding M170 signal suggests that this component might not be entirely face-specific, but may instead reflect neural processing of a broader class of visual stimuli.

33.302 **Rapid extraction of stimulus phase information during complex object processing**

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Most ERP studies of object and face perception have focused on the N170, an ERP component that is systematically larger for faces compared to objects in the time window 130-200 ms. We recently demonstrated that N170 effects cannot be explained by differences in amplitude spectrum or stimulus variance, but rather depend on phase information (Rousselet, Husk, Bennett & Sekuler, Journal of Vision 2005, NeuroImage 2007). In the present study, we examined the phase tuning function of EEG single-trials evoked by complex objects. Stimulus phase was systematically manipulated in a parametric design, with 11 steps of phase information, ranging from 0% (noise), to 100% (original stimulus). Contrast and amplitude spectrum were maintained constant across noise levels. Subjects (n=8) had to discriminate between 2 faces, a task orthogonal to the stimulus manipulation. ERPs from each subject were entered into a multiple linear regression model including stimulus phase information, skewness, kurtosis and their interactions as regressors. This simple model explained up to 48% of the variance on average (min=20%, max=67%), with scalp topography very similar to the one of early visual evoked responses. Sharp non-monotonic changes in EEG activity occurred between 100-150 ms. Theses changes were explained by an increased phase sensitivity modulated by the image kurtosis, an interaction that peaked around the latency of the N170. A control experiment using the same task but pink noise (1/f) textures instead of faces did not show EEG phase sensitivity, demonstrating that the effect is not task related. However, wavelet textures preserving higher-order image statistics (skewness and kurtosis) as well as multi-scale phase correlations elicited significant phase sensitivity modulations, albeit overall much weaker and delayed compared to face stimuli. These results suggest that a large part of early responses to complex objects like faces correspond to a rapid bottom-up extraction of higher-order image statistics.

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33.303 **Early electrophysiological correlates of the influence of familiarity during face identity adaptation paradigm**

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Human beings are experts at face perception, but this ability is greatly improved for familiar as compared to unfamiliar faces, as shown in individual face matching tasks across viewpoint for instance (Young et al., 1986). Here we seek to clarify whether this effect reflects a change of perceptual representation for familiar faces, and more generally when it takes place during face processing. We used a face identity adaptation paradigm in event-related potentials (ERPs) (Jacques, d'Arripe & Rossion, 2007). In each trial, two faces, either the same or different identities, were presented sequentially with a short ISI (~250 ms). The adapting face appeared for ~ 2800 ms and the test face appeared for 200 ms. The adapting face was presented in a frontal view, and the test face was presented in a three-quarter view. In half of the trials, the faces were personally familiar (same classroom as the participant). Twelve participants performed an identity matching task between the adapting and test faces, performing better for personally familiar faces (96% vs. 89%; p<0.001). The amplitude of the N170 component at occipito-temporal sites to the second face stimulus was reduced for identical as compared to different faces (p=0.035), confirming previous results of an early identity adaptation effect (Jacques et al., 2007). In addition, a triple interaction between familiarity, repetition, and hemisphere (p=0.016) revealed an adaptation effect for familiar faces in the left hemisphere and for unfamiliar faces in the right hemisphere. A stronger effect of identity adaptation for familiar faces, independent of hemisphere, emerged only after 250 ms following stimulus onset (p=0.04). Overall, these data suggest that personally familiar and unfamiliar individual faces can be distinguished as early as 170 ms in the occipito-temporal cortex, and that these two types of faces are processed differently by the two cerebral hemispheres at that latency.

33.304 **Holistic facial representation is required for some but not all face processing: Evidence from event-related potentials**

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Familiarity with a face modifies perceptual and semantic processing as revealed in event-related potential (ERP) repetition effects (i.e., modulation of amplitude due to successive repetition of the same stimulus) at putative face-related components. Changes in perceptual processing are reflected in the N170 and N250 components; familiarity eliminates N170 repetition effects and enhances N250 repetition effects. Changes in semantic processing are reflected in the N400: familiar faces produce larger repetition effects than unfamiliar faces. It is unclear whether a holistic facial representation or partial information of the face (e.g. features) is required to engage these component processes. We created 40 composite faces, aligning the top half of one famous person's face and the bottom half of a different famous person's face. This created a stimulus set in which the parts of each face were familiar but the face as a whole was novel. We recorded ERPs for both the original famous faces and the composite faces as participants performed a 1-back identity-matching task. If a holistic facial representation is necessary to engage processes reflected by each face-related component, then the composite faces should elicit responses akin to unfamiliar faces. If only partial information is sufficient then we may observe similar responses to both famous and composite faces. Famous and composite faces elicited similar responses at N170 and N400, both resembling that of familiar face processing. In contrast, famous and composite faces were differentiated at the N250, showing smaller N250 repetition effects for composite faces compared to famous faces, a response pattern typically observed for unfamiliar faces. These results suggest that perceptual processing as reflected by the N250 requires holistic facial representation, whereas processing reflected by the N170 (perceptual) and the N400 (semantic) is possible with partial face information.

URL: http://brain.mcmaster.ca

33.305 **The face-selective ERP component (N170) is correlated with the face-selective areas in the fusiform gyrus (FFA) and the superior temporal sulcus (fSTS) but not the occipital face area (OFA): a simultaneous fMRI-EEG study**

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Human neuroimaging studies of face processing reveal robust and reliable face-selective responses. Event-related potential studies report that faces elicit a negative component, which peaks 170ms after stimulus onset (N170), which is higher for faces than non-face objects. Functional MRI studies typically reveal three face-selective regions in the fusiform gyrus (FFA), superior temporal sulcus (STS) and occipital face area (OFA). Despite the extensive investigation of these face-selective neural responses in the past decade, hardly any study has examined the relationship between them and no study measured them simultaneously. Given the high-temporal resolution of ERPs and the relatively high-spatial resolution of fMRI, such an investigation may shed light on possible neural sources of the N170 on one hand, and the time when information is processed by fMRI face-selective regions, on the other hand. Here we report the first simultaneous EEG-fMRI study of face processing. Faces and non-faces (chairs) were presented in a rapid-event related design. We first demonstrate that despite the major artifacts that the MR gradients generate in the EEG signal, we are able to remove these artifacts and obtain reliable face-selective N170 during simultaneous recording. Furthermore, the laterality of the N170 (the difference between its face-selectivity over the right and left electrodes) was strongly correlated with the laterality of the volume or the face-selectivity of the FFA and the STS but not the OFA. These findings are consistent with recent TMS data, which suggests that the OFA is engaged in face processing 100ms after stimulus onset, prior to the 170ms latency and with models that suggest that the OFA sends parallel inputs to the more anterior FFA and STS. These two regions may operate on different types of face information, but at the same latency of 170ms after stimulus onset.

33.306 **The Occipital Face Area is not necessary for symmetry perception in faces**

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Symmetry pervades our visual world. Many biological organisms have acquired a particular sensitivity to subtle symmetry detection cues in their environment and conspecifics. The balanced distribution of duplicate body parts is a fundamental characteristic of living organisms, and for many biological species this structural property seems to be related to their phenotypic condition - an aspect that plays a key role in mate selection. Symmetrical human faces are perceived as sexually attractive, healthier and more intelligent - all representing crucial factors for social and biological interactions. Interestingly, symmetry detection is better for upright compared to inverted faces despite these visual stimuli are matched for their low-level properties (Rhodes, et al. 2005), suggesting that high-order mechanisms subtend to this human ability. Recently, the neural bases of facial symmetry perception have been investigated within the face-sensitive regions using functional Magnetic Resonance Imaging (fMRI). Chen et al. (2006) found sensitivity for symmetry uniquely in the right Occipital Face Area (rOFA), whereas Caldara and Seghier (2006) found such sensitivity only in the right Fusiform Face Area (rFFA). Consequently, the identification of the neural substrates involved in the processing of facial symmetry remains to be clarified.

Here we tackled this discrepancy by testing facial symmetry perception in PS, a pure case of prosopagnosia, with a lesion encompassing the rOFA and sparing the rFFA (Sorger et al., 2007). We confronted PS and an age-matched control group of participants with a normal and a perfectly symmetrical version of the same face. The face-pairs were presented for 200ms and 500ms in separate blocs. PS identified symmetrical faces as accurately as the controls, showing that prosopagnosia does not necessarily involve a deficit in symmetry perception. Crucially, these observations provide unequivocal evidence that symmetry perception for faces does not rely on neural populations within the rOFA.

33.307 **Gaze direction is in the eye of the Superior Temporal Sulcus**

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Human eyes have a unique morphology and play a crucial role in social interactions and communication. The importance of the eyes for processing facial identity and expression has been clearly established with behavioural, image classification (e.g., Bubbles) and brain imaging studies. Humans are also highly sensitive where another person is looking, and functional Magnetic Resonance Imaging (fMRI) studies have consistently reported gaze related responses in the right Superior Temporal Sulcus (rSTS). Yet, whether information processed from the eyes during perception of facial identity, expression or gaze is coded by the same neural substrates is not yet understood.

To address this question we tested PS, a pure case of acquired prosopagnosia with lesions sparing the neural substrates sensitive to eye gaze (rSTS) (Sorger et al., 2007), using a gaze adaptation paradigm and fMRI. We previously revealed with Bubbles (Gosselin & Schyns, 2001) that PS does not use the eyes but only the mouth to identify short-term familiar faces (Caldara et al., 2005) and to categorize facial expressions, even fear in which the eyes are highly diagnostic for normal observers (Caldara et al., 2006). Consequently, the PS case represents a unique opportunity to test whether the distributed neural face system relies on a unique set of substrates for coding information from the eyes.

Adaptation to averted gaze eliminates perception of gaze in the adapted direction (Jenkins et al. 2006). Strikingly, PS showed sensitivity to gaze direction, but no gaze adaptation effect. Contrary to intuition however, PS showed larger activations in the rSTS for averted gaze than for direct gaze and eyes closed conditions. These data suggest separable functional routes for gaze information, with gaze adaptation requiring the integrity of the occipito-temporal face-sensitive network. Critically, sensitivity to gaze direction is independently coded in the rSTS.

33.308 **Invariant Representation of Face Identity in the Fusiform Face Area (FFA): The Effect of External Facial Information**

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Several studies have shown that the fusiform face area (FFA) codes the identity of individual faces. The extent to which this representation is invariant to various face changes is still unclear. Here we examined the effect of external facial information such as hair or a cap on the representation of internal facial features. External information is usually excluded in most face studies, but it may have a significant influence on the representation of the internal face features. In our study we presented pairs of faces of same or different identity in three different variations: in a cap condition faces wear a cap that covers their hair, in the hair (no-cap) condition the hair is shown and in a cap-hair condition one face had a cap on and the other did not. We used fMR-adaptation to examine whether identity representation is influenced by external information. Consistent with previous studies we found a robust release from adaptation for the cap and hair conditions in the FFA. However, there was no adaptation for faces of same identity that differ in external information (cap-hair condition). Interestingly, our behavioral data show that although identity discrimination for faces that differ in external information (cap-hair condition) is somewhat lower than when external information is similar (cap & hair conditions), discrimination level is still very high. We suggest two possible interpretations to the lack of invariance to face identity in the FFA: either the FFA is sensitive to any facial information rather than just the identity of internal facial features or that inconsistent external information (hair-cap) may modify the perceived identity of the internal features (e.g. a composite effect). To decide between these two possibilities we currently conduct the same experiment with faces in which the top hair/cap part is misaligned with respect to the internal features.

33.309 **Encoding of age-invariant identity versus identity-invariant age from faces: an fMRI-adaptation study**

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Humans can both estimate the age of people from their faces and recognize the same individual at different times of life. This indicates an ability to perceive age-related characteristics that generalize across identity, and also an ability to derive age-invariant representations of facial identity. We investigated the degree to which either or both of these abilities reflected the operation of processes within the fusiform face areas (FFA), of the left and right hemispheres, through the use of an fMRI adaptation paradigm.

Our stimuli were 3D avatar faces created with FaceGen software. Ten different individual male faces were chosen with the aim of maximizing the perceived differences between faces. We created images of each face at 10 different ages ranging from 20 to 60 years. Eleven healthy subjects participated in this study. First, an FFA in both the right and left hemisphere was identified in each individual using a functional localizer that contrasted blocks of viewed objects with blocks of viewed faces. Following the localizer, subjects underwent a block-design adaptation run consisting of three experimental conditions; blocks of avatar faces which differed in both identity and age, blocks of avatar faces which differed in identity but all of the same age, and blocks of the same avatar face at different ages.

We found that adaptation for identity regardless of variations in age occurred most strongly in the left FFA ($p<0.00003$), with a trend to a similar effect in the right FFA ($p= 0.09$). Neither the left or right FFA showed adaptation effects for age.

We conclude that age-invariant representations for face identity may be encoded within the FFA, possibly predominantly within the left hemisphere, and that representations of age-related characteristics of faces may be encoded elsewhere in the face-processing network.

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33.310 **Dynamic versus static stimuli for localization of the cerebral areas involved in face perception**

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Functional Magnetic Resonance Imaging (fMRI) studies investigating human face perception use localizers to identify specific brain areas, such as the fusiform face area (FFA), occipital face area (OFA), and superior temporal sulcus (STS). These usually consist of a simple block design contrasting viewing of static pictures of faces and viewing of other objects. Functional localizers seldom identify all regions in all participants, however, reducing their utility in the study of single subjects. We asked whether the use of more ecologically valid dynamic stimuli, such as video clips of faces and objects, may result in a more reliable activation of face-processing areas in all participants. Sixteen young volunteers participated in an fMRI study that contained two functional localizers, one with static photographs and the other with dynamic video clips of faces and objects. The results showed that the use of the static localizer resulted in the identification of the FFA bilaterally in 13 participants, the left OFA in 11, the right STS and right OFA in eight, and the left STS in four. The use of the dynamic localizer allowed us to detect activity within the FFA bilaterally, the right STS and the right OFA in all 16 participants, and the left STS and left OFA in 13. Furthermore, face-selective regions identified with the dynamic localizer had peaks with 25% greater t-values and had, on average, twice many voxels than the regions identified with the static localizer. These findings suggest that the use of more realistic dynamic stimuli, rather than static photographs, results in a more reliable localization of the brain regions involved in face perception.

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33.311 **Neural correlates of categorical face perception**

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Human observers excel at categorical face perception and can accurately and consistently distinguish true faces from very face-like non-face objects. The neural correlates of such categoricity are unclear, although it has been well demonstrated that the fusiform gyrus is involved in visual face processing. Here we report neuroimaging evidence suggesting that the left and right fusiform areas behave quite differently in terms of their facial analyses. Our experimental strategy involved compiling a set of 300 images, extracted from natural scenes, ordered to gradually become increasingly face-like, and thereby span a continuum of facial similarity from non-faces to genuine faces. We then measured brain activity corresponding to each of the 300 images using fMRI. We find that the pattern of activity in the left fusiform changes in a graded fashion as the image stimuli become increasingly face-like, while the pattern of activity in the right fusiform shows a step-like response corresponding to a categorical difference between faces and non-faces. Besides improving our understanding of the organization of face processing in the adult human brain, this evidence of an anatomical dissociation between categorical face processing and image level facial similarity processing might help account for the previously unexplained lateral differences in face processing, and also provide nominal references against which to compare brain activation patterns of children and patients with face-perception deficits.

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33.312 **Ranking 96 object images by their activation of FFA**

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The fusiform face area (FFA) is a region in human inferior temporal cortex that has been shown to respond most strongly to faces. Previous imaging studies only assessed category-average activation as they grouped stimuli into predefined natural categories. Here we ask whether there are particular non-face object images that elicit a strong FFA response or particular face images that elicit a weak response. In addition, we investigate whether specific faces consistently elicit a stronger FFA response than others. To address these questions, we rank 96 particular object images by the activation they elicit in FFA.

Blood-oxygen-level-dependent fMRI measurements were performed at high resolution (voxel size 1.95x1.95x2 mm3), using a 3T scanner. First, FFA was defined conventionally at varying sizes using a separate block design experiment. Then, the activation in those voxels in response to 96 different object photos was measured in two separate sessions, as subjects performed a fixation-cross-color discrimination task. FFA responses to the 96 object images were ranked according to response amplitude.

Group results (n=4) indicated that single-image activation of both left and right FFA was stronger for face images than most other object images (average choice probability = .92). This result was clearest for maximally face-selective FFA voxels. Right FFA responses were stronger and more robust against increasing size than left FFA responses. Activation in the parahippocampal place area (PPA) and early visual cortex (EVC) did not rank faces before most other object images. These results were consistent across sessions and subjects. Preliminary further analyses failed to show evidence for consistency of within-face ranking orders either within or across subjects. This would suggest that the FFA activation profile is flat across different individual faces.

33.313 **Representation of 3D face shape and 2D surface reflectance in the Ventral Temporal Cortex**

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Recent behavioral studies have shown that in addition to three-dimensional (3D) shape, two-dimensional (2D) surface reflectance information (color and texture) is important for perception of facial identity (e.g., O'Toole et al., 1999; Lee & Perrett, 2000; Jiang et al., 2006; Russell et al., 2006, 2007). However, it is unclear how shape and surface reflectance of faces are processed in the human brain.

In the present study, we used a long-term event-related fMRI adaptation paradigm to identify brain regions that encode these two types of facial information. Following 3-second adaptation to an adapting face, participants were asked to match the identity of a briefly presented (300 ms) test face and the adapting face. Using a 3D morphable model (Blanz & Vetter, 1999), we manipulated the shape and surface reflectance properties of the test stimulus with respect to the adapting stimulus. Four test conditions were included: (1) repetition of the same adapting face; (2) variation in 3D shape only; (3) variation in 2D surface reflectance only; (4) variation in both 3D shape and 2D surface reflectance. We also implemented a 15-degree viewpoint change between the adapting and test faces to reduce the contribution from low-level features.

We found that changes in either 3D shape or 2D reflectance affected participants' matching performance. Neurally, despite the change in viewpoint, repetition of the same face identity induced significant activation suppression in the functionally localized right and less significantly in the left fusiform face areas ("FFA"). Release from adaptation occurred when changes in either 3D shape or 2D surface reflectance were introduced to the test stimulus, but changes in the two properties induced the strongest adaptation release. Combined, our results indicate that both face shape and reflectance information are coded for face identification in face-sensitive areas. Moreover, these two types of facial information may share overlapping neural representation.

33.314 **Behavioral and neural evidence for preserved holistic face detection in acquired prosopagnosia**

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Prosopagnosia is an impairment at recognizing faces following brain damage whose study offers invaluable information to understand the neural and functional aspects of normal face processing. It has been claimed that a deficit in integrating facial features, i.e. holistic/configural processing, underlies prosopagnosia (e.g. Levine & Calvanio, 1989; Sergent & Signoret, 1992; Barton et al., 2002), but the exact nature of this impairment remains unclear. To clarify this issue, we tested the patient PS, a pure case of acquired prosopagnosia following a dominant lesion in the right inferior occipital cortex sparing the right fusiform face area ('rFFA', Rossion et al., 2003). First, we show that PS can categorize a stimulus as a face even when it requires holistic processing. Specifically, her detection of faces in 2-tones Mooney figures or in Arcimboldo's paintings (faces defined only by the organization of non-face features) is accurate and fast. Second, a whole brain analysis of fMRI data during a face detection task with Mooney face stimuli indicates that holistic face detection is subtended primarily by the patient's 'rFFA', [q(false discovery Rate)<0.05; 34, -50, -14] as in normal controls, rather than by low-level visual areas. These results indicate that the prosopagnosic patient PS is able to integrate facial and non-facial features into a global/holistic generic face representation. This preserved ability contrasts with the patient's impaired ability to integrate facial features into a global individual face representation (Ramon & Rossion, 2007), suggesting a functional dissociation between two different forms of holistic face processing. The first one allows the basic-level categorization of the stimulus and is common for faces and objects, being deficient in patients suffering from both prosopagnosia and integrative visual agnosia. The second process is necessary for individual encoding of faces only and can be selectively impaired following brain damage.

33.315 **Reversed visual field advantage for face matching in developmental prosopagnosia**

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Experiments involving brief lateral presentations of faces demonstrate that right hemisphere mechanisms used for face processing tend to be superior to those in the left hemisphere, and this behavioral effect is consistent with neuroimaging, neurophysiological, neuropsychological, and developmental evidence showing right hemispheric superiority. Developmental prosopagnosia (DP) is a condition defined by severe face recognition deficits due to a failure to develop the mechanisms necessary for face recognition. To identify whether one hemisphere or both contain the defective mechanisms, we tested a group of right-handed DPs with a sequential matching task and compared their performance to right-handed controls. A frontal view was presented centrally for 2000 ms, and after a brief ISI, a 1/3 profile was presented for 180 ms. Whereas nearly every control showed left visual field superiority, the majority of the DPs showed right visual field superiority. Of the DPs with a reversed laterality bias, most scored in the normal range in the right visual field. These results indicate that DP often results from deficits to right hemisphere mechanisms and that mechanisms used for face recognition in the different hemispheres depend on different developmental processes.

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33.316 **Training of familiar face recognition and visual scan paths for faces in a child with congenital prosopagnosia**

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In the current report we describe a successful training study aimed at improving familiar face recognition in K, a four year old girl with congenital prosopagnosia (CP). A detailed assessment of K's face processing skills showed a deficit in structural encoding, most pronounced in the processing of facial features within the face. In addition, eye movement recordings revealed that K's scan paths for faces were characterized by a large percentage of fixations directed to areas outside the internal core features (i.e. eyes, nose and mouth), in particular by poor attendance to the eye region. Following multiple baseline assessments, training focussed on teaching K to reliably recognize a set of familiar face photographs by directing visual attention to specific characteristics of the internal features of each face. The training significantly improved K's ability to recognize the target faces, with her performance being flawless immediately after training as well as at a follow up assessment one month later. In addition, eye movement recordings following training showed a significant change in K's scan paths, with a significant increase in the percentage of fixations directed to the internal features, particularly the eye region. Encouragingly, the change in scan paths was not only observed for the set of familiar faces, but it generalized to a set of faces that was not presented during training. In addition to documenting significant training effects, our study raises the intriguing question whether abnormal scan paths for faces may be a common factor underlying face recognition impairments in childhood CP, an issue that has not been explored so far.

33.317 **Cross-modal identity recognition in a patient with prosopagnosia**

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We recognize individuals effortlessly and rapidly by looking at the face and also by hearing a person's voice. It has been suggested that visual and auditory identity recognition processes work in a similar manner (see Belin et al. 2004). Here we tested the interaction of face and voice information in identity recognition. Does bimodal information facilitate or inhibit identity recognition? Further, is recognition ability enhanced when both visual and auditory information are available in a patient who is unable to recognize faces (prosopaganosia)? SB, a 38 year old male with acquired prosopagnosia, and controls (n=10) learned the identities of three individuals consisting of a face image paired with a voice sample. Subsequently, participants were tested on two unimodal stimulus conditions: 1) faces alone, 2) voices alone, and the bimodal stimulus condition, within which new/learned faces and voices were paired in five different combinations. SB's poor identity recognition for the faces alone condition was contrasted by his excellent performance on the voices alone condition. SB improved in the bimodal conditions from his faces alone performance. Interestingly, he showed a reduction in performance in the bimodal conditions from that for voices alone. Controls showed the exact opposite pattern. These findings indicate that the control's dominant stimulus modality was vision while that for SB was audition. Identity recognition was facilitated with 'new' stimuli from the participant's dominant modality in the pairing but recognition was inhibited with 'new' stimuli from the non-preferred modality in the pairing. Most surprisingly, these results suggest that SB was unable to ignore visual face information even though he is prosopagnosic. These findings demonstrate perceptual interference from the non-dominant modality when vision and audition are combined for identity recognition and suggest interconnectivity of the visual and auditory identity pathways.

Perceptual Development Across the Lifespan

33.318 **Optics and Psychophysics in a Clinical Setting: Success of a Screening Battery for Assessing Visual Functioning in Human Infants**

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Purpose: The emergence of new time-efficient, portable, and user-friendly psychophysical technologies for young children now creates the possibility of mass screening programs for detecting early eye and visual dysfunction. Recent experimental work suggests that vision screening in 3-5 yr-old preschool children is feasible and that it can prevent or reduce long term visual pathology. Here, we expand on this work by attempting to extend vision screening to even younger children, namely infants who are still within the most critical phase of visual and CNS plasticity.

Methods: 6- and 12-month-old infants (n = 70) were assessed with a battery of the latest optical and psychophysical tests. Within a single session, we attempted to measure, for each eye, optical refractive error (Welch Allyn SureSight non-cycloplegic autorefractor), visual acuity (TAC), contrast sensitivity (CS sine-wave cards and PV low contrast faces test), and conducted a full ocular alignment/motility examination. For comparison, 2- and 3-year-olds (n = 120) were assessed with an equivalent battery of tests.

Results: The test battery was reasonably successful. With the exception of the CS card test, most infants and preschoolers completed all tests for each eye [83% (6 months), 70% (12 months), 62% (2 years) and 71% (3 years)], in a mean time ranging from 9.2 - 14.6 min.

Conclusions: Given the subject population, this was an ambitious test battery, especially as all infants and young children had to wear monocular occlusion for most tests. Nonetheless, most completed all tests for each eye within a single session. This speaks to the progress made by psychophysical and clinical researchers in developing effective pediatric vision tests. Moreover, in settings with continuous or repeated access to young children, (e.g., a daycare, public health or breast-feeding clinics), it should be feasible for even young infants to complete a full vision screening during this critical developmental period.

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33.319 **Cross-modal influences on low-level sensory processing early in development**

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Purpose: The integration of information across sensory modalities allows us to create a meaningful, unified percept of events in the world. Although the development of cross-modal integration has been studied previously, most studies have focused on higher-level visual and auditory stimuli, or on the spatial and/or temporal constraints on integrating lower-level sensory stimuli. Here we investigate whether auditory cues can influence the detection of a near-threshold visual stimulus.

Methods: We used a forced choice-preferential looking paradigm to obtain contrast detection thresholds for a visual stimulus (a square subtending 11x11 degrees of visual angle, centered 15 degrees to the left or right of monitor center). The luminance of the visual stimulus fluctuated at 1Hz under three auditory conditions: (1) In-Phase (IP). The visual stimulus fluctuated in-phase with an auditory stimulus (white noise, presented bilaterally) fluctuating in loudness at 1 Hz, (2) Out-of-Phase (OP). The visual stimulus fluctuated out-of-phase with the same auditory stimulus, or (3) No Sound (NS). The visual stimulus was presented with no concurrent auditory stimulus. Visual stimulus contrast (3-100%) was randomized across trials. Threshold was defined as the contrast yielding 75% correct performance (where correct indicates that infants looked to the monitor side containing the visual stimulus). For each subject, visual contrast thresholds were obtained for two of the three possible conditions (IP, OP, NS). If the presence of synchronized auditory information enhances visual detection, we expect lower contrast thresholds for the IP versus the OP or NS condition. The converse would be true if synchronized auditory information hinders visual detection.

Results: In 6-month-old infants thresholds were higher for the IP condition, suggesting that synchronized auditory information may diminish visual detectability. Furthermore, our findings suggest that for low-level sensory processing, infants may have a limited capacity for attending information in more than one modality at a given time.

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33.320 **Spatial distribution of visual attention during childhood**

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In recent years, there has been a strong body of evidence indicating that observers can split the spotlight of attention towards noncontiguous spatially separated areas (Canto-Pereira & Ranvaud, 2005). This study was aimed to investigate how children allocate their attentional resources by measuring reaction times under different experimental conditions. Participants were children aged 8, 10 and 12 years (n=12 per age) divided in different groups according to age. There were two different experimental conditions. In experiment I participants were asked to direct their attention towards a square frame subtending 4°of visual angle located in the center of the screen. In experiment II participants were instructed to attend, simultaneously, two square frames subtending 4°of visual located 10° to the right and left of the center of the screen. The task was to respond (key presses) to the onset of a target, a white dot subtending 0.2°of visual angle presented at 154 different positions, while always fixating a small cross in the center of the visual field. Stimulus duration was brief (100ms) to avoid eye movements and concomitant attentional shifts. Experiments were carried out in a counterbalanced way. Our results confirm the findings of Surnina & Lebedeva (2002), participants in the older group showed an increase in performance (faster reaction times and lower error rates). In experiment I, as expected, reaction times were faster in the attended region (central square frame). However, in experiment II (divided attention condition) participants were not able to disengage attention from fixation. These results suggest that children by 12 years of age have not reached the ability to divide attention as adults.

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33.321 **Array heterogeneity prevents catastrophic working memory failure in infants**

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Working memory is a limited capacity system in which both infants and adults show an abrupt upper limit on the number of items they can store (Luck & Vogel 1997, Feigenson & Carey 2003, 2005). However, infants, unlike adults, show a catastrophic memory failure when capacity is exceeded. For example, when infants see 4 identical objects hidden and are allowed to retrieve 1 or 2 of them, they stop searching for the remaining objects (but search appropriately when only 1, 2, or 3 objects are hidden; Feigenson & Carey 2003, 2005). This suggests that infants try, but fail, to remember the entire array rather than storing just a manageable subset of these items.

Here we tested the effect of array heterogeneity on infants' memory capacity. In contrast to infants' previous failures to remember 4 identical objects, we find that 12-month-olds succeed with 4-object arrays that contain perceptually unique objects. Thus, array heterogeneity appears to improve infants' working memory. Two possibilities could account for this effect. First, heterogeneous arrays might allow infants to increase their working memory capacity to 4 items. Alternatively, infants might be able to store up to 3 heterogeneous items, without actually exceeding the 3-item limit of working memory (thus remembering "4" as "3"). In other words, heterogeneity might prevent the "catastrophic forgetting" typically observed when infants' working memory limit is exceeded. To decide between these possibilities, we presented infants with arrays of 4 heterogeneous objects and either allowed them to retrieve 2 or 3 of them before measuring any subsequent searching for the "missing" objects. Infants searched after retrieving 2 of 4, but not 3 of 4, unique objects, suggesting that heterogeneity allows infants to successfully remember a subset of items when presented with arrays exceeding their memory limits. Thus, heterogeneity appears to increase memory efficiency without actually expanding capacity.

33.322 **High-contrast contour integration and aging**

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Contours comprising elements aligned parallel to the contour are detected more easily than those comprising elements orthogonal to the contour (e.g., Saarinen and Levi. VisRes, 2001). Recently, we found that element orientation had no effect on the ability of older observers to detect C-shaped contours against a blank background (Roudaia et al, VSS 2006), indicating that aging impairs contour integration processes, at least in near-threshold conditions. Recently, using closed contours, Del Viva and Agostini (IOVS, 2007) suggested that aging also may affect contour integration in high-contrast patterns. Here we examine the effect of local orientation on contour integration in younger and older observers at suprathreshold contrast levels with clutter.

We compared performance of older and younger adults in discriminating a high-contrast, C-shaped contour comprising 16 Gabor patches embedded in a field of identical, randomly-oriented distractor Gabors. The C shape appeared centrally with the gap facing one of four different directions. In two conditions, Gabors were presented in positive cosine phase and were all aligned along the contour or were all orthogonal to it. In the third condition, Gabors were aligned along the contour but alternated positive and negative cosine phase. Two interleaved staircases manipulated stimulus duration to estimate the minimum time required for correct gap localization.

Both groups exhibited lower thresholds in the aligned conditions than in the orthogonal condition. Older observers had higher thresholds than younger observers in all conditions, but were most severely impaired in the orthogonal condition, where thresholds were four times higher for older observers than for younger observers. Thus, although younger and older observers show facilitation with collinear contour elements, aging appears to disproportionately impair the integration of orthogonal contours. We are presently investigating whether these results can be explained by reduced levels of retinal illumination in older adults.

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33.323 **Vision and Language: Recoding of visual representations**

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Although most researchers agree that language and vision are domain specific each with different representational primitives, it is also true that these systems interact allowing us, e.g., to talk about what we see. What is the mechanism, development and consequence of an interaction between language and vision? We describe one language-vision interaction and lay out a hypothesis and some evidence to explain the underlying mechanism.

The visual system sometime fails to encode or bind relevant features of an object. In several experiments we asked whether language could help children and adults bind and maintain visual properties that are difficult to retain in visual memory. In a delayed-matching task, participants were shown squares that were split in half by color (e.g., a square with red-left, green-right) and after a delay, they were shown the target replica, the target reflection (e.g., red-right, green-left), and another distracter.

We found that providing specific directional terms to children accompanying the target enhanced their ability to find target matches, avoiding foils. Non-linguistic attentional manipulations did not show these effects, nor did linguistic instructions that did not include the directional terms. Finally, when adults are given the same task as the children in one of three conditions (No-Shadow, Verbal-Shadow, and Rhythm-Shadow), they performed significantly worse in the Verbal-Shadow condition compared to the other shadow conditions.

Language appears to play a crucial role in maintaining feature conjunction in memory for both adults and children. We propose the Asymmetric Recoding Hypothesis which states that given an object without an inherent figure and ground, language forces the creation of an asymmetry between the parts, and forces the encoding of a directional relationship between the parts. We argue that given visual and linguistic information, a hybrid representation is formed that combines crucial details from each source.

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33.324 **The representation of the orientation of objects in children**

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Representing the orientation of objects in the visual field is essential for interacting with the world. For example, representing orientation allows us to interpret visual scenes, comprehend symbols and pick up objects. The present study explores the representation of object orientation in young children. Many studies have investigated the ability of children to perceive and remember the orientations of lines and other simple stimuli. These studies have documented, for example, children's difficulty in distinguishing left-right mirror images, at least in tasks requiring memory for orientations. However, stimuli used in these studies are inadequate for identifying specific form(s) of error in representing orientation. In the present study we apply a theoretical framework proposed by McCloskey and colleagues. This framework conceives of orientation as a relationship among reference frames and assumes orientation representations have a compositional structure. The framework also defines possible forms of orientation error and relates these errors to failures in specific components of orientation representation. Finally, the framework specifies types of stimuli appropriate for probing orientation representations. In previous work we applied this framework to orientation representation in the adult visual system (Gregory & McCloskey, VSS, 2007). Here we use the framework to explore development of orientation representation. Pictures of objects were presented and children reported the orientation of the stimuli. The results indicate that the error pattern of young children has both similarities to and differences from the pattern exhibited by adults. As in the case of adults, children's errors support the assumption that orientation representations have a componential structure and argue for a key role of object-centered reference frames in orientation representations. Differences between children's and adults' error patterns suggest further that certain specific elements of orientation representations may develop later than others. Finally, the results contribute to our understanding of children's difficulties with mirror image orientations.

33.325 **Form and motion processing in preterm children**

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Distinct neural areas are involved in the global processing of form and motion cues. These two types of visual processing also develop at different rates, and may be differentially vulnerable to early brain injury or atypical neurodevelopment (Braddick et al., 2003, 2007). Children born extremely prematurely show elevated global motion coherence thresholds relative to full-term peers (Downie et al., 2003; Jakobson et al., 2006), and those with white matter pathology do not show normal sensitivity to biological motion (Pavolva et al., 2003, 2004). Here, we measured sensitivity to global form, global motion, and biological motion in a sample of 23 5- to 9-year-old children born at <32 weeks gestation, and in 20 full-term controls matched to the clinical sample in age and estimated Verbal IQ. As a group, premature children performed worse than controls on each of the 3 tasks ($Fs > 4.1$, $ps <0.05$), with performance being correlated with birthweight and gestational age for global form sensitivity only. For each premature child, we calculated a deficit score for each task (ratio of threshold for premature child vs mean threshold for 3 age-matched controls). A deficit score of 1 indicates performance comparable to controls', while a score greater than 1 indicates some level of impairment. A series of one-sample t-tests revealed that mean deficit scores were significantly greater than 1 for biological motion and global motion ($ps <.03$). In contrast, the mean deficit score for global form was not significantly different from 1. Rates of clinically significant impairment (deficit score ≥ 2) were 4 times more common for global motion than for global form ($p <.04$). Our findings of greater deficits in biological motion and global motion than in global form in preterm children compliment previous studies demonstrating dorsal stream vulnerability (e.g., Braddick et al., 2003, 2007).

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33.326 **High-density VEP measures of global form and motion processing in infants born very preterm**

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Infants born preterm show a delay in the onset of visual evoked potentials (VEP) for direction reversal, even when their responses to orientation reversal are comparable to term-born infants (Birtles et al, 2007, NeuroReport 18:1975). Does this developmental difference between form and motion processing extend to the later development of systems responding to global organization in these domains?

We tested a group of infants born ≤32 weeks gestation with term born controls, between 4.5-7 months post-term age. Using a 128-channel geodesic sensor net, we recorded high-density steady-state VEPs to (a) motion coherence transitions of a pattern of concentric dot trajectories alternating with randomly directed trajectories; (b) form coherence transitions of a similar pattern in which the dots of each trajectory were plotted simultaneously to form short concentric arcs. As in our earlier work (Braddick et al VSS 2006, 2007) a statistically significant first-harmonic signal was taken as evidence of a neural response to global structure.

The control group confirmed our previous findings in showing a substantially lower incidence of global form responses (31% of infants significant) than global motion responses (100%). The preterm group showed a similar proportion with global form responses (42%) but a substantially lower proportion with global motion responses (67%).

We conclude that, compared to the global form processing mechanisms of the ventral stream, the global motion mechanisms in extrastriate dorsal-stream areas are differentially vulnerable to neurological insults, likely to involve cerebral white matter, associated with preterm birth. Further analysis will relate these global processing measures to indicators from brain MRI in the neonatal period. We will also discuss the relation of these results to 'dorsal stream vulnerability' found in preterms and other neurologically compromised children in later childhood. (e.g. Williams syndrome, autism, fragile-X, hemiplegia; Braddick et al, Neuropsychologia, 2003)

33.327 **Orientation tuning in the visual cortex of human infants**

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Purpose:Behavioral studies have determined that infants are sensitive to Gabor-patch contour configurations by 3 months of age (Baker, Tse, Gerhardstein, & Adler, in press; Gerhardstein, Kovács, Ditre, Feher, 2004). Completion of this task depends on the orientation tuning of cortical neurons and their interactions across space. The present study sought to determine the orientation tuning of neurons in primary visual cortex in human infants, using a nonlinear steady-state VEP paradigm.

Methods:Three month-old infants and adults were presented with two overlapping 1cpd, 40% contrast spatial sinusoids, subtending 12 degs (Regan & Regan, 1987; Candy, Skoczenski & Norcia, 2001). One, the reference, counterphase reversed at 3.27 Hz, while the other was presented at 5.14 Hz at orientation offsets of 0, 3, 7, 10, 15 & 30 deg to the reference across conditions. A steady-state VEP was recorded from O1, Oz & O2 for 6, 21 sec trials in each condition.

Results:The response amplitudes at the second harmonics of the stimulus frequencies and their intermodulation frequencies were derived, and normalized to the aligned, 0 deg offset, value. The amplitude of the reference second harmonic (6.54 Hz) remained above 80% of the aligned value at all orientation offsets in adults and infants, while the amplitude at the sum frequency (8.24 Hz) fell to less than 50% of the aligned value by 7 deg in adults and 15 deg in infants.

Conclusions:The presence of an intermodulation response indicates processing of the two stimuli by a common nonlinear process. The decrease in intermodulation as a function of relative orientation suggests that the orientation tuning of neurons contributing to this population response is within a factor of two of the adult value by three months of age.

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33.328 **Assessing the effect of aging on orientation selectivity of visual mechanisms with the steady state visually evoked potential**

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Orientation selectivity in V1 macaque neurons decreases with aging (Leventhal et al., 2003). However, using psychophysical masking techniques, we found no effect of aging on human orientation selectivity (Govenlock et al., Vision Res, submitted). One explanation for these discrepant results is that psychophysical thresholds may be mediated by a few highly-selective neurons whose tuning properties do not vary significantly with age. To test this idea, we measured the bandwidth of orientation-selective mechanisms using the steady-state visual evoked potential (ssVEP), which is an index of the activity of large populations of visual neurons. The ssVEP has been used previously to measure orientation tuning in younger adults (Regan & Regan, 1987) and infants (Candy et al., 2001), but not elderly adults. We recorded EEG while subjects viewed 2 superimposed Gabor patterns (contrast = 40%; SF = 1cpd). One Gabor was horizontal and the orientation of the other Gabor varied in different experimental conditions. The Gabors were counterphase-flickered at F1 (6.67 Hz) and F2 (8.57 Hz). Preliminary results from 5 young (mean age = 22) and 6 elderly (mean age = 69) subjects show that F1+F2 amplitude is tuned to the orientation offset of the two Gabors, just as Candy et al. found. The slope of the function relating F1+F2 amplitude to orientation offset does not differ with age [F(1,9) = 1.71; p = 0.22], which is inconsistent with the hypothesis that orientation selectivity broadens with age. However, the results were influenced significantly by one unusual younger subject whose ssVEP showed virtually no orientation tuning. With that subject removed, the amplitude vs. orientation offset function is significantly shallower in older subjects [F(1,8) = 5.37; p <0.05], suggesting that orientation-selective mechanisms are more broadly tuned in older subjects.

33.329 **Impact of luminance and blur combinations on older drivers' acuity and preferred speed**

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Previous literature has shown that steering performance is robust to both reduced luminance and increased blur unlike visual acuity. While previous studies held driver speed constant focusing on steering performance to observe effects from the challenging visual conditions, the study reported here used ten older licensed adults, who drove a simulator on curvy rural roads with a 55 mph speed limit under nine conditions (luminance: 1, 0, and -1 log cd/m2; blur: 0, +2, and +5 D). These conditions were selected to represent ranges in luminance to correspond with civil twilight and common levels of refractive error, those that typically go unnoticed or untreated (excluding +5 D). After training, the vehicle speedometer was no longer available, and participants were instructed to drive at a speed where they could comfortably stay within the lane. Visual acuity significantly declined with each decrease in luminance and increase in blur. Steering performance was robust; drivers were within the lane a minimum of 90% of each trial. An investigation of driving speed failed to reveal a significant interaction or main effect of luminance. While a main effect of blur was identified, follow-up tests indicated that drivers slowed down only under the extreme blur condition (+5 D; M=38 mph). On average the speed for the +5 D blur condition was 5 mph slower than the more commonly occurring blur conditions (0 & +2 D). One unexpected finding was that drivers reduced their speeds when given a choice. Drivers slowed down from 53 mph when instructed to drive the speed limit using the speedometer to 47 mph when instructed to drive a comfortable speed without the speedometer. Future studies should examine how different instructions and speedometer use influence driver speed. More importantly, other age groups should be investigated for comparison with this sample of the older population.

33.330 **Life-Span study of visually driven postural reactivity: A fully immersive virtual reality approach**

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The objective of this study was to assess the development of visuo-motor integration across life-span by measuring the postural reactivity in response to an immersive moving virtual tunnel. Seventy participants whose ages ranged from 5 to 75 years old were tested. They had a normal or corrected to normal visual acuity and a normal stereoscopic vision. Each participant was placed in a virtual tunnel that oscillated in an anterior-posterior fashion at 0.125 Hz, 0.25 Hz and 0.5 Hz. Participants' Body Sway (BS) and Instability Index (II) were measured with a magnetic motion sensor located at the head level. The same two measures were also taken during the fixation of the static tunnel condition and during the eyes closed condition (no visual cues available). A significant main effect of age was found for both BS and II, where children (5 to 16 year-old) and the elderly (65 year-old onward) were more reactive to the stimulation than were the adults (17 to 60 year-old) for all dynamic conditions. Our results suggest that visuo-motor integration, as defined by postural reactivity is not fully developed until 16 to 19 years old as indicated by younger than 16 year-old children's over-reliance on vision to control their posture. This over-reliance on vision disappears during adulthood but seems to come back at an advanced age (65 years onward). Possible explanations are that children over-rely on vision because the primary elements for postural control are not fully developed; whereas in aging it might be explained by a degradation of these systems forcing observers to "spread the load" across alternate sensory systems.

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33.331 **Age-related changes in the representational momentum effect**

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Humans have a tendency to perceive motion even in static images that simply "imply" movement. This tendency is so strong that our memory for actions depicted in static images is distorted in the direction of implied motion. Freyd (1983) referred to this phenomenon as representational momentum (RM). The current study extends the work of Freyd and Finke

(1984) to a healthy elderly population. In their study, three rectangles (differing in orientation) were presented sequentially in a pattern that implied clockwise rotation. Participants judged whether or not a fourth rectangle (the target) was shown in the same orientation as the third rectangle in the inducing display. The fourth rectangle was presented either in the same orientation as the third or displaced forward or backward along the path of implied rotation. Young adults showed a RM effect, responding that the target's position was further along the path of implied motion than it really was. In the present study, we replicated this effect in young adults, and went on to show that healthy elderly do not show a RM effect ($p < .05$). We also computed weighted means to quantify the memory bias. Here, positive scores signify that responses are biased in the direction of continuing motion, while negative scores signify that responses were biased in the opposite direction. These scores correlated negatively with age, $r(28) = -.393$, $p = .039$. One-sample t-tests showed that means of young adults ($M = 2.06$, $SD = 1.35$) were significantly greater than zero, while those of young-old (ages 66-72; $M = 1.36$, $SD = 2.31$) and old-old (ages 75-86; $M = -0.25$, $SD = 2.44$) participants were not. We speculate that the reduced RM effect seen in healthy aging reflects age-related changes in areas of the brain that are involved in processing real and implied motion.

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Spatial Vision: Crowding and Eccentricity 1

33.332 A crowded face influences the ensemble representation of a set of faces

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Parkes et al. (2001) showed that when an object is crowded, although specific features of the object do not reach awareness, this information is not completely lost; rather, it is incorporated into precise ensemble statistics about the entire set. Thus it appears that a detailed representation of a crowded object survives at least until an averaging stage in the processing stream. Recently, it was established that higher-level objects such as faces and houses can be readily crowded using appropriate distractors. It has also been shown that observers can accurately report ensemble statistics, such as mean emotion, from a set of faces. Here, we tested whether a face that is crowded from perception can nonetheless influence observers' judgments about the ensemble statistics of the set in which it falls.

Subjects simultaneously viewed two sets of faces in which a central face was crowded by six flanking faces. Individual faces varied on an emotional range from neutral to disgusted, and the mean emotion of each set was manipulated independently of the emotion of the central, crowded face. In separate runs, subjects were asked to make two judgments: 1) Which central face was more disgusted? 2) Which set of faces was more disgusted, on average? Despite observers' inability to determine which crowded face was more disgusted (performance was near chance on the individual face judgment), the emotions of the central faces substantially influenced judgments about the relative mean emotions of the two sets. The results demonstrate that despite observers' inability to access specific information about a crowded face, such information remains intact at least until the stage at which an ensemble representation is generated. Thus, averaging occurs subsequent to holistic face processing, or at multiple levels in the processing stream.

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33.333 Visual Boundaries and Perceived Eccentricity: Evidence that Boundary Reduction Changes the Scale of Space

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The ability to locate objects in space not only depends on accurate depth perception but also the ability to localize objects across the visual field. The present study investigated the accuracy of perceived eccentricity for target dots briefly flashed on a computer screen. Thirty-six normal-vision participants completed one of three conditions. The first two groups completed the experiment with a visible boundary created by a circular aperture, 30deg in radius, over the computer screen. Participants in one group made magnitude estimates of the targets' distances from fixation to the edge of the aperture while participants in another group made magnitude estimates relative to the edge of their visual fields. A third group of participants wore welder's goggles, eliminating the visibility of the aperture's edge, and made magnitude estimates of the targets' distances relative to the edge of their visual fields. In all conditions, seven equally spaced eccentricities were randomly tested along each of the four radii from fixation. For each participant, power functions, $J = \lambda(S\gamma)$, were then fit to the estimated magnitudes as a function of eccentricity for the horizontal and vertical meridians. 3(Experimental Group) x 2(Meridian) ANOVA's were calculated on the constants and exponents. For the constants (λ), no main effects or interaction were found. However for the exponents (γ), a main effect of Group was found with exponents increasing when participants judged eccentricities relative to the edge of their visual fields and no visual boundary was available (1.2 vs. 0.98 and 1.0). No effect of Meridian or Meridian x Group interaction was observed. This suggests an expansion of the estimated locations with increasing eccentricity when no visual boundary was available that is independent of the instructions given. The results also contrast with findings of expansion in perceived eccentricity by individuals with actual peripheral field loss.

33.334 The opposite of crowding revealed using classification images

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Observers' acuity for discriminating the tilt of a parafoveal target is hampered by similar stimuli nearby, this is known as crowding. In an attempt to better understand this phenomenon, we obtained classification images for discriminating between ±8° tilted Gabor patterns at 5° eccentricity in two conditions: when presented alone and when appearing in the center of an annularly windowed, vertical grating of similar spatial frequency. To our surprise, performance was better with the annulus. To verify that we could produce crowding in observers, we removed part of the annulus, leaving a ring of eight vertical Gabors, each of which was the same size as the target. Consistent with previous research, acuity was severely hampered by this geometry. Compared with those obtained without an annulus or flanks, the classification images obtained in the presence of the annulus indicate the use of a more oblique and narrower band of orientations. We propose that the strong perceptual border between target and annulus benefits performance by allowing observers to ignore the output of less-informative channels. Given that observers' performance is limited by external noise, our data do not support the theory of improved acuity through disinhibition.

33.335 Amblyopic eyes are particularly susceptible to motion-induced distortions of space

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When the internal structure of a stationary visual object moves, the object as a whole appears perceptually displaced in the direction of motion. In normal observers, the magnitude of this illusory offset can be dependably manipulated by systematically varying stimulus uncertainty. In this study, we investigate the role of neural uncertainty in the generation of motion-induced distortions of visual space. Nine subjects performed a 3-patch vertical alignment task using their amblyopic and non-amblyopic eyes. The central element consisted of a luminance grating (carrier frequency 4 cyc/deg) drifting either rightwards or leftwards (temporal frequency 6.3Hz) within a static contrast-defined envelope. The reference elements were luminance-defined patches, of the same size, located 2 degrees above and below the central element. In a separate control condition, subjects also performed an identical alignment task with the exception that the central carrier grating was stationary. For both stationary and moving carrier conditions the magnitude of the motion-induced positional offset was linearly related to the precision with which the central element could be localised. In subjects with amblyopia, where judgments of spatial position are less reliable, they become increasingly susceptible to an illusory shift in position. More importantly, when these motion-induced shifts are expressed in units of sensitivity, virtually all subjects show greater illusory offsets in their amblyopic eye relative to their non-non amblyopic eye. This result suggests there exists an additional deficit in position coding, over and above the well-documented sensitivity deficit. Due to the existence of positional deficits in amblyopia, location cues derived from the static contrast envelope may be down-weighted relative to motion cues arising from the carrier.

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33.336 Perceived spatial frequency varies as a function of location in the visual field

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Goal: Performance in a visual acuity task (Landolt-square) is better on the horizontal than on the vertical meridian and for the isoeccentric locations, it is better at the South than the North (Carrasco et al., 2002). In addition, performance in a visual short memory spatial frequency judgment task is better on the horizontal than on the vertical meridian (Montaser-Kouhsari & Carrasco, VSS 2007). Given that performance in these two tasks is related to spatial frequency, here we investigated whether perceived spatial frequency varies as a function of the stimulus location.

Method: Observers performed a spatial frequency judgment task at 4 different isoeccentric locations of the visual field (North, South, East and West). Each block started with the presentation of a 7-cpd Gabor patch (standard) at the center of the display for 30 s. In each trial, a Gabor patch (test) was presented for 100 ms at 6 deg of eccentricity. The spatial frequency of the test stimulus ranged from 6.6 to 7.4 cpd. Observers were asked to report which of the two Gabors, the standard or the test, had a higher spatial frequency. We obtained psychometric functions for perceived spatial frequency for each location.

Results: Perceived spatial frequency varied as a function of location. The point of subjective equality (PSE) was lower than the standard in the East and West locations but higher than the standard in the North and South locations. These results suggest that differences in perceived spatial frequency at different locations may be related to performance differences across the visual field in spatial resolution tasks (Carrasco et al., 2002). Moreover, perceived spatial frequency may mediate performance differences in visual short term memory tasks across the visual field (Montaser-Kouhsari & Carrasco, VSS 2007).

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33.337 A Texture-Perception Model of Crowding for General Stimuli, Version 10

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Crowding refers to phenomena in which a task such as object recognition becomes difficult in the periphery due to the presence of flanking stimuli. We may be unable to identify a letter when it is flanked by other letters, or unable to identify a face seen peripherally. Subjectively, we perceive "jumble" of features. Researchers suggest that crowding is due to feature integration over an inappropriately large region (Pelli et al, 2004), or to "compulsory texture perception" (Parkes et al, 2001). For displays consisting of simple stimuli such as oriented Gabors, such texture perception may amount to perception of orientation statistics such as mean orientation (Parkes et al, 2001). But what does compulsory texture perception mean for arrays of letters, for faces, or for natural scenes viewed peripherally?

Many texture synthesis algorithms generate new samples of a texture from a set of image statistics taken from a sample texture patch. Texture synthesis makes an explicit statement about what "texture processing" means for the visual system: If texture synthesis adequately generates new sample textures, the statistical properties it employs are sufficient to describe the texture percept. Recent work, particularly (Portilla & Simoncelli, 2000, inspired in part by Heeger & Bergen, 1995) constrains synthesized textures by statistics of biologically plausible features. The generated texture is often difficult to distinguish from the original texture, particularly when viewed briefly or somewhat peripherally (Balas, 2006).

Synthesized textures may be generated from arbitrary stimuli, to visualize what "compulsory texture perception" of these stimuli might mean. These "texturized" images subjectively capture some of the percept of the original stimuli viewed under crowded conditions. Furthermore, we demonstrate that difficulty performing a task, such as letter recognition, in foveated texturized displays is correlated with difficulty in performing that task with the original displays under crowding conditions.

33.338 Crowding and Feature Conjunction in Human Amblyopia

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Crowding is a phenomenon generally characterized by decreased ability to identify a target among non-overlapping distractors in the normal periphery and central visual field of observers with amblyopia (a condition of degraded spatial vision generally caused by early monocular form deprivation). Several recent studies have related crowding to the feature integration stage of visual processing. Additionally, it has been reported that spatial extent and boundaries of an "attentional spotlight" may have a profound effect on the way in which features are integrated. In order to study feature conjunction in crowding, we chose stimuli that had at least two easily identifiable features (orientation and color). We tested normal and amblyopic observers using a paradigm in which observers were asked to identify the central stimulus among an array of distractors under one of three conditions: (1) no cue, (2) the target was cued with a spatial cue and (3) either the target or one of the distractors was cued using a spatial cue in the same manner as in condition (2). Our stimuli consisted of vertically and horizontally oriented black and white bars as well as possible conjunctions of two bars (one horizontal and one vertical) presented on an otherwise homogeneous gray field. We found that for an observer with a history of abnormal visual experience, cuing the target location (but not distractor locations) improved performance in her affected eye but not her fellow eye. Random location cuing reduced performance in both eyes relative to cuing the target location only. Analysis of incorrect responses revealed that observers are most likely to confuse targets that are combinations of one black bar and one white bar.

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33.339 Configural modulation of crowding

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The ability to make judgments about a peripheral target stimulus can be impaired when the target is surrounded by flanking stimuli. This effect is called crowding. Crowding is often related to relatively simple low-level mechanisms that pool visual information over spatial location. We tested this hypothesis by determining the effect of stimulus configuration on crowding. We manipulated only the `global' configuration, keeping constant the orientation, spatial frequency, and spatial phase of the elements making up the stimuli.

We measured thresholds for contrast and orientation discrimination using a vertical Gabor patch as a target. The target was presented at an eccentricity of 5.7 degrees and was flanked on both sides by seven vertical Gabor patches. The spatial frequency of all stimuli was 3.3 cycles per degree.

Contrast and orientation discrimination were both strongly impaired when the target was flanked on both sides by Gabors of equal length. However, when the flanks were either shorter or longer than the target, the impairment was largely reduced or even abolished, indicating that crowding was strongly modulated by stimulus configuration. Control experiments confirmed that this modulation was not due to a change in contrast energy with changing flank size or to reduced uncertainty about the target location. Further, crowding was reduced when the flanks were composed of small collinear Gabors that had the same orientation, spatial frequency, and spatial phase as the target.

These results are not readily explained by a simple pooling account of crowding. Crowding seems to be weak whenever the target does not make up a coherent texture with the flanks, even when the `low-level' properties of the stimuli are kept constant.

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33.340 Figural grouping affects contextual modulation in low level vision

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Embedding a target within contextual elements can influence performance in visual tasks. For example, when a vernier is flanked by two lines, discrimination performance deteriorates strongly compared to unflanked presentation. This contextual modulation is usually explained by local spatial interactions. In a number of experiments, we have shown that this explanation is inadequate. We propose instead that flanks interfere most strongly with the vernier when they are grouped with the vernier i.e., when they share attributes such as size or color. This interference is lessened when the flanks form their own group and thus allow the vernier target to stand out. Here, we extend these results to flank grouping by geometrical properties. For example, vernier discrimination thresholds are significantly lower when the vernier is flanked by two cuboids compared to being flanked by two lines even though these lines are contained in the cuboids. Our results show that global figural aspects are crucial in contextual modulation and may even point to an anticipatory re-wiring of early visual cortex.

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33.341 **Spatio-Temporal Map of Crowding in Normal and Amblyopic Vision**

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Purpose: Crowding is known to be a limiting factor for spatial vision both in normal periphery, and in the central visual field of amblyopes. However, the spatio-temporal dynamics of crowding have received little attention. The current study investigates the spatio-temporal perceptive field for crowding for both normal and amblyopic observers.

Method: We measured orientation discrimination of the target (Gabor patch) embedded in similar flankers randomly presented at a combination of positions (five possible separations) and times (nine frames with 30ms for each frame), at the fovea and 5 degrees in the lower visual field of two normal and three amblyopic observers. Correlations between the flanker spatio-temporal positions and the observers' performance were calculated to obtain spatio-temporal classification images for crowding.

Results: For normal central vision, the spatio-temporal map of crowding is almost flat with a small elevation only at time zero and the smallest separation. In normal periphery, the space-time inseparable crowding map shows a much higher peak. Along the time axis, at the smallest separation, the curve is fit by a Gaussian with mean 0ms and a width (two standard deviations) of 60ms; along the space axis, at time zero, the curve is fit by a half Gaussian with mean 0ms and a width of 1.5 deg in the periphery. For amblyopic observers, the crowding map obtained from the central visual field has a shape similar to that of normal periphery, the width of which along space axis depends upon the amblyopic observer's crowded acuity but the width along the time axis may be broader in general.

Conclusion: Our study provides new results revealing the dynamics of crowding in space and time. Crowding in amblyopic central vision has various spatial extents but a broader time course than normal peripheral vision.

33.342 **Mechanisms of Crowding and Learning to "Uncrowd"**

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Nearby patterns adversely affect identification of an eccentrically presented target in a phenomenon known as crowding. In peripheral vision, perceptual learning improves single-target identification (Gold, Bennett, Sekular, 1999; Chung, Levi, Tjan, 2005) and reduces the extent of crowding (Chung, 2007). However, the mechanisms of crowding and of the "uncrowding" effect following learning remain unknown. We used a noise-masking paradigm, combined with perceptual learning, to uncover these mechanisms. Pre- and post-tests measured threshold contrast energy (at 50% correct identification) versus noise energy (EvN function) for identifying isolated and flanked letters at 10° in the lower visual field; letter size was 2.5x a subject's acuity. Flanking letters, when present, were at 33% Weber contrast and placed on both sides of the target letter at a center-to-center distance of 1 x-height. Four levels of static white luminance noise (rms contrast = 0, 7.9%, 12.6%, 20%) were added within the largest bounding box of the target letter. Six days of training immediately followed the pre-test at the same letter size and eccentricity, but with a target-flanker separation of 0.8 x-height. Training was effective (+10% correct, N=3). Pre-test EvN functions indicated that crowding both reduced sampling efficiency to 25% of the value of the isolated-letter condition and increased an observer's intrinsic noise by the equivalent of adding a white noise of 19% rms contrast to the target. Following training, the ratio of post- to pre-test efficiency was practically unchanged (1.1), but the flanker-induced intrinsic noise was reduced to 30% of its pre-training value. Our findings indicate that (1) both the precision and computational strategies of the visual system are severely affected by crowding, and (2) perceptual learning reduces intrinsic noise without affecting sampling efficiency. Thus, perceptual learning moderates crowding by partially restoring some of the lost precision but makes no improvement on computational strategies.

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33.343 **Crowding in the amblyopic fovea can be unlike crowding in the normal periphery**

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Form vision is impaired in the fovea of an amblyopic eye. One hypothesis for the neural mechanism underlying amblyopia is that it results from a cessation of the development of the visual system, thus explaining why the amblyopic fovea shares many characteristics of the normal periphery. Consistent with this view, it is believed that crowding in the amblyopic fovea is qualitatively identical to that in the normal periphery. Here we reexamined this hypothesis using the first- and second-order classification image techniques described in Nandy & Tjan (2007, Journal of Vision). Two strabismic amblyopes with comparable visual acuities, GK & RH, participated in the study; both had extensive experience in psychophysical experiments. They were tested at their "fovea" for the non-amblyopic and amblyopic eye separately, with the target letters ("o", "x") presented with or without flankers. For both subjects, contrast thresholds were significantly higher for the flanked than the unflanked conditions, indicative of crowding. As is the case for peripheral crowding, the first order classification images at the target location showed no distortions except for a reduction in image contrast. The similarity with peripheral crowding broke down for RH but not for GK when we obtained the classification images at the flanker locations and in the second-order analysis. Specifically, RH did not show any systematic link between flanker features and response errors, which is prominent in peripheral crowding. RH also showed fewer changes in feature utilization compared to GK and normal periphery, even though the effect of crowding in terms of threshold elevation was comparable between the two subjects. For RH, unlike crowding in normal periphery, the flankers behaved as if they induced a strong stochastic internal noise that masked the target.

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33.344 **Retinal mapping can distort to avoid the "impossible space" outside the visual field**

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We recently found that direct stimulation of visual cortex using TMS could result in phosphenes that extended outside the visual field (Wu et al, VSS 2006). Brightness was perceived to emanate from positions inside the mouth, beneath the head, or even behind the ear. Though previous studies using retinal stimulation had failed to produce similar results (Hayhoe & Williams 1984, Cavanagh & Barton VSS 2001), we decided to revisit the use of retinal afterimages with a larger number of subjects and stronger stimuli.

Vivid rod-based afterimages were induced in dark-adapted subjects using four 2400W flash tubes to illuminate a grid-shaped stimulus. Shortly after the flash, subjects made a large eye movement (e.g. downwards), causing parts of the stimulated retinal area to point in directions beyond the visual field (straight down, etc.).

As in the TMS study, some (4/8) of the subjects reported that the afterimages extended well outside the natural field of view (below or behind the head). Only one subject reported a simple truncation of the afterimage at the edge of the visual field. The other (3/8) subjects reported that the afterimage was constrained within the natural visual field via compression along an anisotropic gradient. The compression was strongest near the impinged edge of the visual field, where the afterimage of the grid appeared as thin rectangles. Meanwhile, other regions of the grid remained veridically square. Two subjects also reported compensatory translation of the afterimage—the afterimage did not follow their eye movement completely, and they felt they were looking directly at a lower portion of the afterimage.

This study confirms and elaborates on earlier findings that visual representations of light outside the visual field are possible, and that distortions and shifts in retinal mapping can occur when an image might otherwise extend beyond the natural visual field.

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33.345 **Evidence for misplaced target information with letter crowding**

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Purpose: Recent debates on mechanisms of visual crowding are focused on whether crowding results from lower-level target-flanker feature binding, or higher-level insufficient resolution of attention. We took a novel route to understand crowding by investigating whether and where the correct target information could be traced when wrong responses are made. Methods: A letter target with flankers was presented in the right visual hemi-field (10° eccentricity). Subjects reported either the central target letter (partial report) or all three letters from left to right (full report). Results: 1) With the target size set substantially sub-threshold, full-report data suggest: a. The correct report rate of the target at the center location was comparable to that with partial report; b. Report of the center target at the right flanker location was substantial; c. So was the left flanker being reported at the center location. 2) Halving the left flanker contrast increased the center report rate of the left flanker, which, however, unchanged the center report rate of the center target. 3) Restricting stimulus misplacement by assigning half letters as target and half letters as flankers, which the subjects knew, reduced crowding by 30-40% in partial report. 4) Under the same conditions of 3), crowding became much weaker when flankers were pixel-scrambled (no more features), but was stronger when flankers were stroke-scrambled (intact features but broken Gestalt). Conclusions: 1) A significant portion of target information is not lost during crowding, but is positionally confused with flankers, presumably in the visual memory. 2) Flanker misplacement (Strasburger, 2002) had little effect on pure target identification. Center target identification under crowding may be earlier than flanker, and probably also center target, misplacement. 3) Top-down influences which control target misplacement improve correct report rate. 3) Lower-level stimulus configurations affect stimulus identification under crowding, consistent with the feature binding account.

Sunday, May 11, 8:30 am - 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

3D Pictorial Cues
Attention: Inattentional Blindness and Change Detection
Perceptual Learning 2

3D Pictorial Cues

33.401 **Perceived Size Is Affected By Blur and Accommodation**

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The tilt-shift effect is a photographic technique in which blur is exaggerated by slanting the image plane, which causes the scene to look small. This makes sense because discriminable blur only occurs when objects in a real scene are relatively close. We used the effect to study how focus cues—blur and accommodation—affect perceived size. A computer-generated image was rendered in sharp focus and blurred in various ways. Four conditions were used, with the validity of focus cues increasing in the following order. 1) The image was shown on a single display surface. 2) A linear blur gradient was applied to the image on a single display surface and oriented to roughly match or lie orthogonal to the depth gradient in the scene (Vishwanath, 2007). 3) The image was shown on one surface but each pixel was blurred to yield the same retinal-image blur as the original scene; this required measuring the aberrations of each observer's eye and appropriately modeling blur due to defocus and aberrations. 4) The sharp image was presented on three planes at different focal distances; blur and accommodative signals from the stimulus were therefore consistent with the signals that would be created by the original scene. The blur and/or accommodation signals were manipulated to be consistent with near (small) scenes or far (large) scenes. We presented two stimuli on each trial and observers indicated the one in which a central unfamiliar object appeared smaller. The results showed that blur and accommodation had a large effect on perceived size in condition 4. Blur had successively less effect in the other conditions as the validity of the cue decreased. Thus, perceived miniaturization depends on how closely the pattern of blur is matched to the depth values within an image, and on whether dynamic blur and accommodation are appropriate.

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33.402 **"Where is the sun" for hemi-neglect patients?**

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The visual system uses prior constraints to disambiguate a scene, in particular that the light source position is preferentially assumed to be comming slightly from the left rather than straight above (Sun and Perona, 1998, Nature Neuroscience, 1, 183-184). One explanation of this bias could be a cerebral hemispheric difference. This hypothesis makes an interesting prediction: hemi-neglect patients might use a default light source position at a location different from the one found for normal observers. The aim of this study was to explore in neglect patients their preferred light source position. For this purpose we used the ambiguous shaded "Polo Mint" stimulus (Gerardin, de Montalembert and Mamassian, 2007, Journal of Vision, 7, 1-11), a ring divided in eight equal sectors. All but one sectors had the same shape, convex or concave, as determined by the light source position. Participants had to report the side (left or right) of the odd sector, and in a second task, to report the shape (convex or concave) of this odd sector. Five neglect patients and fourteen control participants ran the experiment; patients presented a neglect syndrom after a right temporo-parietal lesion due to a stroke or a tumor; they did not present any visual deficits such as hemianopsia or other visual field deficit. Results show a significant reduction of the light source position bias for neglect patients, but they do not present a right bias. This left bias could be explained by an attentional bias on a representation. Such an explanation is consistent with recent theories on mechanisms underlying the neglect syndrome.

33.403 **The Preferred Angle of Illumination in Shape from Shading**

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Recovering 3D shape from shading alone is an ill-posed problem, so the observer must make assumptions about the lighting, surface material, and viewpoint. Typically, the assumed light position is above and slightly to the left (Sun & Perona, 1998). Consider a plane containing the eye, the point of interest on the object, and the assumed light position. The plane would be tilted slightly counter-clockwise from vertical to contain the above-and-left preference. We asked where in this plane is the assumed position of the light. We did so by changing the angle of incident light on virtual 3D objects and determining the accuracy of observer percepts for each angle. The objects were smooth, abstract 3D shapes with local Lambertian shading. They were viewed monocularly. The angle in the above-mentioned plane of the distant point light source was varied across trials over a range of +/-66 deg (above/below) from the viewpoint. On each trial, the observer indicated local surface orientation at a marked point on the object by rotating a gauge figure to appear normal to the surface (Koenderink et al., 1992). Observer settings were more accurate when the light position was above rather than below the viewpoint. The angular difference between the indicated and actual surface normal was minimized when the light was 20-30 deg above the viewpoint. Measurements of slant and tilt errors, as well as the variance of the settings, supported this result. These findings confirm that the human visual system has an above-and-left prior for light position and show that the preferred position is 20-30 deg above the viewpoint.

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33.404 **Shape-from-shading for grating stimuli: slant is proportional to luminance, with some exceptions**

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Humans are able to interpret luminance variations as changes in shading which are in turn interpreted as due to undulations of an illuminated surface. In general, we seem to adopt the implicit assumptions that surfaces are Lambertian and illuminated by a point source such that luminance in proportional to the angle between the surface normal and the direction of the illuminant. Thus, perceived surface slant depends on luminance. Most studies of shape-from-shading use stimuli based on simulations of solid objects viewed under a specified light source. We took an alternative approach; measuring the perceived shape of a range of grating stimuli (horizontal sine-wave, square-wave, and saw-tooth gratings). Observers set the slant of a probe disk to match the slant of the perceived surface at various points on each grating. In most cases perceived slant was proportional to luminance with mean luminance equal to zero slant (surface locally fonto-parallel). Sinusoidal luminance modulations produced sinusoidal perceived surfaces even though sinusoidal corrugations seldom produce sinusoidal shading patterns in real scenes. Square-wave luminance profiles produced triangular perceived surface profiles. Saw-tooth luminance profiles with several repetitions produced perceived surfaces that were dished or bowed (depending of the direction of the luminance ramps) with surface sections meeting at localised ridges/troughs. We found one notable exception to the general result that slant is proportional to luminance. Stimuli consisting of just two linear ramps in a saw-tooth configuration were mapped as a largely flat surface with a single central crease. The regions at the top and bottom of such stimuli were perceived to have zero slant even though luminance varied linearly in these regions and was not close to mean luminance. This result suggests that luminance edges and boundaries affect the perception of shape-from-shading even for relatively simple grating stimuli.

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33.405 **When are reflections useful in perceiving the shape of shiny surfaces?**

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3D shape can be perceived from a single image using contours, shading, and other cues. For shiny objects, an additional cue is available: the surrounding scene is reflected, and the deformation of this reflection varies as a function of the shape of the object's surface. Do human perceivers use this cue? Previous research has produced conflicting results (Savarese et al., VSS03; Fleming et al, VSS03), although the discrepancy might result from differences in the reflected environments. If the reflected scene is composed of objects in close proximity to the mirror surface, then the resulting reflections tend to be uncorrelated to surface shape's principal curvatures. In contrast, when the same scene objects are located further from the mirror objects, the resulting reflections tend to flow along the directions of minimal surface curvature and occluding contours, potentially providing additional cues about the mirrored object's shape. Does this geometric difference correspond to a difference in the ability to use deformation cues to perceive object shape? We tried to answer this question using 35 distinct, computer generated shapes reflecting 28 environments. The environments consisted of a range of objects randomly located in space at increasing distance from the mirror surface. As a control, we used a subset of shapes with no reflective properties but with surface texture. We found that mirror reflections were a weak cue for surface shape for human observers, regardless of the environment and the distance. Further analysis is needed to determine whether other aspects of the objects or environment can contribute to the use of specular reflections in shape perception.

33.406 **High frequency textures provide better support for shape-from-shading than low frequency textures**

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Observers perceive a sinusoidally shaded texture as a corrugated surface even when the texture elements themselves undergo no geometric distortions (Schofield, Heese, Rock & Georgeson, 2006, Vision Research, 46, 3462-3482). Using a similar two-point probe task but Gabor noise textures, we varied the dominant spatial frequency of the texture (from 1.5 to 12 c/deg) and found that high frequency textures support a more robust percept of shape-from-shading than do low frequency textures. Given that our sinusoidal shading patterns were themselves low frequency (0.5 c/deg) we were concerned that this difference may be due to masking. That is, the low frequency textures might simply have reduced the visibility of the shading patterns. To control for this we varied the dominant orientation of the textures so as to reduce their ability to mask the shading pattern; this had no affect. Reducing the spatial-frequency bandwidth of the textures, which should reduced masking, also had no affect. Multiplicative shading of an albedo textured surface produces a change in local mean luminance coupled with a change local luminance amplitude (AM). Schofield et al. (2006) showed that this AM cue modulates the perception of shape-from-shading. Given that AM is a second-order cue requiring comparisons across pairs of pixels, our results are consitent with the idea that second-order processes receive most of their input from high-frequency channels (Dakin & Mareschal, 2000, Vision Research, 40, 311-329). We speculate that when the carrier texture is high frequency, AM is detected well and thus supports shape-from-shading. When the carrier is low frequency AM is detected less well and consequently shape-from-shading is inhibited.

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33.407 **Effect of texture continuity on depth threshold**

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Textures of regions can be used as information for judging whether the regions are continuous or not. In the case of depth perception, if textures in two regions are different, the regions would be different in depth, but if these are the same, the regions would be continuous. This consideration lead to an assumption that when the regions have different textures, the sensitivity for perceiving depth of the regions would be higher than when textures are the same.

To test this assumption, we measured stereoscopic depth threshold between two regions while manipulating the textures of them. Stimulus was a stereogram consisted of short line elements tilted 45 or -45 degrees. The elements within one region were the same and those in two regions were different or same. Disparity was introduced into the central square region of the stimulus and observers responded whether the region was nearer or further than the background. Disparity threshold were determined for each combination of texture and stimulus configuration.

The results showed that depth threshold depended on texture conditions. However, the tendency of the results was opposite to the assumption, i.e. when textures of two regions were different, the sensitivity for perceived depth gap was lower. This might indicate that the difference of texture between regions disturbs the processing of disparity.

33.408 **Unmasking of orientation flows in 3-D shape perception**

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When a textured surface is slanted in depth, components not aligned with the slant increase in spatial frequency, and orientation flows along the slant become more visible. We examine whether this is due to a decrease in visibility of the components that increase in frequency or to a decrease in cross-orientation suppression (COS) of the orientation flows whose frequency is essentially constant. Planar surfaces textured with a 2.0 cpd horizontal grating were presented either in fronto-parallel orientation, or slanted right or left by 50 deg at a viewing distance of 1.0 m. Contrast thresholds for these gratings were measured in isolation and with the addition of full-contrast vertical gratings of either the same frequency, or 0.33 or 3.0 times the frequency. The presence of the vertical grating increased thresholds for detecting the flows, consistent with COS. However, the vertical grating of the same frequency raised thresholds 1.3 to 2.5 times more than did the gratings of three times higher or lower frequencies. Similar results were obtained for 2.0 cpd horizontal-vertical plaid surfaces slanted at 50 deg. Thus the visibility of the orientation flows that convey 3-D slant is unmasked when slanting the surface increases the frequencies of the other texture components, and this enhancement is independent of any direct effect of the decrease in visibility of these components. The results provide evidence for a COS mechanism that is frequency-selective and broadband in orientation, that suppresses responses particularly for those textures that contain similar frequencies across orientations, and the release from this masking due to surface slant gives enhanced responses for image segments where the texture provides cues to 3-D shape. The frequency selectivity of this mechanism may distinguish it from COS mechanisms attributed to contrast saturation in the LGN (Li et al. 2006; Priebe et al. 2006).

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33.409 **Matched Filters for 3-D Shape from Kernel-Based Image Analysis**

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A number of recent optimal statistical analyses of natural images (e.g. PCA, ICA, sparse-coding) have extracted filters that resemble receptive fields of cells in the striate cortex. We examined whether optimal statistical methods could extract higher-level filters matched to the orientation flows and frequency gradients that constitute monocular cues to 3-D shapes.

For the set of test images we used perspective projections of upright surfaces that convey 3-D percepts of concave, convex, left-slanted, right-slanted, and flat fronto-parallel objects folded from 16 patterns out of the Brodatz set of textures. Using pixel-based statistical analyses, sets of images from the same 3-D shape but different textures could not be reduced to lower-dimensional linear sub-spaces, nor could sets of images from the same texture but different 3-D shapes. Hence a bilinear decomposition into shape and texture components is not possible.

As an alternative we have explored the use of kernel-based methods on orientation and frequency decompositions of the images, as could be provided by the outputs of striate cortex neurons. The decompositions were based on convolutions with filters at four harmonic frequencies covering texture variations, and from 16 to 64 orientations. Linear reductions (e.g. PCA) of the high-dimensional space of the convolution images were unsuccessful at approximating desirable features. A major problem is extracting orientation maps that capture the subtle changes that constitute diagnostic orientation-flow patterns. However, non-linear reductions of dimensionality are more successful at producing filters that can be used for shape classification, but different reduction rules lead to different filters. Each non-linear reduction represents a different learning process, and we will present our results in this manner. Our results demonstrate one advantage for expanding the dimensionality of a problem in reaching an optimal solution.

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33.410 **Perception of Impossible Line Drawings by Pre-school Children**

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Impossible figures, like the Penrose Rectangle, provide effective line junction information for the 3-dimensional shape of object parts. What makes a display “impossible” is that the parts cannot be combined into a consistent whole object. Previous work has shown that the ability to detect impossible figures improves between 7 and 14 years of age (Young & Deregowski, 1981). In contrast, in a recent study 4-month-old infants were habituated to a cube in which intersecting bars were occluded by an ellipse and then presented with two test displays in which the ellipse was removed. In one display the depth order of the bars was possible while the other showed an impossible version of the cube (Shuwairi, Albert & Johnson, 2007). The infants looked longer at the impossible cube. The study reported here used this method to investigate the developmental trajectory of the ability to understand impossible figures in toddlers.

This study investigated 3- to 6- year-old preschool children’s ability to detect the impossibility of a tribox (Penrose Rectangle). First, to ensure children were capable of discriminating the subtle differences between the possible and impossible figures, they were shown these figures with the common interior lines removed and asked to do a matching task. Those who passed the matching task were then asked to match a partially covered figure with either the possible or impossible figure. The result showed that children older than 4.5 years selected the possible figure reliably more often than the impossible figure. In contrast, the performance of the younger group was at chance.

These results suggest that 3- to 4.5-year-old children are poorer than older children at attending to conflicts between information provided by local spatial cues. Future work will be needed to reconcile these results with the report of sensitivity to impossible objects in infants.

33.411 **Perception of 3D shapes from line drawings**

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A single line drawing determines infinitely many 3D interpretations. Despite this ambiguity, human observers usually perceive a single 3D shape and the percept is veridical. The underlying perceptual mechanisms are still unknown. In this study we tested the subjects’ perception of symmetrical 3D shapes, and developed a computational model of this visual ability. By comparing the subjects’ percept with the shapes recovered by the computational model, we explored the underlying mechanisms of 3D shape perception. By comparing the subjects’ percept with the original shapes, we explored the phenomenon of shape constancy. Method: 100 random symmetrical polyhedra were generated. Each polyhedron was presented at a randomly selected viewing orientation at one of five slants of the plane of symmetry: 15, 30, 45, 60 or 75 degrees. For each polyhedron an orthographic image was computed and hidden edges were removed. It is known that a single orthographic image of a 3D symmetrical shape determines a one-parameter family of 3D symmetrical interpretations characterized by an aspect ratio. The subjects were asked to adjust the aspect ratio of a rotating 3D shape so that this shape agreed with the 3D percept produced by a single 2D line drawing of this shape. Results: A computational model of human shape perception involves several constraints: symmetry, planarity of contours, maximum compactness (MC) and minimal surface (mS). MC maximizes the ratio V^2/S^3, whereas mS minimizes S, where V is the volume and S is the surface area of a 3D object. The subjects’ percept is strongly correlated with the original shape (i.e. shape constancy is achieved) and with a model that combines MC and mS constraints. Shape constancy is reliably achieved for slants of the symmetry plane between 30 and 75 deg. The slant of 15 degrees leads to systematic errors in both the recovered and perceived shapes.

33.412 **Detection of mirror-symmetry of a volumetric shape from its single 2D orthographic image**

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Purpose. Many objects in our environment are symmetric. This means that symmetry is a potentially useful constraint in recovering 3D shapes from their 2D retinal images. However, symmetric objects rarely produce symmetric retinal images. This study tested, for the first time, human ability to detect symmetry of a volumetric object from its single 2D image.

Method. Orthographic images of opaque polyhedra were used as stimuli. Mirror-symmetric polyhedra and three types of asymmetric polyhedra were used. Parallelism of line segments that connect pairs of symmetric points is the main (perhaps even the only) invariant of an orthographic projection of mirror-symmetric objects. Asymmetric polyhedra were produced by distorting the symmetric ones, so that: (i) all contours of faces were planar, and all pairs of vertices formed a set of parallel line segments, (ii) all contours of faces were planar, but the pairs of vertices did not form parallel lines segments, and (iii) the contours were not planar and the pairs of vertices did not form parallel line segments. Signal detection experiment was performed for two general conditions. In one condition, the subject was asked to discriminate between symmetric and asymmetric polyhedra, for several levels of distortion of symmetry. In another condition, the subject was asked to discriminate between clearly asymmetric polyhedra and polyhedra, which were less asymmetric, again for several levels of distortion of symmetry.

Results. In all conditions and in all trials a single 2D image of a 3D polyhedron produced a 3D percept of a polyhedron. Discrimination involving asymmetric polyhedra (iii) led to best performance. Discrimination involving asymmetric polyhedra (i) and (ii) led to similar performance.

Conclusions. Planarity of faces is a constraint that contributes to symmetry detection. A computational model of mirror-symmetry detection, involving planarity and compactness constraints, will be presented and compared to the results of the subjects.

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33.413 **The role of perspective and angle polarity in perceiving 3D objects: Lessons from reverspectives**

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Purpose. Reverspectives are painted on three-dimensional surfaces with the painted perspective cues competing against the 3-D surface geometry, resulting in depth reversal and illusory motion. The objective was to examine two main factors in the illusion: perspective and angle polarity (convex/concave).

Methods. We designed symmetric 3-D stimuli of two congruent trapezoids forming a convex or concave dihedral angle, to simplify the reverspective form. We used two types of stimuli: Stick figures, where perspective was signaled by the sticks' length and width; full-surface stimuli, where perspective was signaled by the trapezoids' shape and by texture gradients. We used 4 stimuli (2x2 combinations of proper/reverse perspective with convex/concave angles) and 2x2 combinations of monocular/binocular viewing with moving/stationary observers. Task was to judge the relative depth of a lateral probe with respect to a central fixation mark. The predominance of the illusory state, as inferred by the observers' response, was the measure of the illusion's strength.

Results. The data pattern is very similar for the two types of stimuli. Within each type, the variations of results for the 4 stimuli are similar across all viewing conditions. An ANOVA test showed that perspective is a much stronger cue than angle polarity. Binocular viewing weakened the monocular illusion, as expected. We expected a weaker illusion for moving observers, but it was not significantly different from that of stationary observers.

Conclusions. Perspective was the dominant factor in depth perception. A potential reason for observing a weak role of angle polarity is that it was confounded with and overpowered by perspective cues; we are designing a new set of stimuli to isolate the role of angle polarity. One explanation for the strong illusion for moving observers: they maintained the reverse-depth illusion, thus motion parallax signal produced illusory motion, rather than extracting veridical depth.

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URL: http://ruccs.rutgers.edu/~papathom/demo_kastoria.htm

33.414 **Ecological account for ground dominance: comparisons between terrestrial and arboreal primates**

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Recent studies have demonstrated advantages of the ground surface in 3D scene perception in humans (e.g., Bian et al., 2005, 2007; McCarley & He, 2000). These characteristics of humans may be closely linked to strong terrestriality. We have investigated how the ecological factors may influence depth perception from texture gradients. We compared humans, terrestrial baboons (*Papio papio*) and arboreal New World monkeys (*Cebus apella* and *Saimili sciureus*) for their perception of the size constancy illusion. The task was to classify a red disk (sample) into two size categories. In Experiment 1, the sample was placed on a textured background that depicted either "ground" or "ceiling". Humans perceived strong size constancy illusion from texture gradients, with its magnitude larger in the "ground" context. Baboons also showed ground dominance though it is not so strong as humans'. In contrast, New World monkeys perceived the size constancy illusion but showed no ground dominance. The results indicate that primates may have a size constancy system and three-dimensional scene perception from texture gradients in common, but that only terrestrial primates might have acquired the ground dominance. In addition, human visual system might have developed the ground dominance in textured surface processing through exposure to the homogeneous plane surfaces such as floors or paved roads. In Experiment 2, New World monkeys were tested with "side-wall" backgrounds. The monkeys perceived stronger size constancy illusion in "side-wall" than in "ground" and "ceiling" backgrounds, which implies that the strategy of three-dimensional scene perception in arboreal primates may be different from terrestrial primates. The present results suggest that ecological differences give rise to differences in visual environment that may lead to diverging depth perception processes among humans, baboons and New World monkeys.

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33.415 **The ground surface advantage in change detection: coherent surface structure**

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Previous research (Bian, Braunstein, and Andersen, 2005, 2006) has shown that observers organize the 3D layout in scenes based on ground surface information. We also found that changes on a ground surface were faster and easier to detect than changes on a ceiling surface (VSS, 2006). In the current study, we examined whether this ground surface advantage in change detection depends on the existence of a coherent surface or on the layout of objects in the scene. On each trial observers fixated a cross and were presented an original scene and a modified scene for 250ms each in a sequence of A, A, A', A'. The original scene contained a surface, which was either a ground surface, a ceiling surface defined by a randomized black-white checkerboard texture and contained 12 colored objects (6 pyramids and 6 cubes). The variable of interest was the coherent structure of the ground or ceiling surface, which was altered by rearranging regions of the scene in the visual field. When a scrambled surface was presented, the objects either formed a ground-like layout (objects further away from observers were higher in the image) or a ceiling-like layout (objects further away from observers were lower in the image). A change was introduced in the display by changing an objects location in depth. The two scenes were alternated until subjects detected a change. Control trials with no change were also included. The results showed a significant advantage for objects forming a ground-like layout compared to objects forming a ceiling-like layout, suggesting the importance of the layout of objects in a scene. However, a local analysis showed that this ground-like layout advantage was only present when a coherent surface was presented, indicating the importance of a coherent ground surface in organizing 3-D scenes.

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33.416 **The Influences of Array Orientation and of Line Orientation on Visually Perceived Eye Level (VPEL) are Modulated by Line Length and Array Length**

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The elevation of visually perceived eye level (VPEL) is influenced by linear arrays of parallel equal-length straight lines (Shavit, et al., 2005). We examined this influence by varying the line orientation and the independently-manipulable array orientation. "Array orientation" is defined as the orientation of the implicit line that connects the centers of the individual lines of the array; "line orientation" is employed in its usual meaning as the direction of an individual line. Psychophysical measurements of VPEL were made in four experiments employing two otherwise-identical bilaterally-symmetric arrays that were centered at ±25o horizontal eccentricity, and were presented together in a frontoparallel plane to the right eye of the observer. Line orientation and array orientation were separately varied, employing orientation values equal to -10o (ccw), -5o, 0o, +5o, or +10o (cw); line lengths were 3o, 9o, or 15o. Spacing between the centers of the individual lines of an array was always 3o. Array lengths were 6o, 12o or 18o with variation produced by changing the number of lines in the array. VPEL changed monotonically with both line orientation and array orientation. Off-vertical orientations (line or array) shifted VPEL away from true eye level (TEL); vertical orientations (line or array) shifted VPEL toward TEL. Line length and array length modulated the influence of orientation: The influence of line orientation increased with line length; the influence of array orientation increased with array length. The influences of array orientation and line orientation were found to summate. In summary, the net influence of an array of parallel lines on the elevation of VPEL depends on the orientation and length of the array as well as on the orientation and length of the individual lines.

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33.417 **Spatial Induction, Laterality, and Homogeneity of Perceived Space**

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A pitched-from-vertical line in darkness systematically influences both the elevation of Visually Perceived Eye Level (VPEL) and the orientation of Visually Perceived Erect in the pitch dimension (VPE) of a visual target located in an observer's median plane. However, the influence of the inducing line on VPE for the test line does not cross the midline. Thus, while VPE increases linearly with variation of the inducer's pitch when both inducer and test line are on the same side of the midline, VPE is invariant when inducer and test line are on opposite sides of the midline. The present study investigates the possible existence of this homolateral restriction on two tasks: VPEL and Visually Perceived Vertical in the roll-tilt dimension (VPV). In otherwise complete darkness, one 77°-long luminous inducing line was pitched at either +/-5°, +/-15°, or +/-25°. The inducer and test target were located either left or right of S's median plane with horizontal eccentricity 25° and 8.3°, respectively. With a fixation point in S's median plane, and viewing distance 1m, six monocularly-viewing Ss set either a 5°-long test line to VPV or a dim 20 minarc target to VPEL. No homolateral restriction was found for either VPV or VPEL: Although both VPV and VPEL settings changed systematically with the pitch of the inducer whether inducer and test target were on the same side of the midline or on opposite sides, the VPV-vs-pitch function reversed with the inducer on the left as compared to its being on the right side of the median plane, whereas VPEL increased with increasing topforwardness in both cases. These results are consistent with earlier findings regarding influence of line orientation on VPV and VPEL, and also show that perceptual space is homogeneous for induced changes in verticality (VPV) and in elevation (VPEL).

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Attention: Inattentional Blindness and Change Detection

33.418 **The effects of individual differences and task difficulty on inattentional blindness**

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Most studies of inattentional blindness — the failure to notice an unexpected object when attention is focused elsewhere — are limited to one critical trial. Noticing of the unexpected object on that trial could be due to random variability, such that any given individual is equally likely to notice the unexpected object. Or, individual differences in the ability to perform the primary task might make noticing more likely for some individuals than others. Increasing the difficulty of the primary task does decrease noticing rates with brief static displays and visual search arrays (Cartwright-Finch & Lavie, 2007) as well as with dynamic monitoring tasks (Simons & Chabris, 1999). However, those studies did not explore whether individual differences in noticing arise from differences in the ability to perform the primary task. We used a staircase procedure to equate primary task performance across individuals in a dynamic inattentional blindness task (Most et al, 2000) at either 60% accuracy (faster motion) or 90% accuracy (slower motion) and found that subsequent noticing was substantially greater with the 90% threshold. Thus, load of the primary task affected noticing rates when individual differences in the ability to perform the task were effectively eliminated. A second study determined the speed at which each observer could perform the primary task with 75% accuracy and showed that individual differences in that speed did not predict noticing of an unexpected object in a subsequent set of trials. Together, these findings suggest that the demands of the primary task affect inattentional blindness rates, but that individual differences in the ability to meet those demands do not.

33.419 **Inattentional Blindness: Driver Compliance Rates at Pedestrian Crosswalks**

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Globally, driver and pedestrian safety is of great concern because motor vehicle collisions cause more than 11 million deaths or permanent disabilities each year (Murray & Lopez, 1996). Harborview Injury Prevention Research (1997) found that approximately one-half of all fatalities involving motor vehicles in the United States involved pedestrians. In the United States alone, almost 75,000 pedestrians were either killed or injured from a motor vehicle in the year 2003. Throughout Western, Eastern, and developing countries, many of the motor vehicle collisions involving pedestrians occur at crosswalks. In Sweden, the 1996 SCB accident statistics reveal that almost 40% of all report pedestrian related motor vehicle collisions occur at crosswalks (as cited in Varhelyi, 1998). Although there has been an overall decrease in motor vehicle collisions involving pedestrians, there has been an increase of motor vehicle collisions involving pedestrians at crosswalks (NHTSA, 2001). This study looked to evaluate if any of a given number of variables influenced driver stopping rates at mid-block crosswalks; with and without amber flashing warning beacons. To test driver responsiveness, pedestrian confederates of different gender or visibility – i.e. wearing different colored clothing – were placed at each type of crosswalk. After each of the 810 driver encounters, two observers scored drivers and noted variables such as driver gender, cell phone usage, and presence of passengers. Although driver compliance rates in general were overwhelmingly poor, male drivers were more likely to stop than female drivers. A relationship between crosswalk type and driver compliance was also found; more drivers stopped for pedestrians without the flashing amber warning beacon than with it. Results of this study indicate that in part, low compliance rates could be influenced by inattentional blindness in drivers. Because injury and fatality rates against pedestrians remain high, future attempts to understand driver behavior are valuable.

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33.420 **Effects of individual differences on the ability to detect changes in natural scenes**

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The ability to detect visual changes is relevant to many every day tasks. It is important to discover the underlying cognitive processes and individual differences that may influence the ability to detect visual changes. Recent research suggests that individual differences play an important role in a number of cognitive abilities. In addition, the ability to accurately perceive natural scenes requires coordination of many abilities such as figure-ground segregation, encoding of details, focused attention to bind features, working memory, and perceptual speed.

Many factors that are dependent on the visual stimuli (external factors) have already been identified as playing a role in change detection performance. Research suggests that the type of task, type of change, scene complexity, and scene relevancy all influence how accurately observers detect changes. While all of these factors are specific to external components of the task, it is also important to examine factors that are internal to observers. Attentional breadth is one such factor that has been shown to affect change detection performance. Another important factor in detecting changes in natural scenes is the likelihood that certain changes will occur in the environment. In another vein, some cultures that are more holistic in their world view may be more sensitive to certain types of changes. As such, the current project expands this literature base by examining individual differences and their relation to change blindness.

Participants first completed a series of cognitive factors tasks that focus on field independence-dependence, visual memory for locations and perceptual speed. Then participants viewed natural scenes in which one object changed and their task was to detect this change as quickly as possible. Preliminary findings suggest that individual differences in visual memory for locations may account for differences in change detection ability.

33.421 **Proofreaders show a generalized ability to allocate attention to detect changes**

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In proofreading, attention should be allocated to the entire text in order to detect anomalous words that do not fit the sentence context. Professional proofreaders are thought to have excellent control of attentional allocation, which could generalize to other tasks. To test this hypothesis, professional proofreaders were compared to novices using change blindness and visual search tasks. The two groups were matched in age, and did not differ in estimated vocabulary scores or in reading span, which is a measure of verbal working memory capacity. As expected, the professional proofreaders performed much better than novices in an anomalous word detection task. We used the flicker paradigm with a change blindness task using scene pictures as stimuli. The results showed that proofreaders detected more changes than novices. The location of the change had no impact on the proofreaders, while novices missed more changes in the lower half of the scene pictures. These findings suggest that professional proofreaders allocate attention to the entire scene, in contrast to novices' attention which tends to be attracted to the upper part of visual scenes. In the visual search task, where participants reported the number of digits among letters, an exhaustive search was needed even though the targets were predesignated. The results showed no differences in search performance between the two groups. This implies that professional proofreaders have a highly developed ability for attentional allocation in exhaustive search situations where detection targets are not predesignated. This ability to generalize attentional allocation, which is characteristic of skilled proofreaders, is applicable to other tasks such as change detection.

33.422 **Change Blindness and Fearsome Objects**

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Purpose: A number of questions remain unanswered regarding the mechanisms involved in change blindness (CB). Does affective significance of an object affect CB, what effect does the recall task have on CB, and can CB be distinguished from object blindness (OB), where object blindness is defined as simply not detecting, storing, or recalling the object? This study sought to answer these questions.

Methods: 32 subjects participated in a real world interaction involving multiple objects. Objects were replaced by a confederate, while the subject was not observing. Independent variables included the fearsomeness of the object, the replacement type (fearsome=>fearsome, fearsome=>neutral, neutral=>fearsome, neutral=>neutral), and recall task (verbal vs. behavioral). Frequency of CB, OB, temporal reordering on recall, and correct change perception were measured.

Results: We found the following main effects (no interactions): Replacement type and fearsomeness have effects on OB but not CB, recall task has an effect on both OB and CB. A post hoc test showed that the total amount of fearsomeness was more important than a change of fearsomeness status. Temporal reordering proved to be very rare.

Conclusions: These results suggest a number of interesting conclusions. OB appears to be distinguishable from CB, in that pure CB is primarily a function of recall, whereas attentional manipulations affect OB. A change in fearsomeness status should generate attention. However, change in fearsomeness appears to be less important than overall fearsomeness. Finally, the rarity of temporal reordering suggests that CB is due to assumptions of constancy during recall rather than temporal uncertainty.

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33.423 **Seeing changes without seeing what changed**

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Sudden isolated changes in visual scenes are easily detected, and typically produce a rapid spontaneous shift of attention towards the location of the change. The current psychophysics study investigates the information observers have regarding the qualitative nature of such a change. Eighteen colored shapes were presented in a circular array for 500ms (frame 1). This display was immediately (with a 0 ISI) followed by a new array (frame 2) in which one item either changed color, shape or both color and shape. Frame two was presented for 500ms, 100ms or 50ms, with no masking. Results: (1) Observers were able to accurately detect and report the location of the changing element independent of the duration frame 2. (2) Observers were unable to report the initial state of the changed element, irrespective of the duration of frame 2. (3) The ability to report the final state of the changed element degraded as a function of decreasing frame 2 duration. Thus on some short frame 2 durations, observers could detect and localize the change without being able to accurately report either the original element or what it changed to. (4) Despite the inability to report the initial state of the changed element, observers could distinguish color changes from shape changes. These results are discussed in the context of change blindness and iconic memory.

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33.424 **Competitive interaction for visual representation between and within hemifields**

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Previous studies have shown that when multiple objects are presented, performance is sometimes enhanced, and sometimes impaired, when the objects fall unilaterally within one visual hemifield rather than bilaterally in two hemifields. In detecting repetition of letters, for instance, a bilateral advantage is observed when the repeated letters are semantically identical but visually different (e.g., "A" and "a"), while a unilateral advantage is observed when repeated letters are visually identical (e.g., "A" and "A"). This study aims to elucidate conditions under which unilateral objects cooperate rather than compete for processing resources. We presented four items, one in each visual quadrant, and asked observers to judge whether all four objects were different, or whether two of them were the same along an instructed dimension. The "same" objects could fall in the same hemifield, in two separate hemifields, or in diagonal positions. They could be visually identical or different in features irrelevant to the task. Results showed that when detecting the repetition of objects, a unilateral advantage was observed even when the objects differed in size or viewing angle, suggesting that a unilateral advantage is not restricted to the detection of identical objects. The unilateral advantage, however, depends on the complexity of visual objects. It was observed with repetition detection of colors, letters, and simple objects, where simple distinctive features can be used to identify the repetition. No hemifield effects were observed when detecting the repetition of complex scenes and novel objects that lacked distinctive features, and a bilateral advantage was seen when detecting the repetition of faces. We conclude that objects within a hemifield cooperate in tasks that rely significantly on perceptual grouping (Butcher & Cavanagh, 2004 VSS) along a task-relevant visual dimension.

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33.425 **Change blindness for relatively moving target as a result of a single mudsplash**

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Observers often fail to detect the sudden image change when multiple distracters are presented in the scene (change blindness as a result of mudsplashes). In previous study (VSS2008), we found that a single small flash may induce the blindness for the shape change of a moving target. In this study, we investigated whether the relative movement on the retina in terms of tracking a moving fixation point would induce the blindness for the shape change in a stationary target. A white target and/or red fixation point (19.1 x 19.0 arc min) went upward or downward with a constant velocity (9.8 arc deg/s) along a linear course. A flash stimulus (1.6 x 0.3 arc deg) was presented at 5.5 arc deg from the fixation point in the same visual field with the target. In the half of trials, the target changed its horizontal length to 57.3 arc min at the moment of the flash. The distance between the fixation point and target was horizontally 2.6 arc deg and vertically 5.8 arc deg when the target changed its shape. For the moving target with stationary fixation point, observers frequently failed to detect the shape change, especially in the lower visual field. For the stationary target with moving fixation point, observers failed to detect the shape change while the frequency of the failure was lower than that for the moving target. For the stationary target with stationary fixation point, such a frequent fail in change detection was not obtained. These results suggest that the frequent failure to detect the shape change for the moving object involves the processing for the object movement in the object-centered coordination, which has anisotropy between lower and upper visual fields, and the processing for the movement in the retinal coordination, which does not has such an anisotropy.

33.426 **The probability of change influences attentional allocation in foreground- background segmentation**

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PURPOSE: In the change detection task used stimuli with foreground-background segmentation, the performance for the foreground change detection was better than that of the background change detection. Therefore, it has been indicated that attention tended to direct the foreground elements (Turatto, Angrilli, Mazza, Umilta, &, Driver, 2002; Mazza, Turatto,

& Umilta, 2005). However, it is controversial whether attention is always directed toward the foreground selectively or attentional allocation is influenced by the probability of change. The present study explores the influence of manipulating the probability of changes on attentional allocation with foreground- background segmentation.

METHODS: The change detection task used stimuli consisted of the foreground and the background elements was performed. Participants responded whether the foreground or the background changed or not. We set 2 conditions; in one condition, the foreground change was 50% and the background change was 50% (50%- 50% condition), in the other condition, the foreground change was 20% and the background change was 80% (20%- 80% condition). 2 blocks of experimental trials were presented to the participants. On the first block, information about the change was not given to the participants (Default attention). On the second block, participants were informed that the change could occur either the foreground or the background (Divided attention).

RESULTS & CONCLUSIONS: When information about the change was not given, accuracy of the foreground change was higher than that of the background change in both probability conditions. However, when attention was divided, accuracy of the background change is higher than that of the foreground change in 20%- 80% condition. The results suggest that the selective attention was not always allocated to the foreground, but the amount of attentional allocation is controlled according to the situational factor such as the probability of change.

33.427 **The effects of active attention on the change detection task**

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This study investigates the effects of active attention on the detection of a change between two visual scenes. In the integration of information across scene over time, failure of the integration means that the item changed whereas success of the integration results that the item is the same as before. In the change detection task using the one-shot method, there are the target present trials that require the detection of one item changes and other items are the same as before, and the target absent trials that require the detection of all items are the same as before. In the target present trials subject's performances in the detection of the change target dropped as set-size increased when they attended to change item. Otherwise, in the target absent trials subject's performances in the detection of the all items are the same as before (there is no change target) was not affected by set size when they attended to change item. These suggest that serial search property is shown only in the detection of the change item. However when subjects attend the no-change item voluntary, subject's performances in the detection of the no-change target was dropped as set-size increased in the target present trials. Otherwise, in the target absent trials subject's performances in the detection of the all items changed was not affected by set size. These results show that serial search property of the change detection depends on subject's active attention state.

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Perceptual Learning 2

33.428 **Preference in a stochastic visual cognitive task with probability information learned through experience**

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Purpose: Subjects' use of probability information in decision making under risk (DMR) is markedly distorted. Recent research hints that probability information learned through experience (Hertwig et al, 2004, Psych. Science) is less distorted. Here we studied visual decision making in a stochastic visual aiming task in which subjects learned the behavior of "stochastic bullets" through experience. The trajectory of the bullet was simulated by a random walk with fixed Gaussian noise with either high or low variance. Variance was coded by the color of the bullet. During a training phase (300 trials) subjects could learn the probabilities of hitting targets of various sizes with either bullet type.

Methods: In the main experiment, subjects were presented with pairs of possible targets differing in width and now assigned monetary values measured in points. They could choose to shoot at one or the other but not both. The widths of the zones were adjusted so that the subject could win points Oi with probability pi, i = 1,2 by choosing to aim at zone i. In eight conditions, we varied the probability p2 of incurring outcome O2 between 0.8, 0.6, 0.4 and 0.2 (low variance), and 0.63, 0.48, 0.28 and 0.15 (high variance) by varying the size of one of the targets. We used two different sets of rewards (O1 = 500 and O2 = 100; and O1 = 400 and O2 = 200), varied across two sessions. The overall score was converted into a bonus paid at the end of the experiment. Six subjects completed the experiment.

Results: We tested whether expected utility theory (EUT) could predict subjects' choices. We found that, even though probability information was learned through experience, subjects' probability ratios were not constant over the range of target widths tested and thus inconsistent with EUT.

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33.429 **Decision making in an uncertain video game environment**

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How do humans choose the more rewarding of two options when the reward values are initially unknown? To maximize reward in this task, initial choices should explore target options to learn which is best, but choices should eventually converge to exclusively selecting the best target. Previous research involving cognitive decision tasks suggest that people tend to under explore in early choices and over-explore (under-exploit) in later choices compared to optimal. We investigated whether these decision-making biases persist when the choice task was embedded in an engaging visuo-motor task, a video-game (created using Virtools) that involved piloting a spacecraft to attempt to shoot and destroy the more rewarding of two targets. The effect of visuo-motor control was assessed by comparing choice behavior in two versions of the game, one involving full control of the ship, and the other involving key press choices that automatically moved the ship to the target's location. Each target was assigned a different and fixed probability of exploding when hit. Subjects were instructed to destroy as many targets as possible and an on screen score counter awarded points for each successfully hit target that exploded.

The optimality of subjects' choice behavior depended on the target explosion probabilities: For differences between target explosion probabilities greater than 0.2, participants converge to the better target, but fail to converge on average for smaller differences. However, even when they converge on the better target, they still over-explore (the asymptotes are less than 100%). While cognitive and visuo-motor decision strategies were similar, players initially explore more in the full control condition, however, this effect is small and is reduced by experience. While suboptimal for our task, over-exploration may result from an underlying belief that environments may change (be non-stationary) over time.

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33.430 **Video Game Playing Enhances Practical Attentional Skills**

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Recent evidence has shown that habitual video game playing enhances a subset of visual-attentional skills. In this study, we investigated whether prolonged experience playing action video games can improve performance on tasks related to lifeguarding, a job where allocation of attention in the visual field can have life and death consequences. To examine this question, Video Game Players (VGPs) and Non-Video Game Players (NVGPs) were tested on two computerized lifesaving tasks and one conventional measure of attentional performance. To emulate lifeguarding performance, one task was a modified Useful Field of View / Multiple Object Tracking hybrid where we measured participants' ability to detect schematic 'non-swimmers', at either 10º, 20º, or 30º from fixation, amongst a large group of 'distractor' swimmers. A second task used a Change Detection (CD) paradigm requiring participants to detect the absence of a swimmer in a naturalistic scene. Findings revealed that VGPs showed greater 'non-swimmer' detection accuracy at larger eccentricities from fixation; however no reliable group difference in CD performance was found. In addition, basic attentional performance was measured by having participants perform a Temporal Order Judgment task, using a step-function to calculate the amount of time the uncued target needed to appear before the cued target in order for both target items to be perceived as arriving simultaneously. VGPs were found to be more sensitive to the peripheral cue, thereby reliably lengthening the time the uncued target needed to appear before the cued target as compared to NVGPs. Overall, these findings show that playing action video games may improve performance on detecting certain events in the periphery (e.g., motion, onset, etc.), but do not necessarily facilitate the detection of changes presented within the foveal window.

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33.431 **Playing Action Video Games Enhance Visual Sensitivity**

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Contrast sensitivity or the ability to detect small increments in shades of gray is a main determinant of how well a person sees. This ability is notably difficult to improve through perceptual learning. Here, we show that action video games players exhibit higher contrast sensitivity across a range of spatial frequencies as well as shorter critical duration for contrast sensitivity. These changes suggest faster sensory integration following action game playing. In accord with this proposal, action video game players also exhibit substantial reductions in backward masking as compared to their non gaming peers. The causal effect of action video game playing was established through training studies, with individuals trained on an action video game showing greater improvements than those trained on a control game. This work opens new perspectives for clinical rehabilitation of patients with vision problems such as amblyopes or those with low vision.

33.432 **Effects of training on perceptual salience**

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Learning on a visual search task involves plasticity at one or more levels of the visual cortex. Does this plasticity boost the target features and suppress distractors in a manner that would make the target more perceptually salient? We address this question by designing a challenging, attentionally-demanding conjunction search task, where each colored Gabor patch item is defined by a conjunction of 3 features (hue, orientation and spatial frequency). Three subjects' eye movements were recorded while they searched for a target embedded among distractors in 1/f noise. Once the target is spotted subjects report its location and are given feedback based on whether they made the right choice or not. Subjects perform three 100-trial search sessions. Each trial had unique targets and distractors, so subjects gained general task expertise rather than expertise with specific stimuli.

Accuracy improved significantly (one-way ANOVA $p<0.005$) from session to session and subjects achieved on average a 15% boost in accuracy in locating the target. Further, the trajectories of subjects' eye movements through the three dimensional feature space were analyzed and the average Euclidean distance to the target, within the feature space, decreases from session to session. We also found that subjects make first saccades towards items closer to the target in feature space from one session to the next. Moreover, the average Euclidean distance of first saccade target items from the search target (in feature space) was reduced by 20% from the first session to the last. These results provide evidence for subjects making saccades towards items that are more similar to the target during the course of the sessions. These saccades towards target-like items suggest that these items are more perceptually salient and become even more so with training.

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33.433 **Sensitivity of Implicit Visual Rule-learning to the Saliency of the Stimuli**

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Human infants have been shown to implicitly learn rules, such as the repetition of ABB or ABA patterns, regardless of the identity of the participating items, both with sequential information during language development and with simultaneously presented visual patterns. However, in these studies the ABB or ABA patterns were defined by the identity of the items themselves. This leaves open the question of how successful humans are in extracting such rules in more complex situations when the rule is defined by a particular feature dimension of the items rather than by their identity. We examined the performance of adults presented with an implicit rule-learning task where both the color and the size of the items followed some underlying rules. Subjects were first exposed to a series of three different shapes presented simultaneously: five triplet scenes were viewed ten times each in random order during the learning phase. Patterns within each triplet varied in both size and color saturation following two different rules (AAB vs. ABA). The test phase consisted of triplets made of new elements not seen in the learning phase, which varied in size but had identical color saturation. In each trial, subjects saw two triplets, an AAB and an ABA pattern, and judged which triplet seemed more familiar. Surprisingly, adult subjects did not find the pattern of sizes shown during practice more familiar than the alternative, with a size difference of either 100 or 150 percent. These results suggest that successful visual rule-learning requires a much higher saliency of the rule in the given feature dimension than is expected based on the discrimination results.

33.434 **Reinforcement learning and the acquisition of perceptual expertise in ERPs**

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In a category learning task, people are initially unaware when they have committed an error and therefore, require corrective feedback to modify their category decisions. Once the categories are learned, however, external feedback is no longer necessary. Electrophysiologically, the two phases of category learning are indicated by different event-related brain potentials (ERPs): the feedback ERN that is elicited following the presentation of negative feedback and the response ERN that is generated following an incorrect response. In a study of perceptual categorization, participants were asked to discriminate between very similar families of novel geometric shapes (blobs). Participants who learned the perceptual categories (i.e., expert learners) demonstrated a shift from a feedback ERN to the response ERN. The expert learners also showed an enhanced N250 response to the blob families – a component that is thought to index subordinate level representations. For the experts, the buildup of the N250 component was correlated with the shift in the ERN. In contrast, participants who were unable to learn the object families (i.e., novice learners) failed to show a shift in their feedback-to-response ERN nor did they show an increased N250. Collectively, these results suggest that accompanying the acquisition of the subordinate categories, there is a change from an external source of error monitoring to an internal source.

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

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In adult animals, regions of primary visual cortex deprived of normal input show "reorganization" (Kaas et al., 1990): they begin responding to stimuli that normally activate adjacent cortex only. However, it is unknown how quickly this cortical reorganization can happen, and some studies have failed to find it at all, spawning considerable controversy (e.g., Smirnakis et al., 2005). We investigated the existence and speed of reorganization in the adult human visual system, using a novel perceptual test. Specifically, we patched one eye, thus depriving input to the cortical region corresponding to the natural blind spot (BS) in the unpatched eye. To ask whether and how quickly deprivation produces reorganization, we tested for perceptual distortions that have recently been shown to reflect cortical reorganization in retinotopic cortex following stroke (Dilks et al., 2007). Within only one minute of eye patching, participants perceived rectangles placed adjacent to the BS to be elongated toward the BS, exactly as expected if deprived cortex starts to respond to stimuli adjacent to the BS. These findings further document the existence of cortical reorganization in the adult human visual system, show that this reorganization can occur very rapidly, and implicate unmasking of horizontal connections in early visual cortex as the underlying mechanism.

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33.436 **Reward contingency on perceptual learning does not follow rules of classical conditioning**

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Does perceptual learning (PL) follow the same rule as classical conditioning? In classical conditioning, it is suggested that conditioning only occurs when the relative probability of occurrence of unconditioned stimulus (US) in the presence of conditioned stimulus (CS) differs from that in the absence of CS. When the probability of US is higher during CS than at other times, excitatory conditioning occurs and when the probability is lower, inhibitory conditioning occurs. Last year we showed that PL in humans occurs for stimuli that are consistently paired with a liquid reward (Kim, Seitz, Watanabe, VSS, 2007). This raises the possibility that the common mechanism underlies between classical conditioning and PL shaped by reward. To test this hypothesis, we have examined how learning occurs as a function of reward-contingency. Using a classical conditioning paradigm, we presented every 500 msecs a different noise image that filled the display. At random intervals, sinusoidal gratings (20% signal; 2 c/deg; 4 deg diameter) were superimposed on the noise background. To vary the probability of reward-delivery three different orientations were used for each subject: (a) the zero-contingency orientation had reward-probability equal to the background reward-rate of 50%, (b) the positive-contingency orientation had probability of reward of 80%, and (c) the negative-contingency orientation had probability of reward of 20%. Sensitivity tests for the three orientations were conducted before and after nine days of conditioning. We found significant performance improvement for the positive-contingency orientation, marginal improvement for the negative-contingency orientation and no significant improvement for the zero-contingency orientation. These results demonstrate that reward contingencies (not just stimulus reward pairings) shape perceptual learning. However, the performance improvement observed for the inhibitory orientation suggests that perceptual learning does not follow the same rules as classical conditioning.

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33.437 **Task-irrelevant perceptual learning occurs only when the irrelevant feature is weak**

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The role of attention in perceptual learning (PL) has been a topic of controversy. A number of studies have reported that a task-irrelevant feature is not learned (Ahissar & Hochstein 1993 PNAS; Shiu & Pashler, 1992 P&P). It was concluded that focused attention to a feature is necessary for the feature to be learned. In contrast, another line of studies have shown that PL occurs even on task-irrelevant features that are subthreshold, and, therefore, concluded that attention on a feature is not required to learn that feature (Watanabe et al., 2001 Nature; Seitz and Watanabe 2003 Nature; Dinse et al, 2003 Science). Here we attempt to reconcile these divergent results.

Subjects performed 10-days of training with a foveal letter identification task while a dynamic random-dot display (DRD) was presented in the background. Previously we have reported directional specific learning for an exposed DRD direction that was below thresholds. Here, we systematically explore the relation between motion coherence during training and the resultant magnitude of PL. We used a within-subject design in which each subject was exposed to two different directions of motion, each at a different, but consistent, coherence level. Before and after the exposure, subjects were tested on motion-direction discrimination for six directions including the two exposed directions.

We find performance improvements only for the direction trained at a low, perithreshold, coherence level. The present results are in accord with the results of the aforementioned different lines of studies that appeared to contradict to each other. At the same time, the present results more readily support the hypothesis that only irrelevant feature signals that are suprathreshold are "noticed", inhibited (Tsushima et a., 2006, Science) and fail to be learned than the hypothesis that only an attended feature is learned.

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33.438 **Roving in perceptual learning: stimulus interference and overlapping neural populations**

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Performance usually improves when observers train with one type of a visual stimulus. Roving denotes the situation when, instead of one, two or more types of stimuli are presented randomly interleaved (one per trial). For some stimulus types, performance improves also in roving situations whereas for others it does not. To understand when roving impedes perceptual learning, we conducted four experiments. In each experiment, the very same bisection stimulus was randomly interleaved with a different stimulus type. Performance improved when a bisection and a vernier stimulus were randomly interleaved. However, no learning was found when we randomly interleaved this bisection stimulus with another one being twice as long. Based on these results, we propose that roving impedes performance when two stimuli excite strongly overlapping neural populations.

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33.439 **Adaptation induced temporal compression is highly space specific**

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Local adaptation to 20 Hz oscillatory motion or flicker reduces the apparent duration of a 10 Hz dynamic test stimulus, while 5 Hz adaptation has very little influence on apparent duration (Johnston, Arnold & Nishida, 2006, Current Biology, 16(5):472-9). Recently it has been suggested that the duration aftereffect can be attributed to a reduction in apparent speed, rather than a direct effect on neural timing mechanisms (Burr, Tozzi & Morrone, 2007, Nature Neuroscience, 10(4): 423-5). In our present study, we eliminated the influence of temporal frequency adaptation on speed judgements. First we varied the duty cycle of interleaved 5 and 20 Hz adaptation to find, for each subject, the critical ratio at which no change occurred in the perceived speed of a 10 Hz test pattern. We then used those ratios in a second experiment investigating the spatial specificity of temporal adaptation. In this experiment, the adaptor and the standard (10 Hz, 600 ms) always appeared on the right hand side of the fixation point while the comparison (300-1200 ms) always appeared directly on the left of fixation. The standard could appear at the same position, half overlapping (2.5 deg) or completely (5 deg) above and below the adaptation location. We compared the effects of adaptation against a control condition in which subjects made temporal judgements between comparison and standard drifting gratings in the absence of adaptation. In this case trials for the various positions of the standard were blocked. We found that the duration compression relative to the baseline conditions was highly spatially localised, appearing only in the overlapping condition. These results show that temporal duration compression occurs in the absence of changes in temporal frequency or speed and is highly specific to the location of the adaptor.

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33.440 **Task space calibration in Cartesian coordinates**

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Introduction: Numerous studies have shown that visual space: (i) can be adapted following sensorimotor distortion; and (ii) is represented in cyclopean spherical coordinates (e.g. Vetter, Goodbody & Wolpert, 1999). We calibrated participants in a two-dimensional task workspace and tested for error patterns in Cartesian and cyclopean spherical (i.e. polar) coordinates.

Methods: Using methods similar to Mon-Williams and Bingham (2007), we calibrated a) target distance or b) direction in a prehension task and tested generalization across the workspace (participant n=20). The apparatus preserved visual information about the object's location using mirrors but allowed haptic feedback about the object's location to be manipulated. The haptic feedback was changed, one dimension at a time, within a polar coordinate arrangement where the starting location of the pinched thumb and index finger, directly below the eyes, was the origin. In condition one, participants were recalibrated in distance at one location and tested at other angular directions. In condition two, participants were recalibrated in angular direction at one location and tested at other distances. We calculated the difference between pre and post calibration reach errors as a measure of the calibrations' generalization.

Results: The error patterns in both the "calibrate distance" and "calibrate direction"generalized across reach space and together, were best described by shifts in a Cartesian (x,y) coordinate system.

Conclusions: The results suggest that the task did not calibrate performance within a spherical (visual) coordinate system; rather, the adaptation was within a map of the workspace, i.e. an environmental frame of reference. This interpretation is consistent with the task demands, in which the visual input remained constant and the haptic information changed. Participants adapted their performance, rather than the visual information that performance was based on, to maintain accurate prehension. Calibration is therefore a task specific and functional process.

Acknowledgement: The first author was funded by The Wellcome Trust and the Dorothy Campbell Studentship

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Sunday, May 11, 8:30 am - 12:30 pm
Poster Session, Orchid Ballroom

Higher Cortical Processing
Multiple Object Tracking 2
Object Perception: Recognition and Categorization

Higher Cortical Processing

33.501 **TMS-induced oscillations in orientation discriminations**

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Dynamic theories of visual information processing emphasize the importance of recurrent or feedback processing, or continuous updating of visual information, in conjunction with the feedforward cascade of processing through the visual hierarchy (Lamme & Roelfsema, 2000; Bullier, 2001). Transcranial magnetic stimulation (TMS) has proven a powerful tool to study this interactive theory of visual processing with several studies suggesting that primary visual cortex (V1) is required for visual awareness (e.g., Pascual-Leone & Walsh, 2001). TMS has also been proposed to disrupt oscillatory behavior emerging from dynamic interactions between highly-connected regions of visual cortex, possibly disturbing reentry of visual information into V1 from higher level visual areas (Lamme & Roelfsema, 2000). The following experiments explore functional characteristics of these recurrent networks by measuring the impact of TMS over V1 and the motion-sensitive human middle temporal complex (hMT+). Subjects made a 2AFC orientation discrimination on limited lifetime cinematograms moving coherently in a single direction, or on oriented gabors. The 4 deg stimuli were viewed 3 deg in the periphery within the region of visual space affected by the TMS pulse (assessed via reported spatial location of phosphenes as measured prior to the experiment). TMS was applied over V1 or hMT+ at various latencies between 100 msec pre-stimulus onset to 100 msec post-stimulus onset. We find multiple latencies of stimulation affect performance on these tasks, both pre- and post-stimulus onset. Both before and after stimulus onset, the TMS pulses alternately facilitate and impair performance at regular intervals, in an oscillatory manner. The TMS-induced facilitation/impairment alternate at a higher frequency for the motion discrimination. These experiments suggest that a virtual lesion analogy may be inadequate for TM stimulation; instead, the TMS pulse interacts with oscillatory activity in networks processing the visual stimulus.

33.502 **Frontal Eye Field and Visual Motion Discrimination: a Transcranial Magnetic Stimulation study**

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Visual perception is driven not only by feed-forward processing of visual stimuli, but also largely by expectancy. The frontal eye field (FEF) is a candidate region for exerting such top-down control.

The FEF is a cortical region that participates in eye movements control, attention, and vision. Studies in human and non-human primates have shown that FEF activity influences visual activity in remote cortices. We have shown previously that a single pulse of transcranial magnetic stimulation (TMS) applied shortly before the onset of a visual flash facilitates the detection of this target. Silvanto and colleagues have reported that TMS applied over the FEF increases the probability of perceiving phosphenes induced by TMS of MT/V5. The goal of the present study is to investigate whether FEF could also influence discrimination tasks carried out by MT/V5 and modulated by attention.

We applied TMS over FEF or MT/V5 at various times, before or after stimulus onset, while participants had to indicate the direction of coherent motion embedded into a random dot kinematogram presented contralaterally for 50 ms.

Data from four participants show that: (1) TMS applied over MT/V5 at stimulus onset or 100 ms after reduced performance, as expected from previous studies. (2) TMS applied over the FEF 100 ms after stimulus onset also reduced performance. (3) TMS applied over the right FEF at the onset of kinematogram improved performance. (4) TMS applied over FEF increased the probability of participants reporting, correctly or not, a leftwards motion. This was observed for most SOA for the left and right hemisphere stimulation, although the effect was more pronounced for right FEF stimulation.

These results suggest that the FEF can modulate visual motion discrimination in a time-dependent way and that it may be related to directional perceptual biases.

33.503 **Degraded eye proprioception after 1Hz rTMS over the anterior parietal cortex**

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The extraocular muscles have proprioceptive receptors that project to the primary somatosensory cortex (Wang et al., Nat Neurosci, 2007). The role of eye proprioception in oculomotor behavior is unknown. A step in elucidating this role would be to observe this behavior in the absence of proprioception. To the best of our knowledge, no method for acute proprioceptive deafferentation of the eye muscles in healthy humans is currently available.

We aimed to reduce proprioception in the right eye with 1Hz rTMS over the left somatosensory cortex, a method previously shown to reduce hand proprioception (Balslev et al., J. Neurosci 2004). We measured the perceived straight ahead in monocular vision and in darkness, a task sensitive to changes in eye proprioception (Gauthier et. al, Science, 1990). Healthy subjects sat with the head fixed in front of an array of 48 LEDs at 2 degree separation. A random LED was first lit, and the subjects verbally instructed left or right movement until they perceived it to be directly in front of their nose.

rTMS over the somatosensory cortex but not over motor cortex shifted the perceived straight ahead a mean of 3 degrees to the left . This effect can be explained by the underestimation of the angle of gaze of the right eye when fixating the target.

To test whether this effect was related to eye proprioception we applied a passive deviation by pushing the right eye through the closed eyelid before the task. The shift to the left in the perceived straight ahead induced by somatosensory rTMS was significantly reduced by the passive eye displacement. This displacement did not affect the perceived straight ahead at baseline or after motor cortex rTMS.

We suggest that depression of somatosensory cortex using rTMS interferes with the processing of eye proprioception.

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33.504 **Improving the signal-to-noise ratio of the visual P300**

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The P3b (“P300”) [1] of the event-related potential is considered to reflect cognitive —or even conscious [2]— stimulus processing. P300 recording sessions employ an “oddball paradigm”: target stimuli appear only infrequently among non-target stimuli. Thus they are quite lengthy and difficult to use with patients. We tested different strategies for minimizing the time needed to record a reliable visual P300. Targets were gratings of different orientation for target and non-target stimuli. Since previous studies only assessed absolute amplitude [e.g., 3, 4], we first determined the optimal signal-to-noise ratio for different target infrequencies. We found target-to-non-target ratios of 1:4 to 1:8 to be optimal. We next assessed whether shrinking the interval between stimulus onsets from 1000 ms to 214 ms would improve the signal-to-noise ratio when the recording time is kept constant, despite a temporal overlap of responses. This was indeed the case by a margin of up to 60%, but depended on the presentation duration of the stimuli. Finally, we assessed whether it is feasible to record a P300 in a manner similar to a steady-state visual evoked potential with a fixed number of intervening non-targets. We found a high inter-individual variability, but could reliably identify responses in all subjects with a multi-harmonic frequency-space analysis. Compared to conventional P300 recordings, less recording time was needed to acquire significant responses. In conclusion, the signal-to-noise ratio and the efficiency of visual P300 recordings can be improved by choosing optimal target infrequencies and by employing rapid stimulation schemes.

[1] Linden DEJ (2005) Neuroscientist 11:563–576
[2] Kotchoubey B (2005) Progr Brain Res 150:427–444
[3] Johnson Jr R (1986) Psychophysiology 23:367–384
[4] Polich J, Margala C (1997) Int J Psychophysiol 25:169–176

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33.505 Electrophysiological evidence for the role of extrastriate visual cortex in visual awareness

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Recent studies have suggested a critical role for cortico-cortical interactions in human visual awareness. However, to date there is no direct electrophysiological evidence for their involvement. To address this issue, Transcranial Magnetic Stimulation (TMS) was combined with Electroencephalography (EEG) while single pulses of TMS were delivered over right V1/V2 and V5/MT at phosphene threshold. Wavelet event-related power (ERPow) transformation, a measure of the regional oscillatory activity of neural assemblies, was used to identify electrophysiological correlates of conscious perception induced by TMS. The perception of phosphenes induced from the extrastriate area V5/MT was associated with a specific increase in oscillatory alpha-band activity (alpha-syncronization) but not beta-band activity in parieto-occipital regions across the two cerebral hemispheres relative to the pre-TMS power level. This findings demonstrate that synchronization of cortical oscillatory activity is a neural correlate of conscious perception. We also observed a network effect with a modulation of cortical oscillations that spread from the stimulated right parieto-occipital cortex to contralateral homologous regions, presumably via the corpus callosum. While our results clearly demonstrate a role for extrastriate visual cortical areas in visual awareness, it is likely that subcortical structures are also involved in the phenomenon. Indeed, it is possible that stimulation of the cortical cells generates feedback signals to the thalamus, as the thalamus is believed to play an important role in synchronising cortical oscillations. Our results demonstrate the value of the combined TMS/EEG approach when studying cortico-cortical interactions in the visual system. As interactions between cortical regions are central to most current theories of visual awareness, this approach will undoubtedly be pursued in future studies.

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33.506 The role of feedback in visual masking, visual awareness and attention

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We discuss the role of feedback in visual masking, visual awareness and attention. Our analysis reveals constraints for feedback mechanisms that limit their potential role in visual masking, and in other general brain functions. We propose a feedforward model of visual masking, and provide a hypothesis to explain the role of feedback in visual masking and general visual processing. We review the anatomy and physiology of feedback mechanisms, and propose that the massive ratio of feedback versus feedforward connections in the visual system may be explained solely by the critical need for top-down attentional modulation.

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33.507 Neural correlate of visual awareness in the superior colliculus of the animal model of blindsight

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Human blindsight patients, who have damages in the primary visual cortex (V1), can discriminate the target positions while they deny awareness of the targets. Macaque monkeys with a unilateral lesion in V1 have been used as an animal model of blindsight. Here we sought for neural activity related to blindsight behavior. First, we examined whether the monkeys showed behavior analogous to human blindsight patients. Two macaque monkeys with a unilateral V1 lesion were tested with two saccade tasks. 1) A forced-choice (FC) task, in which the saccadic target comes on one of two possible positions, requires discrimination of target positions. 2) A yes-no (YN) task, in which the monkeys have to maintain fixation when the saccadic target is absent, requires detection of the target. When the target was presented in the ipsilateral hemifield, the monkeys' performance was more than 95 % in both tasks. On the other hand, when the target was presented in the contralateral hemifield, the monkeys had a better performance in the FC task than the YN task. These results suggest that the monkeys exhibit behavior that parallels to the human blindsight patients. Next, we recorded neural activities from the superior colliculus (SC) of the monkeys performing the YN task. The tasks were modified as a delayed saccade version so that the neural response to the visual target was dissociable from saccade-related activity. We found that the transient response of the ipsilateral SC to the visual target was larger when the monkeys successfully detect the target than when the monkeys missed it in the YN task. Such modulation was not found in the contralateral SC. We conclude that the transient response in the ipsilateral SC comprises a part of neural correlates of reduced visual awareness specific to blindsight.

33.508 No McCollough effect in a patient with cerebral achromatopsia but spared V1

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The McCollough effect is a colour aftereffect contingent on pattern orientation. It has been extensively studied and, historically it has been thought to be mediated by the primary visual cortex (V1). However, more recent neuroimaging data has shown left V4 is involved in the induction of theMcCollough effect (Morita et al, 2004). To determine whether the primary visual cortex is sufficient to drive the McCollough effect or whether connections to higher cortical colour areas are necessary, we tested a patient with acquired brain damage to ventrotemporal cortex but spared V1 in one hemisphere (SB) and controls. Patient SB lacks orientation discrimination and has cerebral achromatopsia but has been shown to have some subconscious colour discrimination ability forhighly saturated colours (Lê et al., 2002). A similar experiment was conducted with Patient DF who has similar deficits but shows conscious colour discrimination (Humphrey et al., 1991). Here we asked whether this effect could be induced in a patient without conscious colour abilities. Participants performed a 2AFC same/different orientation discrimination task for oblique pairs or vertical/horizontal pairs of square wave gratings. Participants then adapted to highly saturated red and green oblique gratings for 20 minutes before re-testing on the orientation discrimination task. Control participants were better at discrimination of horizontal and vertical gratings compared to obliquely oriented gratings in the pre-adaptation period—this is the well-known Oblique effect. Following adaptation, control participants showed the greatest improvement for oblique compared to horizontal/vertical grating discrimination. Post-adaptation, the more difficult oblique orientation discrimination judgments were a simpler colour discrimination judgement as a result of McCollough adaptation. SB, however, did not show improvement specifically for oblique gratings. This suggests that V1 must be connected to higher cortical colour areas to drive McCollough adaptation.

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33.509 Cortical Lesion Projection Zone Activity in Retinal Disease Patients is Caused by Object-Specific Feedback, Not Plasticity

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Retinal degenerative diseases like macular degeneration offer a means to investigate adult cortical plasticity in retinotopic visual cortex following topographically-constrained loss of retinal input. Functional neuroimaging studies of stimulus-driven activity in the cortical lesion projection zone (LPZ) have provided conflicting evidence regarding plasticity. Baker et al. (J. Neurosci. 2005) reported cortical remapping in a one-back task with object stimuli in two patients with impaired foveas, while Sunness et al. (Ophthalmology 2004) observed little or no remapping using a contrast-reversing checkerboard stimulus in a patient with a spared fovea. This suggests that the absence of foveal input is critical for remapping. Evidence from three patients reported by Masuda et al. (VSS 2007) provides an account of remapping in which postulated cortico-cortical signals modulate activity in the LPZ during a one-back task (but not during passive viewing), suggesting that LPZ activity depends on task rather than stimulus. We used fMRI in patients with no spared fovea during a blocked one-back task (using either full-field faces or scrambled faces in each block), and during viewing of full-field contrast-reversing checkerboards. On Baker's account, we should observe activity in the LPZ in all conditions (due to cortical remapping). On Masuda's account, we should observe remapping during the one-back task but not during checkerboard stimulation. We observed large inactive areas near the occipital pole for all patients during checkerboard stimulation. Furthermore, we observed activity in face-selective extrastriate cortex during face (but not scrambled-face) epochs of the one-back task, confirming face detection. Critically, a contrast of activity during the face versus scrambled-face epochs of the one-back task produced LPZ activity in some patients. Thus, our data suggest that when activity in the LPZ is observed, it is due to feedback from object-specific cortex, rather than cortical plasticity or the memory demands of the one-back task.

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33.510 Response lateralisations in visuo-motor cortex and consequences of abnormal visual input

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Purpose: A dominance of the representation of the contralateral visual field is evident not only in occipital, but also in parietal visual areas. Here we devised a paradigm to activate great expanses of visual, visuo-motor, and motor cortex for a separate assessment of the visual and motor response lateralisations. This paradigm was applied in humans with normal visual input and in albinotic humans with abnormally lateralised input to V1.

Methods: Brain activity was studied during a visuo-motor task in 14 controls and 14 albinotic subjects (3Tesla, Siemens; SPM5; event-related design): While the subjects fixated a central dot monocularly, a coloured target embedded in an array of grey distractors (6.5°x6.5°; centered at 5.5° from fixation) was presented for 250 ms either in the left or right visual hemi-field. After a variable delay the subjects were to indicate the target-location by pressing the upper or lower response button with the left or right thumb for blue and red targets, respectively.

Results: (1) Normal input to V1 resulted in representations of the contralateral visual field in occipital visual areas, in area MT, and in the intraparietal sulcus (IPS1-IPS3). While there was little or no activity in somatosensory (BA1-3) and motor areas (BA4 and BA6) during visual stimulation, these areas responded contralaterally to the effector during the motor response. Early visual areas were also activated during the motor response, remarkably with dominant activities ipsilateral to the preceding visual stimulus. (2) Abnormal input to V1 induced lateralisation abnormalities of responses in occipito-parietal areas during visual stimulation, but left somatosensory- and motor-responses unaltered.

Conclusion: Contralateral visual field representations appear to be a fundamental characteristic not only of occipical, but also of parietal visual areas in humans. However, this representation principle appears to be severely disrupted by abnormally lateralised input to V1 as evident in albinotic subjects.

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33.511 Does cortical reorganization lead to a corresponding change in readout?

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Recent studies have demonstrated reorganization of retinotopic cortex in some individuals with macular degeneration (MD): stimuli presented to the subjects' visual periphery activate cortical regions that are normally responsive only to stimuli presented at the fovea (Baker et al., 2005). Here we asked whether this cortical reorganization leads to a corresponding change in the interpretation, or "readout" of the activation in the altered part of the cortical map. That is, when normally-foveal cortex is activated, do subjects with an altered cortical map perceive the stimulus to be at the fovea (according to the original "meaning" of this activation), or at the periphery (in the location that now drives this part of cortex)? The latter result would imply that the interpretation of information from reorganized cortex has changed accordingly; the former result would imply it has not changed. To answer this question we compared the effects of transcranial magnetic stimulation (TMS) to the occipital pole in control subjects and two individuals with MD who showed massive reorganization of the normally-foveal cortex as revealed by fMRI (see Baker et al. 2005). TMS elicited a sensation of faint light (phosphenes) in the central visual field in all (n=10) control subjects. TMS led to distinctly different outcomes in the two MD subjects. One MD subject systematically reported the phosphenes near the center of gaze, in locations where he had no visual experience for years. The other MD subject consistently reported phosphenes in the visual periphery, about ~20deg from the fovea where none of the control subjects ever reported a phosphene. Thus, the second subject showed a change in the readout of his reorganized cortical map, but the first subject did not. Future work will attempt to identify the critical factors that determine if a change in readout will occur following cortical reorganization.

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33.512 Object representations in the dorsal pathway: fMRI adaptation effects in macaque posterior parietal cortex

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The visual system is divided into two separate pathways, which are specialized for functionally distinct tasks (Ungerleider & Mishkin 1982). The dorsal stream is directed into the posterior parietal cortex (PPC) and is associated with visually guided action, while the ventral pathway is directed into the temporal cortex and is involved in object recognition. Using fMRI-adaptation under passive viewing conditions, we previously reported object-selectivity in two topographically organized areas in human PPC (Konen & Kastner 2008). Electrophysiological studies in non-human primates have shown shape-selectivity in neurons of the lateral intraparietal (LIP) area (Sereno & Maunsell 1998). Here, we used fMRI-adaptation in monkeys in order to investigate object-selectivity at a larger scale in PPC. The monkeys were trained to maintain fixation while passively viewing geometric objects such as 2D-objects.

At least two areas along the intraparietal sulcus exhibited object adaptation effects, i.e. the signal was reduced when identical objects were presented repetitively compared to an equivalent number of non-repeated objects. One area was located in the lateral bank (LIP) and the other area was located ventral (VIP) in the intraparietal sulcus. The response profiles found in these areas were similar to those in TEO, an area of the ventral stream thought to be critical for object recognition.

Taken together, our results indicate object-selectivity in more than just one area of monkey PPC. Importantly, the dorsal object responses were found under passive viewing conditions and thus independent of a behavioral context that required action planning. Furthermore, the findings were strikingly similar as compared to human PPC.

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33.513 **Repetition suppression and category selectivity in the human ventral stream: fMRI evidence for the scaling model**

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When specific stimuli are repeated, neural activity to these stimuli in the ventral stream is reduced. This is referred to as repetition-suppression (RS). It is unknown whether RS as measured with fMRI reflects reduced firing of the neural populations responding to the repeated stimulus proportional to the initial response (referred to as "scaling"), or whether RS reflects a reorganization of the neural representation in which less neurons respond to repeated stimuli and the tuning of neurons selective to the stimulus becomes narrower (referred to as "sharpening"). Critically, scaling predicts that RS is largest to the preferred stimulus, while sharpening predicts smallest RS to the preferred stimulus. Therefore we examined the relation between RS and category selectivity in the human: (i) object-selective cortex (the lateral occipital complex, LOC), (ii) face-selective regions in the fusiform gyrus (Fus), the inferior occipital gyrus (IOG), and the posterior superior temporal sulcus (pSTS), (iii) body part-selective regions in the Fus and the IOG, and (iv) house-selective regions in the parahippocampal gyrus (PHG). Ten subjects performed a categorization task while viewing repeated and nonrepeated images of faces, limbs, flowers, cars, guitars, and houses in a high-resolution fMRI scan (1.5 x 1.5 x 1.5 mm). We measured the effects of RS and category selectivity within these regions of interest (ROIs) that were defined from separate localizer scans. Our results indicate that significant RS occurred for all categories in the LOC as well as within the category-selective regions. That is, within all ROIs, RS occurred to both preferred and nonpreferred categories and RS was largest for the preferred category. Furthermore, the level of RS was linearly correlated with the initial response – larger responses were coupled with larger RS. Overall, our data supports the scaling model for RS in the ventral stream.

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33.514 **Colour and texture processing in human extrastriate cortex: An fMRI study**

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Purpose: A neuroimaging investigation was conducted to determine the visual areas of the human brain involved in the discrimination of visual textures and wavelengths.

Methods: Six healthy adults performed forced-choice, match-to-sample tasks within a 1.5T whole body clinical MRI. A block design was used in which the ability to match target and choice patches on the basis of wavelength or texture was assessed separately for isoluminant colour patches from the red, yellow and blue regions of colour space and for Brodatz textures. Participants completed five blocks for each of the four types of visual stimuli.

Results: Relative to a fixation condition, discrimination of colour and visual textures resulted in distinct but significantly overlapping patterns of activation. Both wavelength and texture discrimination were accompanied by increased activation in the left striate and left lingual gyrus. Unique activation for texture or wavelength discrimination was limited to extrastriate areas. Wavelength discrimination uniquely activated more anterior areas, including the left posterior fusiform gyrus (-22, -65, -13) and right lingual gyrus (6,-84,-10); the overall patterns of activation in these areas appeared to demonstrate a dependency on wavelength. Texture showed a smaller regional extent of activation that was more posterior than that for wavelength.

Conclusions: Our study, which employed an active discrimination task rather than the more commonly employed passive viewing, suggests that colour discrimination uniquely activates an area of lingual and fusiform gyri that may represent the human homologue of area v4 in macaque. Furthermore, our results support a human homologue of the wavelength-dependent organization within extrastriate colour processing areas that has been demonstrated previously in macaque. Despite the role of middle temporal areas and anterior fusiform gyrus in form processing, activation in this area was not greater during the discrimination of visual textures than during the discrimination of similar wavelengths.

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33.515 **Identification and characterization of the Visual Character Form Area (VCFA) in Chinese readers and illiterates**

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Written language represents a special category of visual information. Literate people have extensive visual experience and expertise with written language, yet reading skills have to be acquired with serious effort over many years. The question of whether there are specialized neural mechanisms and cortical modules for visual word processing is important and remains debated. Three issues were investigated in this study: category selectivity in the mid-fusiform cortex, orthographic sensitivity of the presumed VCFA, and experience-dependency of its development. First, we examined category selectivity for Chinese characters in native Chinese readers as well as native Chinese illiterates and native English readers. A detailed distribution of BOLD signals across the mid-fusiform cortical surface and the spatial pattern of responses to Chinese characters were obtained. Results show that a region with peaked response to Chinese character-like stimuli could be consistently found in the lateral part of the left fusiform gyrus in Chinese readers. Additionally, different levels of orthographic properties (i.e., characters, false-characters consisting of radicals in wrong positions, radicals, and stroke combinations) of an input stimulus were reflected in differential spatial patterns of activation across voxels, with the left lateral mid-fusiform region showing the highest specificity for Chinese characters. Finally, minimal responses to Chinese characters were found in Chinese illiterates and English readers, supporting the idea that functional specialization and response selectivity to written language in the mid-fusiform cortex is experience dependent.

Multiple Object Tracking 2

33.516 **Object-specific preview benefit enhanced during explicit Multiple Object Tracking**

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Object file theory provides a framework for object representations and is demonstrated by an object-specific preview benefit (OSPB) (Kahneman, Treisman & Gibbs, 1992). This framework supports object-based attention by showing that a priming effect for object identity travels with the object in which information initially appeared. The present study explores OPSB effects during Multiple Object Tracking (MOT).

In Experiment 1, four identical circles moved unpredictably in MOT and a preview letter appeared in one circle during the trial. At the end of the trial a test letter appeared and subjects had to indicate whether or not the test letter matched the preview letter (SOAs between preview and test letters varied at 1, 2, and 4 seconds). Subjects' reaction times in matching letter conditions (i.e., same preview object versus different object) showed a significant OSPB effect of 90 ms (p=.000) for the 1-second SOAs, and this benefit was reduced with longer SOAs. In Experiment 2, two preview letters were presented in two objects. The results exhibited similar patterns as Experiment 1 but with a smaller preview effect (47 ms; p=.013).

To explore the effect of explicit tracking in Experiment 3, two preview letters were shown within two circles prior to object movement (constant 4-second SOAs). In block 1, no explicit tracking was required. In block 2, subjects tracked and identified the circles that had contained letters in addition to judging whether a test letter was one of the preview letters. There was no OSPB effect in the nontracking condition (replicating the 4-second SOA results in Experiment 2), but there was a significant preview effect of 94 ms (p=.000) in the explicit tracking condition.

These findings replicate the original OSPB experiments but using the dynamic MOT framework and suggest that explicitly tracking objects extends the OSPB effect.

33.517 What limits performance in multiple object tracking?

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Multiple object tracking (MOT) is a common task used to investigate limitations on human visual attention. However, the nature of these limitations is still unknown. A priori, there are at least four plausible constraints that could limit performance. First, there could be a fixed upper bound on the number of objects tracked. Second, there may be a limit on sampling speed, a possibility consistent with a hypothesized 'alternating spotlight' of attention. Third, there may be limits on memory for the velocity and position of any particular object (a fixed resource determines the precision of memory for the tracked objects). Finally, there may be a limit on the precision of observations, consistent with the hypothesis of a fixed distribution of attentional enhancement which improves sensitivity in particular regions of space. The multiple object tracking task is computationally identical to an "aircraft tracking" problem (finding the correspondence between objects from one time to the next). Therefore to model human performance in MOT, we implemented a probabilistic tracking model and included each of the four constraints described above. Experimental data on MOT show a standard pattern: as the number of objects increases, human tracking performance decreases. Consistent with work by Alvarez & Franconeri (in press), putting a simple limit on the number of objects our model can track does not account for existing patterns of data. However, simulations with limited memory, limited precision, and limited sampling speed all produced a close fit to existing datasets. We describe the probabilistic model we used to conduct these simulations as well as a set of experiments in progress in which we independently vary both the predictability of object motion and the sample rate of object displays.

33.518 Online measurement of dynamic changes in tracking load

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In the multiple-object tracking paradigm (MOT), subjects are asked to covertly track several target objects simultaneously as they move randomly amongst identical distractors. Our previous electrophysiological experiments have shown that the sustained contralateral delay activity (CDA) provides an online neural measure of the number of objects being actively tracked (Drew & Vogel, VSS 2006). Recently, Wolfe, Place, & Horowitz (PBR 2007) have demonstrated that observers can dynamically change which items are being tracked during the course of the trial. Here we utilized the CDA to study the neural mechanisms underlying this process.

Observers fixated centrally while performing a lateralized MOT task. They tracked a changing subset of items in one hemifield while ignoring similar stimuli and events in the opposite hemifield. Observers initially tracked either one or three targets. On 50% of trials, a switch cue instructed observers to either add or subtract targets. This yielded four types of trials. On add trials, an observer tracking one target would end up tracking three, while on subtract trials, an observer tracking three targets would drop to one. On constant-1 and constant-3 trials, the target set was unchanged. Behavioral data indicated that observers were following instructions: performance on add trials matched performance on constant-3 trials, while performance on subtract trials matched that on constant-1 trials.

On add trials, CDA amplitude increased from constant-1 to constant-3 levels within roughly 500 ms post-cue. In contrast, on subtract trials, CDA amplitude took over 1000 ms post-cue to decrease from constant-3 to constant-1 levels. This may reflect a form of attentional hysteresis, as subjects appear to continue tracking items after the switch cue despite the attentional cost of tracking irrelevant items. The CDA provides a method for measuring rapid dynamic changes in tracking load.

33.519 Separating specific from general learning in a napping paradigm on Multiple Object Tracking and Rotary Pursuit tasks

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INTRODUCTION: Some perceptual learning studies report that improvement is stimulus-specific, while others argue for generalized learning. We investigate this discrepancy by examining tasks that have opportunities for both types of learning (stimulus-specific and general) in a napping paradigm. We utilized the Multiple Object Tracking (MOT) task (ala Yantis 1992), which examined whether perceptual grouping via speed cues (stimulus-specific) influenced attentional object tracking (general). In addition, we utilized a Rotary Pursuit Task (ROT), which examined whether improvement was due to pattern extraction (stimulus-specific) or visuomotor improvement (general). METHODS: Subjects were tested twice in one day (9AM and 5PM). Subjects either had a polysomnographically recorded nap or quiet rest (listening to relaxing music on headphones) between 1-3PM. At the start of session one, a speed discrimination threshold at 66% correct was obtained for each subject and applied to the speed of objects in MOT. Four MOT conditions were tested: all high velocity, all low velocity, target high velocity/nontarget low velocity, and target low velocity/nontarget high velocity. If learning on the MOT was stimulus-specific, nappers would show greater learning for the segregated-speed conditions than the uniform-speed conditions. In the ROT, subjects used a mouse to track a red dot moving on the computer screen. The dot trajectory was created by adding two horizontal and one vertical sine wave. In session one, two conditions were tested: a patterned and a random trajectory. In session two, four conditions were tested: patterned, patterned rotated by 90°, random, and random rotated by 90°. If learning on the ROT was stimulus-specific, nappers would only show improvement for the patterned conditions. RESULTS: In MOT, subjects showed general improvement and no preference for segregated conditions. In ROT, learning is shown for patterned, but not for random conditions. We hypothesize that the specificity of learning is task-dependent.

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33.520 Multiple object tracking is surprisingly robust to abrupt onsets

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There has been much debate over whether salient but irrelevant items ('singletons') ubiquitously capture attention in a bottom-up fashion. There seems to be general agreement, however, that abrupt onsets capture attention. Most of the evidence has come from cueing or visual search paradigms, where presentation of the target display is effectively an abrupt onset (potentially making an abrupt onset singleton relevant). However, in the natural environment, objects of interest may move and vary in a continuous fashion. Here, we used a multiple object tracking paradigm to study the effect of irrelevant singletons on a continuous attentionally-demanding task. Our stimuli comprised a set of identical, independently moving disks. Observers tracked a subset of target disks for several seconds, and reported at the end of the trial whether a randomly selected disk was a target or not. In Experiment 1 (N = 16), an irrelevant stationary singleton appeared at some point during the trial, and remained visible until the end of the trial. Control singletons were present from the start of the trial, before the tracking phase, while onset singletons appeared abruptly during the tracking phase. Singletons could be unique in colour, shape, both, or only in being stationary. We observed no difference between onset and control singletons, regardless of salience. In Experiment 2 (N = 16), singletons moved according to the same algorithm as the tracking disks, and could be identical to the tracking disks (additional distractor) or different in colour. We also added a no-singleton baseline condition. Here, the colour singleton impaired performance relative to the baseline condition, while there was no effect of an additional distractor. Again, however, there was no difference between onset and control singletons. These results demonstrate that performance on a continuous tracking task is surprisingly robust to the abrupt onset of irrelevant singletons.

33.521 Object localization at speeds below and above the attentive tracking limit

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Attending to a moving object helps to keep track of it among other objects. We wondered what the consequences for object localization would be if attentive tracking were prevented by using objects traveling too fast to be tracked. We measured performance in a position judgment and a sensorimotor synchronization task for a range of speeds above and below the limit of attentive tracking. To measure the tracking limit, a luminance-defined blob among identical distractors orbiting the fixation point was cued at the beginning of an interval of orbiting and subjects attempted to identify it at the end. A low speed limit of 1.5 rps was found, replicating Verstraten, Cavanagh and Labianca (2000). To test position judgments, one to four blobs orbited fixation. The task was to report a blob's position at the unpredictable time of a cue such as a change in fixation color. Finally, in the sensorimotor synchronization task, the same subjects were asked to press a button at the moment the blob became aligned with a stationary landmark. Responses in the sensorimotor synchronization task were much more precise, indicating that the position judgment task underestimates our abilities. For both tasks however, precision was constant in temporal units regardless of blob speed – the standard deviation of responses corresponded to ~100 ms of the blob's trajectory for the position judgment task, and ~50 ms for the sensorimotor synchronization task. The absence of a drop in precision at high speeds indicates that neither task relies on attentive tracking. This was especially surprising for the synchronization task, as estimating time-of-alignment might benefit from the progressive updating of position and velocity earlier in the trajectory. Moreover, there was no relationship between speed and the bias in position judgments (a.k.a. the flash-lag effect), further dissociating attentive tracking and object localization.

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URL: http://www.dlinares.org/tracking/

33.522 **The interdependence between multiple attentional foci in attentive tracking**

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Previous research reveals that several independently moving objects can be tracked with attention, suggesting that attention may be split into multiple, independent foci. This study aims to test whether the attentional foci are fully independent of each other, or whether they are yoked together during tracking. We asked viewers to track 4 designated moving circles among a field of 8 circles and measured tracking accuracy as a function of the objects' motion characteristics. In Experiment 1, all eight objects moved at the same speed on a given display (the speed could be slow, medium, fast, or very fast on different trials), or the four targets moved at four different speeds among nontargets that also moved at these four speeds. In both conditions speed did not distinguish the tracking targets from nontargets. However, tracking was better when all objects moved at the same speed than when they moved at different speeds. This finding suggests that multiple attentional foci are interdependent and function best at a uniform speed. Experiments 2 and 3 introduced redundancy in motion trajectories, such that a varying number of objects moved briefly in parallel to each other on 50% of time during a motion trial. Tracking accuracy was higher when the number of correlated targets or correlated nontargets increased but did not change when the motion trajectories of targets were correlated with those of nontargets. This finding suggests that the correlation was used to establish segregation between targets and nontargets. We conclude that multiple attentional foci are not completely independent but are yoked to facilitate perceptual segregation of attended from unattended objects.

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33.523 **Attention to the Center of the Target Array During Multiple Object Tracking**

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Previously we established that, when tracking multiple objects, people tend to look at the center of the array of targets rather than saccade from target to target. The present goal was to determine whether participants attend to the location of their eye gaze during multiple object tracking. While it is possible to dissociate attention from fixation, people may attend to where they fixate as much as to peripheral targets. In the first experiment observers tracked 4 of 10 randomly moving dots. In addition to tracking, participants were asked to detect the presence of a brief flash that could occur either on a dot or the background. Eye movements were recorded using an ASL 120 Hz video-based eye tracker. Results replicated previous work by showing that gaze was closer to the targets' centroid – the center of the shape formed by the target dots – for significantly more of the time (40%) than to any of the target dots (10%). Flash detection was better for flashes presented at the centroid (99%) and on targets (86%) than for those presented on distractors (72%) and blank space (76%). Equating for eccentricity, performance showed a similar, but not significant, trend. This result suggests that the center of the target array may be attended in addition to the targets. A second experiment determined whether the center was inhibited when a distractor item was presented at its location. No flashes were presented. On some trials, a target or distractor dot was shown at the centroid. Participants continued to look at the centroid when there was a distractor item there (53%), even more so than when nothing was presented there (34%). Together, the results of these two experiments suggest that people pay attention to the center of the target array when tracking multiple objects.

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33.524 **Spatial Attention in Multiple Object Tracking: Evidence from ERPs**

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In multiple object tracking (MOT) tasks participants are typically asked to keep track of a set of target items presented among identical distractors as they move around a display. Typically, participants perform this task accurately when tracking up to about four items. Although the object-based nature of this tracking ability has been demonstrated in a variety of ways, it may be that spatial attention also plays a role. The current work used the N1 component of the human event-related potential (ERP) to determine if spatial attention is preferentially allocated to target items during MOT. Participants tracked two of four objects as they moved around a display. In order to measure ERPs, probes (i.e. white flashes) were presented randomly on targets, distractors, or the background. Since the amplitude of the N1 is known to be affected by the allocation of spatial attention, we reasoned that if spatial attention tracks objects during MOT then probes presented on target items should produce larger amplitude N1s than probes presented on distractors or background locations. In accordance with this prediction, we observed larger amplitude N1s for target probes, but this effect was only reliable at electrode locations over the left hemisphere for probes presented in the right (contralateral) visual field. These results, at least in part, support the idea that spatial attention may be used to track objects during MOT. They also suggest that the left hemisphere may be particularly important in MOT.

33.525 **Abrupt viewpoint changes during multiple object tracking**

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Humans are able to track several independently moving objects among identically looking distractor objects. However, the question of whether this ability relies on allocentric or retinocentric coordinates is part of a controversial debate. Liu et al. (2005; J. Exp. Psychol. Human, 31:235-247) showed that multiple object tracking (MOT) in a 3D-scene is robust against smooth movements of the whole scene and concluded that MOT relies on allocentric coordinates. On the other hand, Seiffert (2005; J. Vision, 5:643) showed that retinocentric coordinates are important for MOT in 2D-displays. In her experiments, MOT was impaired if a 2D-display was shifted smoothly across the retina either as a result of eye movements around a stationary display or as a result of display movements while eyes were fixated. MOT was also impaired if a 2D-display was translated abruptly without overlap between the two views. We studied MOT in dynamic 3D-scenes and introduced abrupt and unpredictable viewpoint changes, but gradually varied the change by rotating the entire scene either by 10°, 20°, or 30° during a filmic cut. In the reported experiment, observers tracked targets that moved independently among identically looking distractors on a rectangular floor plane. The tracking interval was 11s. Abrupt rotational viewpoint changes of 10°, 20°, or 30° occurred after 8 s. Accuracy of tracking targets across a 10° viewpoint change was comparable to accuracy in a continuous control condition, whereas viewpoint changes of 20° and 30° impaired tracking performance considerably. This result suggests that tracking is mainly dependant on a low-level process whose performance is saved against small disturbances by the visual system's to compensate for small changes of retinocentric coordinates. Tracking across large viewpoint changes succeeds only if allocentric coordinates are remembered to relocate targets after displacements.

URL: http://www.iwm-kmrc.de/cybermedia/mot-exp1/

33.526 Contour Interpolation Affects Multiple Object Tracking

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Question: Subjects can simultaneously track four target objects that move among an equal number of moving distractors. It is unknown whether inter-object contour relations—especially those that promote interpolation— can affect multiple object tracking. Method: Ten subjects each performed 160 trials in which four out of eight moving objects were tracked. Objects appeared initially as circles, changed into wedged circles with movement onset, and returned to full circles 1 sec before movement cessation. There were four conditions. In two conditions, wedged circles always produced two interpolated (Kanizsa) quadrilaterals that changed shape with object movement. To ensure that quadrilaterals never collapsed, two objects were confined to each quadrant - one was always a target and one always a distractor. In the first interpolation condition, four targets formed the vertices of one of the interpolated quadrilaterals (TI condition). In the second condition, two targets aligned with two distractors to form each of two interpolated quadrilaterals (TDI condition). In two otherwise identical control conditions, the wedged circles were oriented outward to block perception of an interpolated figure. In these trials, all four targets maintained a constant contour relation toward one another (TC condition), or a set of two targets and two distractors maintained such a relation (TDC condition). Results: The difference between the TI and TDI conditions was greater than the difference between the TC and TDC conditions. Tracking was reliably worse in the TDI than in either the TI or TDC conditions. Conclusions: These data suggest that contour interpolation, though perhaps not other sorts of contour relations, can influence the ability to track multiple objects at a time. The data further suggest that contour relations of even unattended objects can affect multiple object tracking.

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33.527 A Dynamic Neural Field Model of Multi-Object Tracking

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The Multi-Object Tracking (MOT) task has been a central tool for studying object-based attention and the nature of the connection between on-line percepts and the location of objects in a scene. Despite a long empirical tradition, there are few formal models that specify the processes that underlie performance in this dynamic task. Here we propose a Dynamic Neural Field (DNF) model that captures the central empirical effects in this literature and integrates multi-object tracking with other known characteristics of the visuo-spatial cognitive system.

Our DNF model has three layers of spatially-tuned neurons. The first layer—the perceptual layer—receives input from the world and forms activation "peaks" that are stabilized by input. The second layer—the working memory layer—receives both direct input from the world as well as input from the perceptual layer. This field is able to form self-sustaining peaks that maintain activation even when input is removed. Finally, both the perceptual and working memory layers are reciprocally connected to a shared layer of inhibitory interneurons.

To explain the model's performance, consider a single trial that begins with the presentation of 6 objects, 3 of which are cued. In response to this input, the DNF model forms 6 stabilized peaks of activation in the perceptual layer and three working memory peaks due to the strong input at three locations. These activation peaks are maintained by locally-excitatory and laterally-inhibitory interactions. Consequently, once the inputs begin moving the activation peaks in working memory track their associated inputs provided that the inputs are within the range of locally-excitatory interactions. Moreover, the peaks maintain their fidelity via lateral inhibition even when they come near other peaks. We will show how this basic architecture can perform the MOT task and show proximity effects as well as the ability to track objects behind occluders.

33.528 Impact of stereoscopic vision and 3D representation of visual space on multiple object tracking performance

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Classical multiple object tracking (MOT) studies use 2D visual space representation. Also, they do not take into account stereoscopic vision capacity that allows better discrimination between the relative positions of multiple objects in space. However, our reality is a 3D world where multiple objects move at different depth position with different speeds. We have conducted several experiments to evaluate the impact of different non-stereoscopic and stereoscopic representation of space on MOT performance. Moreover, instead of measuring the number of targets that can be tracked, we have used a new kind of measure based on the evaluation of the greatest speed at which the observer is capable to track a set of moving targets (four targets). This kind of measure allows a more precise threshold measurement to discriminate the performance of two observers that can track the same number of targets. The results of our experiments have shown that, relative to the non-stereoscopic conditions, significantly better speed thresholds were obtained with the stereoscopic representations of space. These results suggest that to better conform to our reality, 3D representation of the visual space should be use to optimally measure MOT performance. Finally, contrary to the classical method using the number of objects tracked, the evaluation of the speed threshold for a set of moving target appears to be a better representative measure to differentiate MOT performance between individuals.

33.529 Early Adulthood Losses in the Effective Number of Tracked Trajectories in Human Vision

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Human performance in most visual tasks is known to reduce with age, with the rate of decline being task dependent. Here we investigated how performance in a multiple object tracking (MOT) task is affected by age. The stimuli consisted of 8 dots that moved along linear trajectories from left to right at a speed of 3.76 deg/s. At the midpoint of their trajectories, a certain number of dots, D (1, 2 or 3), deviated either clockwise or counter-clockwise by a certain magnitude (57°, 38° or 19°), and the task for observers was to identify the direction of deviation. Percent correct responses were measured for 22 observers aged 18 to 62 years (mean = 35.3 years, SD = 13.0 years) and these were converted to effective numbers of tracked trajectories (E) using techniques described in Tripathy, Narasimhan & Barrett (2007, Journal of Vision, 7:6:2:1-18). For each combination of D and magnitude of deviation tested, values of E were plotted against age and regression lines were fitted to the data. In 5 out of the 7 experimental conditions tested, the regression line had a significant negative slope, indicating an age-related decline in E. Furthermore, when performance was averaged across different values of D, there was a significant negative correlation between age and E for each of the three magnitudes of deviation tested. The rate of decline over the age-range tested was found to be equivalent to 0.38 trajectories per decade for deviations of ±57°, 0.36 trajectories per decade for ±38°, and 0.12 trajectories per decade for ±19°; this corresponds, approximately, to a 15% drop in performance for each decade of our adult lives. Performance in this tracking task begins to drop relatively early in adulthood, rather than remaining constant over much of adult life and then decreasing in middle or old age.

Object Perception: Recognition and Categorization

33.530 Rapid Object Category Detection in Visually Degraded Stimuli

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Thorpe et al. (1996) showed that humans can detect the presence of object categories in natural images in as little as 150ms. The purpose of our study is to see if this rapid category detection is possible in the context of visually degraded images. Previous studies have demonstrated that humans can accurately process images in severely degraded conditions. Harmon and Julesz (1973), and Bachman (1991) demonstrate that only 18x18 pixels per face are sufficient for robust recognition, and these findings have been extended to the domains of objects and scenes by Torralba et al. (2007). Along the dimension of luminance depth, Mooney faces are a classic demonstration of visual processing working in extreme cases of luminance depth degradation. However, it is not clear whether or not rapid category detection is possible in visually degraded images.

In this study, we explore the phenomenon of rapid object categorization in the context of both singly and multiply degraded images. Our experimental setup is modeled after Kirchner et al.'s (2006) 2AFC Animal/Non-Animal detection task. In each trial, subjects are flashed a pair of natural scenes for 30ms where only one scene contains an animal. Subjects are directed to choose the image containing an animal and measured for accuracy in different conditions. In our first experiment, each condition contains images degraded to different degrees along one of the following dimensions: spatial resolution, luminance depth, contrast, inversion and reverse contrast. In our second experiment, each condition contains images degraded along pairs of the aforementioned dimensions. We find that even with severe degradation, such as natural images with only 50x38 pixels or 1 bit plane, humans can rapidly identify images containing animals with high accuracy. For multiply degraded images, we find subjects' performance impacted by a non-linear interaction between different types of degradation.

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33.531 **Do you know what it is as soon as you know it is there?**

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Object recognition involves different steps of visual processing, such as detection, categorization and identification. A previous study on object recognition reported counter-intuitive results that basic-level categorization occurred as accurately and fast as object detection (Grill-Spector & Kanwisher, 2005). However, we often experience that object detection is faster than categorization. We suspected that the null results found in the previous study might be due to either lack of sensitivity in their measurements or insufficient modulation of task difficulty. In Experiment 1, the exposure duration was more finely varied from 1 to 5 frames (1 frame: 11.7ms) as compared to the previous study. Object detection performance was better than basic level categorization when the exposure duration was from 2 to 4 frames. In Experiment 2, we measured thresholds for each task. To measure thresholds, percentage of visual signal was manipulated by scrambling images. The threshold was defined as the level of visual signal in which participants detected/categorized images. Participants' threshold (38.8%) in the detection task was significantly lower than that (48.5%) in the categorization task. In Experiment 3, we increased the task difficulty by introducing positional uncertainty. Specifically, the location of the target to be detected/categorized was randomly chosen among multiple locations. We simultaneously presented 100% scrambled images in the rest of the locations. The number of locations was either 2, 4, or 8. Participants' performance decreased as the number of locations increased in both tasks. More importantly, overall accuracy in the detection task (95.3%) was significantly higher than that (67.9%) in the categorization task. Across all three experiments, we found that object detection performance was better than the basic-level categorization. These results suggest that object detection occurs before categorization when either the sensitivity of measurements or the level of difficulty increases.

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33.532 **Dissociating Detection and Categorization: As Soon as You Know It Is There, You Don't Necessarily Know What It Is**

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Recent work by Grill-Spector and Kanwisher (2005) discovered a tight temporal coupling between object detection and categorization. Specifically, in an experiment where participants performed a task requiring both a detection and categorization judgment on the same trial, they found entirely dependent performance between detection and categorization. Categorization did not occur without successful detection and vice versa. Grill-Spector and Kanwisher concluded that object detection and basic-level categorization are both carried out by an initial stage of visual processing that precedes categorization at more subordinate and abstract levels.

In the present study, we decoupled performance on detection and categorization by manipulating the level of specificity of the categorization judgment. The categorization in Grill-Spector and Kanwisher's study (person vs. car) was at the superordinate level (not the basic-level, as asserted in their paper), a level of categorization that can occur very rapidly (Thorpe, Fize, & Marlot, 1996) and is available early in processing (Rogers & Patterson, 2007). With superordinate-level categorization, we found a dependent link between detection and categorization, replicating Grill-Spector and Kanwisher. In contrast, when the categorization decision was at the basic level (e.g., car vs. boat), the coupling between detection and categorization was severed such that successful detection occurred without successful categorization. Evidence of this decoupling of detection and basic-level categorization was observed across a range of presentation durations.

Similar dissociations of the time courses of detection and categorization have previously been shown with stimulus inversion and degradation (Mack et al., in press). The current study significantly extends earlier results by providing a dissociation with fully intact and canonically-oriented stimuli.

The closely linked performance between detection and superordinate-level categorization remains a provocative finding. However, our selective manipulation of categorization performance casts doubt on any claim for an initial processing stage that both detects objects and categorizes objects at the basic level.

33.533 **2D images are not sufficient for testing 3D object recognition**

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Most current models of object recognition assume that initial input is two-dimensional (2D). We tested this assumption by displaying familiar objects in two different conditions; mono, where stimuli were displayed as flat, 2D images, and stereo, where objects were displayed with stereoscopic depth information. In a series of experiments, participants performed a sequential matching task, where an object was rotated up to 180° between presentations. The pattern of viewpoint costs differed markedly between the two conditions. In the mono condition, performance costs due to rotation were highest at rotations of 60° or 120°, a finding attributed to these views having an outline shape that was maximally dissimilar from that at 0°. In the stereo condition, however, performance costs increased monotonically as the rotation size increased, with highest viewpoint costs at 180°. The only exception to this rule came from an experiment in which the initial viewpoint of the object showed it with the axis of elongation running parallel to the viewing plane, that is, a side-on view; here the mono and stereo depictions were very similar (as all components of the object were roughly the same distance from the viewer) and in both conditions recognition performance was better following rotations of 180° than for smaller rotations. These results suggest that 3D objects are encoded with a mixture of 2D and 3D information. As the features of an object have greater variation in 3D space, 3D cues seem to become more salient, and recognition performance may deviate from that predicted by 2D information. As such, these results provide a challenge for experiments that test theoretical models of 3D object recognition by using 2D images; such images may provide an appropriate test of these models under only some viewing conditions.

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33.534 **Effects of viewing time and viewpoint changes on 3D shape recognition: evidence for the role of nonvolumetric primitives in 3D shape representation**

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An important issue in object recognition concerns the nature of shape primitives used to represent 3D objects. 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 viewpoint and the effect of viewing time on whole-part matching performance. There were three types of shape primitives: volumetric components, surfaces and non-volumetric regions in the representation of 3D object shape. In two experiments, participants were required to match object parts to novel surface-rendered 3D objects. In Exp. 1 the parts were presented either in the same or a plane-rotated orientation relative to the whole object. Volumetric and surface parts led to faster matching than contour parts for both orientations. There was no difference in matching between volumetric and surface parts in either orientation, suggesting that volumetric effects do not arise even under viewpoint changes. In Exp.2 the whole object were presented for 1,200, 2,000 or 5,000 msecs. The results showed matching benefits for volumetric and nonvolumetric parts over edge contour parts in all three viewing times. The results are discussed in terms of the volumetric and nonvolumetric theories of 3D object shape representation.

33.535 **Learning sequence of views of three-dimensional objects: The effect of temporal coherence on object memory**

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How humans recognize objects remains a contentious issue in current research on high-level vision. Here, I test the proposal by Wallis and Bülthoff (1999 Trends in Cognitive Sciences) suggesting that object representations can be learned through temporal association of multiple views of the same object. Participants first studied image sequences of novel, three-dimensional objects in a study block. On each trial, the images were from either an orderly sequence of depth-rotated views of the same object (SS), a scrambled sequence of those views (SR), or a sequence of different objects (RR). Recognition memory was assessed in a following test block. A within-object advantage was consistently observed—greater accuracy in the SR than the RR condition in all four experiments, greater accuracy in the SS than the RR condition in two experiments. Furthermore, spatiotemporal coherence did not produce better recognition than temporal coherence alone (similar or less accuracy in the SS compared to the SR condition). These results suggest that the visual system can use temporal regularity to build invariant object representations, via the temporal-association mechanism.

33.536 **Three-quarter view is good because object orientation is uncertain**

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For most familiar objects, canonical view is a three-quarter view (i.e., oblique view between frontal view and profile view). Why does oblique orientation provide subjectively good, typical view of object? Here we propose a novel account for this.

We conducted an object-orientation evaluation experiment. Pictures of familiar objects were presented, and participants evaluated the object orientations (i.e., azimuth angles) by rotating a disk so that its orientation matched to the orientation of presented object. Results showed that front, side and back orientations were evaluated accurately but oblique orientations were evaluated with significant errors (i.e., greater deviations from true orientations). Based on this data, we estimated the participants' sensitivity to object orientation, and found that they showed relatively low sensitivity to oblique orientations. This finding suggests that oblique orientations are only coarsely represented in the human visual system.

To examine the relationship between object orientation perception and view-goodness, we conducted an analysis by objects. Based on the data mentioned above, we calculated orientations in which the orientation sensitivity is lowest (i.e., orientations which the participants can determine worst) for each of the stimulus objects. We also conducted a view-goodness rating experiment and estimated the orientations in which view-goodness is maximum for each object. Finally, we found that the least-sensitive orientations and maximum view-goodness orientations were significantly correlated, that is, views in which object orientation is poorly perceived are subjectively good views.

Because oblique views contain more view-invariant features, they lack clues to determine object orientation precisely. Such characteristic would yield a consequence that views of various oblique orientations are visually similar to each other and perceived as single category of view, namely, a three-quarter view. This category includes broad range of object orientation, and then that view would be rated more familiar and typical.

33.537 **Position Independence in Object Recognition**

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Although object recognition is often assumed to be position invariant or independent,the human behavioral evidence is ambiguous, with studies reporting evidence both for and against position independence. Moreover, many of these studies also suffer from potential attentional and semantic confounds. Critically, two key predictions derived from the properties of the ventral visual pathway have not been explicitly tested. First, there has been no reported test of the relative transfer between and within hemifields, despite the clear expectation from both single cell and human physiology that between hemifield translations should engage different pools of neurons and hence evidence less transfer. Second, there has been no explicit test of translations between the periphery and fovea, despite their known differences in the neural representation. Here we utilized masked subliminal priming to test the limits of position invariance in purely visual object recognition. In an object decision task, participants were asked to indicate whether a briefly presented (66ms) and masked stimulus was a whole or scrambled line drawing of an object, which could be either familiar or novel. The amount of priming observed during a later (128-256 trials) presentation of the same object served as the measure of transfer. In a series of experiments we show that 1) between hemifield translations evidence less priming than within hemifield translations, 2) priming decreased with increasing numbers of intervening stimuli, and 3) there was an asymmetry in priming between the fovea and periphery even when acuity was controlled for. These results provide evidence for only limited position invariance in object recognition.

33.538 **The Relationship Between Local Feature Distributions and Object Recognition**

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We investigated the structure of image features that support human object recognition using a novel 2-AFC form coherence paradigm. Grayscale images of everyday objects were analyzed with a multi-scale bank of Gabor-wavelet filters whose responses defined the positions, orientations and phases of Gabor patches that were used to reconstruct a facsimile of the original image. Signal Gabors were assigned the parameters of the original image, noise Gabors were assigned random positions, leaving the other parameters, and therefore the overall amplitude spectrum, unchanged. Observers were shown the reconstructed, 100% signal image and were then required to discriminate a target image containing a proportion of signal elements from one containing only noise elements. A staircase determined the proportion of signal elements that were required for correct identification on 75% of trials. We used the statistics of the original image to determine which elements were designated signal and which were designated noise in seven conditions. Signal elements were selected at random or from areas where local orientation variability, density or luminance contrast was either high or low in the original scene. Thresholds were the same for random, orientation variability and density conditions, but were significantly lower for the high contrast and significantly higher for the low contrast conditions. Importantly, the latter result held whether the contrast of the Gabors in the reconstructed scene were either fixed at all the same value or followed the contrast of the original scene. This means that recognition performance is determined by the feature structure of the original scene that has high contrast and not the high contrast elements of the experimental image. These results show that, in general, image identification depends on specific relationships among local features that define natural scenes and not basic statistical measures such as feature density, variability or the contrast values of individual features.

33.539 **Interaction between outline shape and surface-property processing in object recognition**

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We have previously shown that the processing of shape and the processing of surface properties (i.e. colour and texture) engage anatomically distinct regions of occipito-temporal cortex (Cant & Goodale, 2007). But establishing that distinct cortical regions process shape and surface properties does not imply that these regions function independently during object recognition. To establish true functional independence, it is necessary to use a sensitive behavioural measure which assesses whether the processing of one attribute interferes with the processing of another. In this regard, we used a behavioural paradigm known as Garner's speeded-classification task to assess whether the processing of shape interferes with the processing of surface properties (Cant et al., Perception, in press). We showed that varying the surface properties of objects does not interfere with shape judgments and vice versa. These results suggest that the mechanisms underlying form and surface properties can function independently during object recognition – at least under conditions where perceiving the surface properties means perceiving the material from which the objects were made. But it is also possible for surface properties (such as texture gradients) to provide cues to an object's form. In the present study, we varied surface properties that contribute to the perception of object shape and hypothesized this would interfere with judgments about the width of the objects. In contrast, we predicted that varying the width of the objects would not interfere with surface-property judgments. This is precisely what we found using Garner's speeded-classification task. These results suggest that in some situations the outline shape and the surface properties of objects cannot be processed independently because they share common processing resources. In other situations (where surface properties do not contribute to the perception of shape) these object attributes do not share common processing resources and may indeed be processed by distinct cortical regions.

Acknowledgement: Supported by a grant from the Canadian Institutes of Health Research to M.A.G.

33.540 **Task characteristics modulate the impact of action similarity on visual object identification**

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We previously evaluated the impact of visual similarity and action similarity on visual object identification using a learning paradigm where novel associations were formed between objects and actions. We taught participants to associate novel objects with novel actions, and to identify these novel objects with non-word labels. Specific objects were paired with specific actions, and findings revealed that visually similar objects paired with similar actions were confused more often in memory than when these same objects were paired with dissimilar actions. The actions associated with objects served to increase or decrease their separation in memory space, and influenced the ease with which these objects could be identified. In earlier experiments, this pairing process occurred in two steps: participants first visually identified actions performed on a cylinder, and when participants could correctly identify all actions, they visually identified stationary objects. However, this two-step process may not represent the way we learn about objects in the real world. In the present study, we varied task characteristics to more adequately represent how we learn about objects, and asked participants to concurrently focus on action and object information. We contrasted the performance of participants who completed the original experiment to those who were asked, during test trials, to visually identify objects and either (1) produce their associated action, or (2) visually identify their associated action. All three tasks produced similar patterns of results. An analysis of the effect sizes revealed that the impact of action similarity on visual object identification was strongest in the two-step process and weakest when participants were asked to visually identify objects and their associated actions. Because learning trials and the object-naming part of test trials were identical for all tasks, the findings suggest that characteristics of the action-testing task modulated the impact of action information on visual object identification.

Acknowledgement: This work was supported by an Ontario Graduate Scholarship to the first author, as well as Natural Science and Engineering Research Council grants to the second and third author. Special thanks to Ben Cole, William Oud, Leigh Bloomfield, Maria Cristina Pensa, Zarsheesh Divecha, and Michelle Manios.

33.541 **Novelty vs. familiarity principles in preference decision: Task-context of memory matters**

Hsin-I Liao[1,3] (hiliao@caltech.edu), Shinsuke Shimojo[1,2]; [1]Division of Biology & Option Representative of Computation and Neural Systems, California Institute of Technology, [2]JST, ERATO Shimojo Implicit Brain Function Project, [3]Department of Psychology, National Taiwan University

Whereas memory obviously affects preference, how precisely is yet unknown. Shimojo et al. (VSS '07) reported a segregation of the two principles, novelty and familiarity, across object categories: familiarity preference for faces and novelty preference for natural scenes. However, the results are partly inconsistent with the "mere exposure" effect (Zajonc, '68), i.e., repeated exposure to a visual object, regardless of the object category, leads to an increase in preference. The inconsistency may be partly due to what exact task was repeatedly performed during the experience phase: preference decision, selection of any kind, or mere exposure. To address this issue in relation to object category, we conducted the same two-alternative force-choice preference judgment as Shimojo et al. (VSS '07) in which the same old stimulus was presented always with a new stimulus following either kinds of experience phases: passively viewing all the paired pictures, or performing an objective judgment on the paired stimuli (on roundness of face, color temperature of natural scene, or complexity of geometric figure). The results showed that after passive viewing the old stimulus was preferred significantly more frequently in faces, i.e., mere exposure effect, but not in natural scenes or geometric figures. In the objective judgment task during the experience phase, the novel stimulus was chosen significantly more frequently in both geometric figures and natural scenes, but not in faces, even though the old stimulus was the median in pre-rating of color temperature or complexity. It possibly indicates a habituation at the selection level for certain object categories. The overall results further confirm the segregation of novelty and familiarity principles across object categories, indicate uniqueness of face as a special kind of stimulus, and suggest that different tasks lead to memory effects at different levels such as perception and selection.

Sunday, May 11, 2:30 - 4:00 pm
Talk Session, Vista Ballroom

Cross-Modal Interactions

Moderator: Eli Brenner

2:30 pm

34.11 **Revisiting the Molyneux Question**

Richard Held[1] (heldd@neco.edu), Yuri Ostrovsky[1], Beatrice deGelder[2], Pawan Sinha[1]; [1]Brain and Cognitive Sciences, MIT, [2]Neuroscience Lab, Tilburg University

Three hundred years ago the Irish philosopher-scientist William Molyneux wrote to his friend, the philosopher John Locke the following letter: "Suppose a man born blind, and now adult, and taught by his touch to distinguish between a cube and a sphere of the same metal ... Suppose then the cube and sphere placed on a table, and the blind man be made to see: query, whether by his sight, before he touched them he could now distinguish and tell which is the globe, which the cube ...?"

This question, which bears on important issues of shape representation and cross-modal communication, has so far remained unanswered. Addressing it entails finding appropriate subjects--congenitally blind from occlusive pathology such as cataract or other opacity. The visual system from retina centrally must be functional so that clear optics and hence vision are potentially recoverable by state of the art medical procedures. These must be followed as soon as possible, ideally immediately, by appropriate testing of transfer of object discrimination from vision to touch and vice versa. Patients must be mature enough to be capable of reliable discrimination testing. Project Prakash (Nature, 2006, vol. 441, 271-272) has provided us an opportunity to work with such patients. We report here experiments with two individuals. Our results suggest a complete lack of transfer from normal tactile discrimination to vision immediately after sight onset. Interestingly, however, we find evidence for touch to vision transfer and of cross-modal recognition, about a week after surgery. The mechanisms of such rapid learning are currently unknown.

Acknowledgement: NEI R21 EY015521

2:45 pm

34.12 **Hearing motion in "the mind's ear" - evidence for a vision-to-sound synesthesia**

Melissa Saenz[1] (saenz@caltech.edu), Christof Koch[1]; [1]Division of Biology, Caltech

Here we report a previously undescribed vision-to-sound synesthesia. We studied three healthy individuals for whom seeing visual flashes or motion causes the perception of sound (e.g. tapping or buzzing). Consistent with other synesthesias, the visually-induced sound percepts are automatic and cannot be turned off. This synesthesia conferred a distinct advantage on a visual psychophysics task. Synesthetes (n=2) and control (n=8) subjects were presented with rapid rhythmic sequences (similar to Morse code) composed of either auditory beeps or of visual flashes. Subjects judged whether two successive sequences (either both auditory or both visual) were the same or different sequence (2-IFC trials). All subjects performed well on auditory trials (syn: 86% correct, controls: 88%). However, only synesthetes performed well on visual trials with controls performing near 50% chance level (syn: 77%, controls: 57%; difference $p<0.0005$). These results are consistent with synesthetes being able to hear the rhythms on visual trials, with the sound percepts being closely temporally linked to the visual inducers. Next, we measured BOLD fMRI responses to viewing of moving vs. stationary visual dots (a standard MT+ localizer stimulus). Synesthetes (n=3) reported sound percepts for the moving but not the stationary condition and showed enhanced responses to visual motion compared to controls (n=8) on the bilateral superior temporal sulcus (STS), a previously reported audiovisual integration site. The same region was highly responsive to visual stimuli in both synesthete and control subjects, when given a task that encouraged temporally-linked sound imagery. Furthermore, the same STS region responded to purely auditory stimuli in both synesthetes and controls, verifying its identity as an audiovisual convergence region. These fMRI results suggest that vision-to-sound synesthetes have an exaggerated form of multisensory integration that occurs within the normal population.

3:00 pm

34.13 Time-space associations in synaesthesia: When input modality matters

Michelle Jarick[1] *(michelle_jarick@hotmail.com), Mike Dixon*[1]*, Emily Maxwell*[2]*, Daniel Smilek*[1]*;* [1]*Department of Psychology, University of Waterloo,* [2]*Department of Psychology, Willamette University*

Synaesthesia is a fascinating condition whereby individuals report extraordinary experiences when presented with ordinary stimuli. Here we examined an individual (EM) who experiences time units (i.e., months of the year and hours of the day) as occupying specific spatial locations (January is 30º to the left of midline). This time-space synaesthesia has been recently investigated by Smilek, Callejas, Dixon, and Merikle (2007) who demonstrated that the time-space associations are highly consistent, occur regardless of intention, and can direct spatial attention. We extended this work by showing that for EM, her time-space associations change depending on whether the time units are seen or heard. For example, when EM sees the word JANUARY, she reports experiencing January on her left side, however when she hears the word "January" then this month is synaesthetically experienced on her right side. EM's subjective reports were supported using a spatial cueing paradigm. The names of months were centrally presented followed by targets on the left or right. EM was faster at detecting targets in validly cued relative to invalidly cued locations both for visually presented cues (January orients attention to the left) and for aurally presented cues (January orients attention to the right). We replicated these different visual and aural cueing effects using hours of day. Our findings support previous research showing that time-space synaesthesia can bias visual spatial attention, and further suggest that for some synaesthetes, time-space associations can differ depending on whether they are visually or aurally induced.

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3:15 pm

34.14 Amodal Multimodal Integration

Massimiliano Di Luca[1] *(max@tuebingen.mpg.de), Marc Ernst*[1]*, Wendy Adams*[2]*;* [1]*Max Planck Institute for Biological Cybernetics,* [2]*University of Southampton*

Recently it has been shown that congruent visual and haptic signals are integrated in a statistically optimal fashion. Spatial separation between the signals can preclude this integration. Here we investigate whether optimal integration occurs between an amodally completed visual stimulus and its haptic counterpart. Thus, we ask whether integration occurs despite the sensory information not being derived from the same spatial location. This may indicate that subjects inferred that the visually specified parts of the stimulus and the haptic information have a common cause and thus should be integrated.

The visual stimulus was a disparity-defined bar that was partially occluded (amodal completion condition). The bar could also be touched behind the occluder using two fingers. Subjects' task was to discriminate the size of two successively presented bars using a 2-IFC paradigm, where one interval contained conflicting haptic and visual information. Performance in the amodal completion condition was not different from a condition in which the occluder was removed (visual-haptic condition). Both conditions were consistent with an optimal integration strategy.

More interestingly, integration deviated from optimality when we introduced a slight modification to the visual stimulus – small gaps between the bar and the occluder (gap condition). This manipulation interfered with the amodal completion process and consequently subjects relied almost completely on the haptic information for discriminating the size of the bars.

These findings suggest that visual and haptic information can be combined optimally even when visual information is not directly specified by sensory information, but results from amodal completion. In conclusion, it seems that the perceptual system determines when to combine visual and haptic information based on the likelihood the signals have of belonging to the same object (i.e. if there is a causal relationship between the signals) and not only on signal co-location.

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3:30 pm

34.15 Visual Information in the Ascending Auditory Pathway

Dave Bulkin[1] *(dbulkin@hotmail.com), Uri Werner-Reiss*[2]*, Jennifer Groh*[1]*;* [1]*Neurobiology, Duke University,* [2]*Bar-Ilan University*

Does the brain process the senses independently and then combine them, or are the senses put together early, in putatively "unisensory" areas? Recent studies have found evidence that supposedly unimodal cortical areas are sensitive to multimodal stimuli. This work suggests that multisensory integration begins early, but how early?

We investigated visual responses in the inferior colliculus (IC), a midbrain structure in the auditory pathway. While multisensory responses have previously been shown in the IC's external cortex (ICX), the central nucleus (ICC) is typically considered to be a unisensory structure, and would not be expected to have visual responses. We mapped the location of multiunit clusters within the IC and looked at the distribution of activity in the ICX and ICC. We collected data in parallel with a frequency mapping study, such that the location of responses within the IC could be determined. We observed visual or visuo-motor responses in 56 out of 90 (62%) recording locations throughout the IC. Responses were not limited to the ICX, ICC recording sites showed abundant visual activity. These results suggest that visual signals join the auditory pathway in early (in this case, subthalamic) stages of sensory processing.

3:45 pm

34.16 An irrelevant sound can change peri-saccadic mislocalisation

Femke Maij[1] *(f.maij@fbw.vu.nl), Eli Brenner*[1]*, Jeroen Smeets*[1]*;* [1]*Facultay of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands*

When targets are flashed around the time of a saccade, the flashed target is often mislocalised. It has been proposed that such systematical peri-saccadic mislocalisation is due to an incorrect remapping of space. However, the mislocalisation could also be due to temporal errors in the combination of retinal stimulation and extraretinal information about the eye orientation. In this study, we evaluate the extent to which temporal errors contributes to peri-saccadic mislocalisation by examining whether the time course of the mislocalisation is influenced by presenting an irrelevant tone at different moments before (200, 150, 100 and 50 ms), during (0 ms) or after (50 ms) the flash. In our experiment, the perceived position of the flash was compressed towards the target near the time of the saccade. If the tone was presented before the flash, the time course of this compression shifts in the same way as it would if the flash had been presented earlier with respect to the saccade. The shift was maximal (about 12 ms) when the tone was presented 100 ms before the flash, and negligible when the tone was presented after the flash or more than 200ms before the flash. This result suggests that temporal errors are relevant for peri-saccadic mislocalisation.

Sunday, May 11, 2:30 - 4:00 pm
Talk Session, Royal Palm Ballroom 4-5

Faces: Neural Mechanisms 2

Moderator: Kalanit Grill-Spector

2:30 pm

34.21 Individual differences in face cognition: Distinct component abilities and basic neural processes

Grit Herzmann[1] (grit.herzmann@cms.hu-berlin.de), Olga Kunina[2], Oliver Wilhelm[2], Werner Sommer[1]; [1]Department of Psychology, Humboldt University, Berlin, Germany, [2]Department of Education, Humboldt University, Berlin, Germany

There are large individual differences in perceiving, learning, and recognizing faces swiftly and accurately that have never been systematically investigated. By studying individual differences in 209 participants in a broad variety of indicators, we distinguished three component abilities of face cognition: face perception, face memory, and the speed of face cognition. Our results showed that these component abilities are also distinguishable from such traditional mental abilities as object cognition, general cognitive ability, mental speed, and general memory. We used event-related brain potentials (ERPs) to examine the neural basis of the component abilities in face cognition and to see how individual differences are reflected in relevant ERPs. For this purpose, the N170, the difference due to memory, the early and late repetition effects, and the old/new effect were measured in 85 participants of the original sample. Because the ERPs showed high psychometric quality (that is, internal consistency and unidimensionality), we could use structural equation modeling to investigate the relationships of these ERPs to the three component abilities of face cognition. The latent factors of repetition effects, of old/new effect, and of N170 latency correlated moderately with the component abilities. Individuals with faster structural encoding, as measured with N170, performed better in face perception, but not face memory or speed of face cognition. Individuals with earlier and higher brain activation during face recognition, as measured with priming and old/new effects, performed better in face perception and face memory only. Individuals with higher pre-activation of memory representations, as measured with the early repetition effect, processed faces faster. Our research thus shows that structural equation models can be used both to study individual differences in ERPs, and to clarify the relationships of the processes indicated by specific ERPs.

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2:45 pm

34.22 Task-specific feature codes for face processing

Adrian Nestor[1] (adrian_nestor@brown.edu), Michael Tarr[1]; [1]Department of Cognitive and Linguistic Sciences, Brown University

How is task-dependent feature diagnosticity reflected in the behavioral and neural patterns underlying face perception? We investigated the neural code subserving face processing using a computational framework developed by Ullman, Vidal-Naquet and Sali (2002). Their method, originally designed for automatic face detection but inspired by human face processing, is extended to the task of face individuation. We computed the diagnosticity of facial features (image fragments) for individuation by means of the mutual information between face identity and fragment presence across a set of faces displaying variation in pose and expression. We found that individuation diagnosticity varies systematically with feature size and location across the face. Behavioral results from an individuation task with fragments of equal size indicate that human observers are sensitive to the informativeness of facial features as measured by the algorithm: participants were faster and more accurate at individuating faces with increasing feature diagnosticity. Functional MRI was then used to explore whether this sensitivity is mirrored at the level of neural processing in face-selective areas, for example, right fusiform gyrus. The results above are further extended using a face detection task. We observe that diagnosticity for face detection also modulates behavioral indices of performance along with neural responses. Finally, we examine the differences between results obtained with the two tasks. Our results reinforce the idea that feature codes for object recognition are computed in a task-specific manner and suggest that image fragments provide a functionally meaningful descriptor of the representations used by our visual systems. More generally, we conclude that this computational framework provides an effective tool for modeling visual object recognition in humans, as well as a bridge to automatic recognition systems.

3:00 pm

34.23 Stronger face-selective responses to typical versus distinctive faces when stimulus variability is controlled

Nicolas Davidenko[1] (ndaviden@psych.stanford.edu), David Remus[1], Michael Ramscar[1], Kalanit Grill-Spector[1]; [1]Department of Psychology, Stanford University

A recent study reports that face-selective regions respond more strongly to faces of increasing distinctiveness, defined as deviation from the mean or most typical face (Loffler et al., 2005). In their study, physical variability was smaller among typical faces than among distinctive faces, likely resulting in more fMRI-adaptation, and in turn a lower response, to typical faces. We posit that if physical variability were equated across typical and distinctive faces, face-selective regions might respond more strongly to typical faces, as they are more frequently encountered exemplars of the face category. Here we manipulated face distinctiveness while equating physical variability by using parameterized two-tone silhouetted face profiles (Davidenko, 2007). Nine subjects participated in several high-resolution (1.5mm isotropic voxels) fMRI sessions. Face-selective regions in the fusiform gyrus (defined by gray-scale faces > gray-scale objects, $p<0.001$) responded preferentially to upright face silhouettes compared to similarly constructed nonface shape silhouettes or upside-down face silhouettes, demonstrating that face silhouettes preferentially activate face-selective regions. Next, we manipulated distinctiveness by parametrically varying face silhouettes along a principal dimension of silhouette face space highly correlated with distinctiveness ratings. We defined 9 groups of face silhouettes: one centered at the mean face silhouette, and 4 centered at increasing steps from the mean in each direction along this dimension. At each distinctiveness level, subjects viewed different exemplars with the same physical variability. Responses in face-selective regions decreased as distinctiveness increased, while responses in object-selective regions were not affected by distinctiveness. Further, responses in face-selective regions were highly correlated with how "face-like" subjects rated the silhouettes in a post-scan behavioral task. We conclude that controlling stimulus variability is critical for characterizing response properties of face-selective regions. By controlling face variability, we show that face-selective regions respond preferentially to typical faces, likely reflecting the dense distribution of face exemplars near the mean face.

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3:15 pm

34.24 The Effects of Parts, Wholes, and Familiarity on Face-Selective Responses in MEG

Alison Harris[1] (aharris@alum.mit.edu), Geoffrey Aguirre[1]; [1]Department of Neurology, University of Pennsylvania

Although face perception is commonly thought to rely on holistic, rather than part-based, processing, there is some evidence for part-based representations in the face processing stream. Previously (VSS 2007), we have probed holistic and part-based processing with faces manipulated in stereoscopic depth to appear either behind or in front of a set of stripes (Nakayama et al., 1989), which we have demonstrated behaviorally are perceived holistically or in terms of their constituent parts, respectively. Using these stimuli in functional magnetic resonance imaging (fMRI), we showed that "face-selective" regions respond equally to face parts and wholes. Within the right fusiform gyrus, we further found an interaction of processing and familiarity, with greater adaptation for the holistic relative to part-based condition for familiar but not unfamiliar faces. Here we extend this work by investigating the time course of these processing and familiarity effects using magnetoencephalography (MEG). We examined "face-selective" (Face > House) components in occipitotemporal sensors at early (~170-200 ms) and later (~250-450 ms) latency ranges. While both M170 and "M400" components showed significantly larger responses for familiar versus unfamiliar faces, neither exhibited a main effect of holistic versus part-based processing, as indexed by depth. These data affirm the existence of "face-selective" part-based representations, and additionally demonstrate that such representations are present from relatively early stages of face processing. However, the interaction of familiarity and depth only reached significance in the later M400 latency range, with a larger response to the holistic condition for familiar but not unfamiliar faces. Likewise, behavioral recognition performance was significantly correlated with the M400, but not the M170, and only in the holistic condition. Together, these results suggest that, while face parts are represented from the early stages of processing indexed by the M170 response, modulatory effects of familiarity seen with fMRI occur later in the face processing stream.

3:30 pm

34.25 **EEG correlates of categorical and graded face perception**

Margaret Moulson[1] (mmoulson@mit.edu), Benjamin Balas[2,3], Charles Nelson[2,3], Pawan Sinha[1]; [1]Massachusetts Institute of Technology, [2]Children's Hospital Boston, [3]Harvard Medical School

Face perception is a critical social ability that is subserved by distinct neural systems. Previous research has shown that faces elicit a distinct electrophysiological signature, the N170, which has a larger amplitude and shorter latency in response to faces compared to other objects. However, determining the face specificity of any neural marker for face perception hinges on finding an appropriate control stimulus. Our goal was to use a state-of-the-art computational model of face detection to create a novel stimulus set consisting of 300 images on a continuum from no similarity to faces to genuine faces, in order to explore the neural correlates of face perception in a principled way. Behaviorally, human observers accurately categorized these images as faces or non-faces, but their pair-wise ratings confirmed that the non-face images spanned a continuum of image-level similarity to faces, from no similarity to high similarity. High-density (128-channel) event-related potentials (ERPs) were recorded while 9 adult subjects viewed all 300 images in random order, and determined whether each image was a face or non-face. The goal of our analyses was to determine if the ERP signal reflects strict face/non-face categorization, or rather the continuum of "face-ness" built in to these images. Interestingly, we found evidence for both categorical and graded responses using two different kinds of analyses. Traditional waveform analyses revealed that the N170 component over occipitotemporal electrodes was larger in amplitude for faces compared to all non-faces, even those that were high in image similarity to faces, suggesting a categorical distinction between faces and non-faces. By contrast, single-trial classification across the entire waveform, using machine learning techniques, revealed that high-similarity non-face images were harder to classify as non-faces compared to low-similarity non-faces. These results suggest that both categorical and graded information are available but 'multiplexed' in a subset of the ERP signals.

3:45 pm

34.26 **The neural and behavioral plasticity of other-race face recognition**

James Tanaka[1] (jtanaka@uvic.ca), Lara Pierce[1]; [1]Department of Psychology, University of Victoria, Canada

Although it is well established that people are better at recognizing own- versus other-race faces, the neural mechanisms mediating this advantage are not well understood. In this study, Caucasian participants were trained to differentiate African (or Hispanic) faces at the subordinate individual level and categorize Hispanic (or African) faces at the basic level of race. Training occurred over five consecutive days of learning. Before and after training, participants were administered an old/new recognition test of novel African and Hispanic faces while recording electrophysiological activity. Previous event-related potential research has suggested that two posterior brain components, the N170 and N250, are linked to different aspects of face processing. Whereas the N170 provides an index of category exposure, the N250 is a marker of subordinate level identification. Consistent with this view, after training both African and Hispanic faces elicited a shorter N170 latency regardless of whether they were learned at the subordinate or at the basic level. However, faces trained at the subordinate level of the individual elicited a greater N250 and showed greater improvements in post-training recognition relative to faces trained at the basic level. These results suggest that subordinate level training enhances memory for other-race faces and improved recognition is indicated by the presence of the N250 component.

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Sunday, May 11, 4:30 - 6:15 pm
Talk Session, Vista Ballroom

Binocular Mechanisms 2

Moderator: Martin Banks

4:30 pm

35.11 **The Reliability of Disparity Signals Affects Slant Anisotropy**

Heather R. Filippini[1] (hrose@berkeley.edu), Martin S. Banks[1,2]; [1]UCSF/UCB Joint Graduate Group in Bioengineering, UC Berkeley, [2]Vision Science Department, UC Berkeley

Disparity-defined surfaces with the same physical slant often differ in perceived slant depending on their tilt: Surfaces with tilt 90 (rotated about horizontal axis) appear more slanted than surfaces with tilt 0 (rotated about vertical axis). This slant anisotropy is also observed with disparity-defined sinusoidal corrugations: disparity threshold is lower for low-spatial frequency corrugations when they are horizontal than when they are vertical (Bradshaw & Rogers, 1999). Slant anisotropy is not observed with real surfaces in which other depth cues are consistent with the disparity-defined surface (Bradshaw et al., 2002). This suggests that slant anisotropy is caused by the cue conflicts present in virtual disparity-defined surfaces and/or by differences in the slant prior for tilts 0 and 90. To examine these possibilities, we first made all other depth cues unreliable, thereby reducing their influence. We then varied the reliability of the disparity signal by blurring the dots anisotropically in a random-dot stereogram. Blurring the dots horizontally makes the calculation of horizontal disparity unreliable. Blurring vertically does not affect the calculation of horizontal disparity. In each two-interval trial, observers indicated whether a horizontal or vertical corrugation had more apparent depth. We varied the amplitude of the vertical corrugation to match the apparent amplitude in the horizontal corrugation. When the disparity signal was relatively unreliable (horizontally blurred dots), the vertical corrugation needed greater amplitude to have the same apparent depth as the horizontal corrugation: slant anisotropy was observed. However, when the disparity signal was relatively reliable (vertically blurred dots), the amplitude difference decreased substantially: slant anisotropy was diminished. Thus, the reliability of the horizontal-disparity signal strongly influences slant anisotropy. Our data are consistent with the hypothesis that the slant priors for tilts 0 and 90 differ, the former being more peaked at 0 deg.

Acknowledgement: Supported by the NIH

4:45 pm

35.12 **Binocular slant discrimination beyond interaction space**

Robert S. Allison[1] (allison@cse.yorku.ca), Barbara J. Gillam[2], Stephen A. Palmisano[3]; [1]Centre for Vision Research, York University, Canada, [2]School of Psychology, University of New South Wales, Australia, [3]School of Psychology, University of Wollongong, Australia

Effective locomotion depends on judgements of the support, passability and effort to traverse provided by terrain several metres away. Elementary texts commonly assert that stereopsis per se is ineffective in these judgements beyond modest distances. He et al. (Perception, 2004, 33: 789) proposed that vergence and stereopsis calibrate and anchor depth percepts in near space that are then extended to larger distances by integrating monocular cues over the continuous ground plane. However, stereopsis has a much larger theoretical range and we have shown binocular performance improvements to at least 18.0m (VSS2007). Here we evaluate the contribution of binocular vision to judgements of ground surface properties.

A computer-controlled constellation of LEDs was distributed throughout a volume of space centred 4.5 or 9.0 metres from the subject. LEDs could be selectively lit to create a single ground plane or two planes either adjacent or interleaved (simulating uneven terrain). In separate 2AFC experiments subjects discriminated: 1) the absolute slant of a single plane; 2) the relative slant between two adjacent planes; or 3) whether all the lights lay in a single plane or not (surface smoothness). Viewing was binocular or monocular.

Binocular discrimination of absolute and relative slant showed less bias and was more precise than monocular discrimination for all tasks at both distances. Judgements of surface smoothness were very difficult monocularly compared to binocularly, as reflected in substantial differences in sensitivity (d').

Binocular vision is useful for judgements of the layout and regularity of terrain to at least 9.0 metres (an important range for moment-to-moment path planning during walking, running and assisted travel). In sum, binocular vision can contribute to precise judgements of ground surface properties. This contribution is not simply limited to calibration and anchoring of monocular cues in personal space.

Acknowledgement: Australian Research Council

5:00 pm

35.13 **Using Focus Cues in Solving the Binocular Correspondence Problem**

David M. Hoffman[1] (davidhoffman@berkeley.edu), Martin S. Banks[1,2]; [1]Vision Science Department, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley

To measure binocular disparity, the visual system must match the same object elements in the two eyes' retinal images. Solving this correspondence problem becomes increasingly difficult as similar elements are added to the images. In natural viewing, disparity is nearly always correlated with focus cues: blur in the retinal image and accommodation. We asked whether this correlation helps solve the correspondence problem. We presented a stimulus that specified two planes in depth: a frontoparallel near plane and a far plane that could be rotated about a vertical axis. The planes were textured with smooth sticks in random position (van Ee & Anderson, 2001). The sticks were the same color and angular size, so matches in the two eyes' images were frequently incorrect; incorrectly matched sticks did not appear as part of either plane. When the sticks all had similar orientations, false matches were common; when the sticks had a wider range of orientations, false matches were less common. We presented the stimulus in two ways: 1) on one image plane in a conventional 3d display, 2) on multiple image planes in a novel volumetric display (Akeley et al., 2004). The disparities were identical in the two conditions. In the first condition, focus cues specified one plane and were therefore inconsistent with the disparity-specified stimulus. In the second condition, focus cues specified two planes consistent with the disparity stimulus. The first condition mimics standard experimental technique in psychophysics; the latter mimics natural viewing. We measured slant-discrimination thresholds for the far plane. As expected, thresholds were lower in conditions with greater variation of stick orientation. More importantly, thresholds were systematically lower in the volumetric than in the conventional viewing condition. Thus, the visual system takes advantage of the natural correlation between disparity and focus cues when solving the correspondence problem.

5:15 pm

35.14 **Distinct Neural Signatures of Motion-Induced Blindness in Human Visual Cortex**

Tobias Donner[1] (tobias@cns.nyu.edu), Dov Sagi[2], Yoram Bonneh[2], David Heeger[1]; [1]Department of Psychology and Center for Neural Science, New York University, [2]Department of Neurobiology, Brain Research, The Weizmann Institute of Science

Motion induced blindness (MIB) is a visual phenomenon in which a salient static target spontaneously fluctuates in and out of visual awareness when surrounded by a moving pattern. We characterized the modulation of neural activity in multiple human visual areas correlated with perceptual re-organization during MIB. Observers reported the subjective disappearance and re-appearance of a high-contrast target contour surrounded by a moving random dot pattern (the mask) while neural activity was measured with fMRI. We identified the sub-regions of each visual area in each observer that corresponded to the target and the mask. For each of these sub-regions, average fMRI response time courses were estimated during the disappearance and re-appearance of the target. Responses in target-specific sub-regions of V1 through V4 decreased with target disappearance and increased with re-appearance. These responses were particularly strong in V4 and were followed by a delayed global modulation expressed throughout V1-V4. Mask-specific sub-regions in dorsal stream areas MT and the posterior intraparietal sulcus (IPS) exhibited the opposite pattern of modulation; responses increased with target disappearance and decreased with target re-appearance. The responses time courses in the mask-specific sub-regions of MT and IPS were anti-correlated with the response time courses in the target-specific sub-regions of V2, V3, and V4. Our results demonstrate that the spontaneous perceptual re-organization during MIB has multiple distinct neural signatures in human visual cortex. The responses of the target sub-regions of early ventral stream areas specifically reflect observers' fluctuating awareness of the target.

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5:30 pm

35.15 **The Human Cortical Network for Coherent Stereomotion Processing**

Lora Likova[1] (lora@ski.org), Christopher Tyler[1]; [1]The Smith-Kettlewell Eye Research Institute

To study the roles and interactions among a variety of cues for perception of stereomotion-in-depth, we used fMRI to investigate the whole brain network for the coherent stereomotion of a plane generated in different conditions: (i) correlated disparities and (ii) anticorrelated disparities (both generated in dynamic-RDS, i.e., cyclopean, at 25% dot density on a mid-gray field); (iii and iv) the same two conditions, but now non-cyclopean with the added cue of opposite monocular motions in the two eyes; (v and vi) the cyclopean and non-cyclopean forms of anticorrelated stereomotion but with dot density decreased to 2% and dot size increased to 4x4 pixels in order to recover both the depth and the stereomotion percepts (Cogan et al., 1993). Note that for fMRI, each of these conditions had a corresponding null that fully canceled any differential BOLD response to confounding factors, such as disparity per se, dynamic noise, disparate lateral motion, etc. The fMRI signal was measured with a GE Signa 3T scanner in a block design at 2s TR with 3x3x3 mm voxels.

The lack of any motion-in-depth perception in the high-density anticorrelated stimuli resulted in no differential activation in the occipito-parieto-frontal network for correlated cyclopean stereomotion that we have found previously. In contrast, the low-density anticorrelated stimuli supported motion-in-depth perception and fully activated the network. Overall, the stereomotion network was activated by any condition that generated perceived stereomotion, implying that it has a generic role in 3D-motion processing. Paradoxically, the addition of monocular-motion cue to the disparity cue reduced the signal strength in several areas, posing challenges for theoretical models. The full array of results across cortical areas will be discussed in relation to their implications for understanding the mechanisms of dynamic stereopsis.

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URL: www.ski.org/LLikova

5:45 pm

35.16 **The Dynamics of Binocular Combination**

Christopher Tyler[1] (cwt@ski.org); [1]Smith-Kettlewell Eye Research Institute

Introduction. The detectability of transitions between dichoptic correlation states is highly anisotropic, with the detection of uncorrelation (U) or anticorrelation (A) transitions from a correlation (C) state being one of the most rapid perceptual events, while the detection of dichoptic correlation from uncorrelated or anticorrelated states requires up to several seconds of observation (Tyler & Julesz, 1979). Functional MRI was used to explore the dynamics of these neurontropy processes, together with binocular/monocular (B/M) transitions, throughout the human occipital lobe.

Methods. FMRI response were measured with a GE Signa 3T scanner, 3 s TR and block design to dynamic noise stimuli switching among stereoscopic structure, dichoptic correlated, dichoptic uncorrelated and purely monocular fields.

Results. In retinotopic cortex, presentation of disparity structure activated retinotopically appropriate regions in V1, V2, V3, V3A, ventral area VMO, foveal V7 and the lateral depth structure area ODS/KO, but not for hV4, hMT+ or other lateral cortical areas. Most of the activated areas showed a continuous signal to the depth structure, but had a different dynamic for the binocular/monocular alternation, responding equally to the B>M and M>B transitions. For the dichoptic correlation conditions there was a strong transition anisotropy, with most areas responding with a delayed suppression to the C>U transition and no response to the U>C transitions. Foveal V7, however, showed a rapid positive response to the C>U transition only. There was minimal response in hMT+ to changes between any of these stimulus types.

Conclusion FMRI can reveal striking differences in the cortical response dynamics, both across cortical regions and among different types of dichoptic stimulation. These dynamics suggest that the C>U / U>C transition anisotropy is a result of processing in the higher dorsal retinotopic areas.

Tyler, CW, Julesz B (1976) The neural transfer characteristic (neurontropy) for binocular stochastic stimulation. Biol. Cybernetics 23, 33-37.

Acknowledgement: Supported by the Pacific Vision Foundation

URL: www.ski.org/cwt

6:00 pm

35.17 **Functional specialisation for the perception of disparity-defined depth in the human visual cortex**

Andrew Welchman[1] (a.e.welchman@bham.ac.uk), Tim Preston[1], Sheng Li[1]; [1]School of Psychology, University of Birmingham, UK

Electrophysiological and fMRI studies have revealed selectivity for binocular disparity across primate visual cortex. However, the functional role of this activity in supporting depth perception remains largely unknown. To investigate this relationship, we recorded fMRI responses in the human visual cortex whilst observers viewed random dot stereograms depicting planes with either crossed or uncrossed horizontal disparity. We used multivariate analysis methods (linear support vector machines) to determine cortical regions whose fMRI responses support robust classification of planes presented at different depth positions, thereby indicating selectivity for disparity-defined depth. We contrasted classification for correlated planes against classification for anti-correlated stimuli (i.e. negative correlation between the luminance contrast of corresponding dots in the two eyes) that do not support depth perception. For correlated stimuli, classification of crossed- vs. uncrossed disparity was above chance across the cortical hierarchy from V1 to higher dorsal (hMT+/V5) and ventral regions (LO), with especially high accuracies in intermediate dorsal regions (V3, V3A). Importantly, pattern classification for anti-correlated stimuli highlighted differences between dorsal and ventral areas. Whilst fMRI responses in extrastriate ventral areas (VP/V3, V4) supported the classification of anti-correlated stimuli, such classifications were abolished in dorsal areas (V3B/KO and V7) and higher temporal regions (LO). This suggests a functional distinction between regions, with perceived depth related to disparity processing in dorsal extrastriate regions and higher temporal areas. A further functional distinction was suggested by classifying the fMRI data according to the specific disparity content of the stimuli. In particular, classification performance indicated representations related to the specific depth position in dorsal areas, whilst representations related to the sign (near vs. far) of depth in LO. Our findings provide novel evidence that disparity processing in the dorsal stream is selective for the specific depth position, whilst higher temporal regions encode perceived depth in a categorical manner.

Acknowledgement: BBSRC, UK

Sunday, May 11, 4:30 - 6:15 pm
Talk Session, Royal Palm Ballroom 4-5

Decision and Reward

Moderator: Dana Ballard

4:30 pm

35.21 **Human eye movements correlate with intrinsic reward structure in natural visuomotor tasks**

Constantin Rothkopf[1] (crothkopf@bcs.rochester.edu), Dana Ballard[2]; [1]Center for Visual Science, University of Rochester, [2]Department of Computer Science, University of Texas at Austin

Neurophysiological and psychophysical studies in primates and humans have shown the pervasive role of reward in learning of visuomotor activities. Eye movements and hand movements to targets are executed so as to maximize reward. Moreover, reinforcement learning algorithms have been formulated that characterize the neuronal signals of dopaminergic neurons in response to the occurrences of stimuli associated with rewards and the delivery of the rewards across learning. Common to all these experiments is that the reward structure of the task is explicitly controlled by the experimental setup. By comparing the observed behavior with normative models, it can be inferred how close to optimal the participants perform. But how does this relate to visually guided activities in natural tasks? It has been difficult to answer this question, because the value functions underlying actions such as fixations or control of walking direction are not known a priori. We present a new algorithm for Inverse Reinforcement Learning, which is able to infer these value functions from observing human behavior. The algorithm takes advantage of the inherent structure of a task by compactly representing the value functions with a small number of basis functions. The algorithm was applied to data collected from human subjects navigating in a virtual environment while approaching and avoiding objects. The value functions underlying these tasks are recovered for each participant and the validity of the algorithm is verified by evaluating the RMS-error between the actual trajectories and those simulated utilizing the extracted parameters. Furthermore, it is shown that the rewards of objects inferred from navigation are correlated with the proportions of fixations on the corresponding object classes (rho=0.72). We conclude that Inverse Reinforcement Learning can be utilized to infer the reward structure used by subjects in natural visuomotor tasks and reveals the connection between eye movements and these rewards.

4:45 pm

35.22 **Learning probability and reward through experience: Impact of value structure on reach planning**

Erik Schlicht[1,2] (schlicht@wjh.harvard.edu), Shin Shimojo[2], Ken Nakayama[1]; [1]Harvard University, Psychology, [2]California Institute of Technology, Computation and Neural Systems

Throughout our everyday routine we must make actions in the face of uncertainty. From a decision theoretic standpoint, optimal actions are those that maximize the value associated with the task. However, in order for humans to act optimally, it necessitates the brain has an accurate representation of both the reward and probability associated with each outcome. Previous research investigating how humans use value structure to perform reaching movements has exclusively focused on asymptotic performance, ignoring how this structure is learned. Therefore, this project investigates how value is learned by requiring subjects to reach to targets that appear after completing a portion of their movement towards the possible target locations. Since subjects have no information about the target at the beginning of the reach, their initial trajectories provide a way to quantify reach plans. Value is manipulated by varying either the probability or reward associated with each target. Subjects are awarded points for correctly acquiring the target, no points for reaching to the incorrect target, and are penalized points for taking too much time. Subjects receive bonus money after the experiment that is based on their point total, assuring that value structure in this paradigm has actual utility. Furthermore, we developed a model that learns through the subject's experience what initial biases result in maximal points. We can use the model to make predictions about the biases people should use and what experience is important for forming value estimates. The results show that as the difference in value between the targets increases, subjects' biases also increase at a rate that closely matches the maximum-point predictions. Moreover, changes in biases across trials are better predicted by recent experience, rather than global experience. Together, this suggests that people learn value structure through recent experience, and this knowledge is used to guide reach planning.

Acknowledgement: Shimojo Implicit Brain Function Grant (JST)

5:00 pm

35.23 **Learning to behave optimally in a probabilistic environment**

Anna Seydell[1] (anna.seydell@psychol.uni-giessen.de), Brian McCann[2], Julia Trommershaeuser[1], David Knill[3]; [1]University of Giessen, Germany, [2]University of Texas, [3]University of Rochester

Recent studies have shown that humans effectively take into account task variance caused by intrinsic motor noise when planning fast hand movements. However, previous evidence suggests that humans have greater difficulty to account for arbitrary forms of stochasticity in their environment – both in economic decision making and sensorimotor tasks. We hypothesized that humans can learn to optimize movement strategies when environmental randomness mimics the kinds for which they might have generative models. We tested the hypothesis using a task in which subjects had to rapidly point at a target region partly covered by three stochastic penalty regions introduced as "defenders". At movement completion, each defender jumped to a new position drawn randomly from fixed Gaussian probability distributions. Subjects earned points when they hit the target, unblocked by a defender, and lost points otherwise. Results indicate that after about 600 trials, subjects approached optimal behavior maximizing gain. We further tested whether subjects simply learned a set of stimulus-contingent motor plans or the statistics of defenders' movements by training subjects with one penalty distribution and then testing them on a new penalty distribution. Subjects immediately changed their strategy to achieve the same average reward as subjects who had trained with the second penalty distribution. These results indicate that subjects learned the parameters of the defenders' jump distributions and used this knowledge to optimally plan their hand movements under conditions involving stochastic rewards and penalties.

Acknowledgement: This research was supported by grants DFG TR528 1-3 to A.S. and J.T. and NIH R01-EY13319 to D.K.

5:15 pm

35.24 **Neural correlates of value and probability in decision under risk and in an equivalent visuo-motor task**

Shih-Wei Wu[1] (sww214@nyu.edu), Laurence Maloney[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Purpose. In visuo-motor tasks, it has been shown that humans come remarkably close to that expected of an ideal observer or mover. Research in economic decision under risk, on the contrary, repeatedly demonstrated large deviations from optimality. The sharp contrast in performance between visuo-motor tasks and economic decision tasks revealed modular specificity in the neural systems representing decision variables, i.e., value and probability. However, it is not clear whether modular specificity arises from a common neural system that captures the unique, modality specific representations of decision variables or alternatively, from separate systems representing those variables unique to the kind of decision task the chooser is facing.

Method. We investigated the neural correlates of value and probability using fMRI and by separately estimating the distortions of value and probability in economic decision task and its equivalent visuo-motor task. There were 3 sessions in the experiment. In the first session, subjects performed rapid pointing to a rectangular target varying in size (384 trials). For each subject, his/her motor variability was estimated at the asymptotic level for the purpose of creating motor configurations mathematically equivalent to a single lottery. In the second and third session, subjects faced both economic decision tasks and equivalent visuo-motor tasks. The distortions of value and probability were estimated separately based on the subject's choice in the visuo-motor task and the economic decision task. Subjects did the third session in the MRI scanner.

Results. 4 naïve subjects participated in the experiment. We found that activity in the striatum, the cingulate gyrus, the superior and the middle frontal gyrus tracked the distortions of probability for both the visuo-motor task and the economic task. We take this as initial evidence to suggest that there is a common circuitry representing subjective probability that is independent of decision modality.

5:30 pm

35.25 **Overlapping representation of juice and video rewards in primate OFC**

Michael Campos[1] (mcampos@caltech.edu), Kari Koppitch[1], Richard A. Andersen[1], Shinsuke Shimojo[1]; [1]Biology / CNS, Caltech

Vision can be inherently rewarding. The reward circuitry in the brain supports an animal in identifying and obtaining rewards from its environment. The orbitofrontal cortex (OFC) is known to encode the subjective value of different juice reward options, and therefore supports decisions based on preferences in the context of appetitive rewards. It is unclear, however, whether the brain circuitry supporting the appetitive rewards is the same, distinct, or overlapping with that supporting non-appetitive rewards, which are important to modern human life. To investigate this issue we used a self-initiated free-choice paradigm in which a monkey pressed buttons to receive either the presentation of a 5 sec video clip in the video-watching period ("leisure"), or a drop of juice in a separate period ("work"). The leisure and work periods were run in separate blocks of 20 minutes each, while we simultaneously recorded 2-10 single OFC neurons.

Neural activity was analyzed with respect to the button press. We first identified significant modulations in firing rate activity in any of five intervals defined with respect to the button press when compared to baseline. We found that two-thirds of the OFC neurons we encountered (394/585) were modulated in at least one interval in either the leisure or work period. Of these, approximately 40% were modulated in both periods, 40% were modulated in the work period exclusively, and 20% in the leisure period exclusively. The neurons that responded in only one period suggest that OFC contains at least two internal representations of distinct reward categories. The neurons that participated in both periods suggest that OFC also represents abstract commonalities between rewards of different kinds. These results are consistent with our intuition that perceptual experience itself is rewarding, and indicate that the neural correlates overlap with that for appetitive rewards.

Acknowledgement: Funding: JST.ERATO Shimojo Implicit Brain Functions Project, National Eye Institute to RAA

5:45 pm

35.26 **Target selection for visually-guided reaching in the dorsal premotor area during a visual search task**

Joo-Hyun Song[1] (jhsong@ski.org), Robert M. McPeek[1]; [1]The Smith-Kettlewell Eye Research Institute

Most visual scenes are complex and crowded, with several different objects competing for attention and directed action. Thus, an understanding of the production of goal-directed actions must incorporate the higher-level processes involved in the selection of a target stimulus from distractors. To examine the neural substrates of target selection for visually-guided reaches, we recorded the activity of isolated neurons in the dorsal premotor area (PMd) of rhesus monkeys. The role of the PMd when a target must be selected from distractors is not yet fully understood. However, recent studies have demonstrated that when two potential targets are presented for selective reaching, the PMd can simultaneously encode the two competing movement goals during a delay period before the cue to move (Cisek & Kalaska, 2002). Here, we investigated the role of the PMd in a reaction-time visual search task. We trained monkeys to reach to an odd-colored target presented with three distractors. We traced the time course of target/distractor discrimination and found that PMd neurons typically discriminated the target before movement onset, about 150~200ms after the appearance of the search array. Discrimination in a subset of neurons occurred at a consistent time after search array onset regardless of the latency of the reaching movement, suggesting that these neurons are involved in target selection, as distinct from movement production. In other neurons discrimination time depended on reach latency, suggesting that this latter group of neurons are more involved in movement execution. These results suggest that different groups of PMd neurons are involved in target selection and movement initiation.

6:00 pm

35.27 **Homo economicus in visual search**

Vidhya Navalpakkam[1] (vidhya@caltech.edu), Christof Koch[2], Pietro Perona[3]; [1]Division of Biology, California Institute of Technology, [2]Division of Biology, Engineering, California Institute of Technology, [3]Computation and Neural Systems, Electrical Engineering, California Institute of Technology

Several real-life decisions involve combining sensory information and reward outcomes. Yet, most previous research in human and animal literature has focused on either economic [1] or sensory decision making [2] in isolation. Here, we find that humans combine sensory information with reward outcomes optimally in a visual search task where they detect the presence or absence of a familiar target object in a cluttered scene, and receive reward feedback based on correct vs. incorrect response. We present three additional findings: 1) Rare targets are missed even when the target is salient (replicating results from [3]). 2) Contrary to previous studies [3,4], we find a rapid and optimal influence of reward on sensory decision making and detection rates – humans behave as reward-maximizing agents and decide whether the target is present or not based on whichever maximizes their expected reward. Hence, the poor detection performance for rare targets can be corrected by changing the reward scheme. 3) A quantitative model based on reward-maximization accurately predicts human detection behavior in different target frequency and reward conditions. We use this model to illustrate how reward schemes can be designed to obtain high detection rates for any target frequency. Potential applications of our findings include improving detection rates in life-critical searches for rare targets (e.g., bombs in airline passenger bags, cancers in medical images).

[1] D. Kahneman and A. Tversky. Choices, Values, and Frames. Cambridge University Press, 2000.

[2] J.I. Gold and M.N. Shadlen. The Neural Basis of Decision Making. Annu. Rev. Neurosci, 30:535–574, 2007.

[3] J.M. Wolfe, T.S. Horowitz, and N.M. Kenner. Cognitive psychology: rare items often missed in visual searches. Nature, 435(7041):439–40, 2005.

[4] W Todd Maddox. Toward a unified theory of decision criterion learning in perceptual categorization. J Exp Anal Behav, 78(3):567–595, Nov 2002.

Sunday, May 11, 2:30 - 6:30 pm
Poster Session, Royal Palm Ballroom 1-3

Attention: Object-based Selection
Color Perception
Perceptual Organization: Contours

Attention: Object-based Selection

36.301 **The time course of neural activity in object-based visual attention**

Linda Moya[1,2] (lhmoya@cmu.edu), Sarah Shomstein[3], Anto Bagic[4], Marlene Behrmann[1,2]; [1]Department of Psychology, Carnegie Mellon University, [2]Center for the Neural Basis of Cognition, [3]Deparment of Psychology, George Washington University, [4]Department of Neurology & Neurosurgery, U. of Pittsburgh Medical Center

Numerous studies provide evidence that attention can select objects in their entirety for preferential processing. A classic paradigm for eliciting object-based attentional effects, introduced by Egly et al. (1994), is to present two adjacent rectangles. Attention is cued to one end of one rectangle and then a target appears at the opposite end of the same, cued rectangle or at the parallel end of the adjacent un-cued rectangle. The general finding is that stimuli presented in the cued rectangle are responded to more quickly than stimuli presented in the adjacent rectangle even though both targets are physically equidistant from the cue. This faster reaction time is taken as evidence of object-based attentional processing. Shomstein and Behrmann (2006) adapted this paradigm in a functional magnetic resonance imaging (fMRI) study to locate the neural source of attention and found that the posterior parietal cortex (PPC) was differentially sensitive to the object-based properties of the input, with enhanced activation for locations bound by an attended object. They also found modulated activation in early cortical regions. Although the cortical regions associated with object-based attention are well-established, the temporal dynamics of these regions remains to be determined. The present research extends the paradigm using magnetoencephalography (MEG) to identify the temporal differences that exist between conditions in multiple cortical regions. Results indicate that differential MEG sensor activity and a sensor by condition interaction are found in parietal/occipital cortex. Furthermore, a sensor by condition by time interaction exists in frontal and occipital areas. The present findings provide temporal data that are compatible with the account that parietal/occipital areas modulate object-based attention, and therefore lay the ground work for further research into a comprehensive temporal and spatial understanding of the role of the frontal-parietal areas as the source of object-based attention and their modulation of more posterior areas.

36.302 **Differences in object-based attention in the foreground and background**

Alice Albrecht[1,2] (aliceralbrecht@gmail.com), Alexandra List[3], Lynn Robertson[1,2]; [1]Department of Psychology, University of California, Berkeley, [2]Veterans Administration, Northern California Health Care Systems, Martinez, CA, [3]School of Psychology, University of Wales, Bangor, UK

Object-based effects of visual attention were reported by Egly Driver and Rafal (1994) using a modified Posner cueing paradigm. In a two-rectangle (i.e., "object") display, they cued one end of one rectangle on each trial. Targets were most likely to appear at the cued location. In invalid-within object conditions, the target appeared in the same rectangle as the cue, but at the opposite end. In invalid-between object conditions, the target appeared in the rectangle opposite the cue. Importantly, invalid targets appeared the same distance away from the cue in both within and between conditions, holding space constant. When comparing the two invalid conditions, within-rectangle targets were detected faster than between-rectangle targets; RTs showed object-based facilitation. In a set of similar experiments, we replicated these effects when the shapes were perceived as objects (wholes) but not as "holes". We used stereoscopic goggles to provide sufficient depth cues for the perception of "holes" and objects. To confirm that the disappearance of the object-based effect is due to the "holes" grouping with the larger background region and not simply an effect of depth, we examined object-based effects in holes under conditions in which the background region was either split or connected. The data supported our hypothesis: when the background region was split, the shapes perceived as holes were again individuated, and elicited object-based effects. Specifically, we found significant object-based effects in the split/holes, split/objects, and the connected/objects condition, but not in the connected/holes condition, replicating and expanding our previous findings. The results provide further evidence that attention and perceptual organization interact.

36.303 **Object–oriented perception of emotional information**

Carys K. Ball[1] (c.ball@bangor.ac.uk), Jane E. Raymond[1]; [1]Bangor University

High-level neural representation of the visual world is widely thought to be object-oriented, i.e., neural codes for different features (e.g., colour, shape) appear to be linked together, enabling representation of coherent objects. In addition to visual features, many objects, e.g., spiders, expressive faces, have obvious emotional features that are encoded using very different neural networks than those used to represented visual features. Are these emotional features also incorporated into object-level representations? To test this, we measured affective priming (AP) using a two-object display. AP is faster judgement of the affective valence of a target (good versus bad) when it is just previously primed by a stimulus sharing the same affective valence than when primed with an oppositely valenced stimulus. Participants viewed two boxes on either side of fixation; one was filled briefly with an emotional prime (spider or flower image) and then it or the other box moved to the centre. A target image (happy or angry face) was presented on the centre box and the participant judged it as positive or negative as quickly as possible. Object-oriented perception of emotional information predicts AP only when target and prime appear on the same, as opposed to a different, box. In contrast, automatic attitude activation theories of AP predict no difference in the same versus different object conditions. In line with object-oriented predictions, we found significant AP (i.e., participants were faster to respond to a target when it's emotion valence was congruent with that of the prime) only when prime and target appeared on the same object. This finding indicates that even briefly presented emotional information can be incorporated into an otherwise neutral object's representation (box) in such a way that it influences emotional judgements about that object subsequently. Emotional information appears to be included in object-level representations.

Acknowledgement: This work was supported by an ESRC studentship to CKB

36.304 **Neural fate of unattended features in object-based encoding**

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Both behavioral and neuroimaging studies have shown that there exists an object-based encoding, such that when one object feature is attended, unattended features of the same object may also be automatically encoded. According to the perceptual load theory, however, unattended information is only processed when the central processing resources are unfilled. The question arises: Is object-based encoding always present regardless of processing load? Or is object-based encoding attenuated at high load according to the perceptual load theory? Response of the superior intra-parietal sulcus (IPS) has been shown to increase with increasing display set size and plateaus at the set size corresponding to the number of objects successfully retained in visual short-term memory (VSTM). A similar result for object shapes has been observed in the lateral occipital complex (LOC), an area participating in visual shape processing. Using these two brain areas as regions of interest, in this fMRI study, observers were presented with 1, 2 or 6 distinctive colored shapes and were asked to only encode the color of each shape in VSTM. Observers were able to retain maximally about 3 colors in VSTM. Corresponding to behavioral performance, superior IPS response was low for set size 1, medium for set size 2 and high for set size 6 displays. If object-based encoding exists regardless of processing load, the encoding of the unattended shapes by the LOC should show a response pattern similar to that of the superior IPS. However, if processing load modulates object-based encoding, LOC response pattern should be low for set size 1, high for set size 2, but low again for set size 6. The result is consistent with the second prediction. This finding indicates that object-based encoding only exists when the overall processing load is low and the central processing recourses are unfilled.

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36.305 **Object-Based Attention: Attentional Certainty vs. Attentional Shifting**

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The finding that visual attention is often object-based (e.g., Egly et al., 1994) is no longer disputed in the literature. However, the mechanism underlying object-based attentional selection remains to be a subject of investigations. Recent studies put forth two different mechanisms that give rise to object-based attentional effects. The first suggests that attentional uncertainty is driving object-based effects (i.e., attentional prioritization account) – when target location is unknown, locations within the cued object receive greater attentional priority. The opposing view suggests that object-based effects are observed whenever attentional shifts are demanded, such that objects guide attentional shifting. We used a modified Egly paradigm to investigate directly, by pitting attentional certainty against attentional shifting, which of the two suggested mechanisms is indeed responsible for object-based effects. In a series of experiments we manipulated (1) certainty of target position, (2) shifting of attention (i.e., target appearing in a different location than a cue thus requiring an attentional shift), and (3) the cue to target SOA (100, 300, and 500ms). We observed a complete reduction of the object-based effect, across all SOAs, when attentional shifting was required but attentional certainty was high (i.e., 100% certainty). These results suggest that attentional uncertainty, and not a mere shift of attention, gives rise to object-based guidance of attentional selection. In addition, these results land further support for attentional prioritization account of object-based attention, and provide further constraints on the mechanisms of object-based selection.

36.306 **Attention does not automatically spread to all features of an object**

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What are the units of visual attention? O'Craven, Downing, and Kanwisher (1999) have demonstrated that attending to one feature of an object (e.g., motion) enhances the cortical response to this feature as well as other features (e.g., form) of the same object, even when the latter were wholly task-irrelevant. On this basis, O'Craven et al. concluded that attention automatically spreads to all features of an object. However, the behavioral task used in these studies did not explicitly discourage observers from attending multiple features of the same object. Thus, it remains possible that observers voluntarily selected task-irrelevant features of an object, even though they had no direct incentive to do so. In the present experiments, we sought to provide a more stringent test of the hypothesis that attention automatically spreads to all features of an object. Observers performed a change detection task in which they were required to discriminate differences in either the orientation or color of a single object. To encourage a narrow focus of attention on the relevant feature, task difficulty was continuously titrated for each observer. Using fMRI and a multivoxel pattern analysis (MVPA), we show that when the observer was attending orientation, the pattern of cortical activity in V1 discriminated the currently viewed orientation, but not the currently viewed color. In contrast, when the observer attended color, the pattern of cortical activity in V1 discriminated the currently viewed color, but not the currently viewed orientation. These results are inconsistent with the notion that attention automatically spreads to all features of an attended object. Instead, they suggest that attention may be voluntarily restricted to a single behaviorally relevant feature.

36.307 **Category expectation modulates object-selective cortical activity**

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Selective visual attention directed to a location (even in the absence of a stimulus) has been shown to increase activity in the visual cortex and to enhance perception of targets behaviorally. We further explored this effect by manipulating observers' expectations about the category of an upcoming target. Observers viewed a display in which an object (either a face or a house) gradually coheres from a state of dynamic noise; a cue established expectation about the object category. Behavioral data demonstrate that observers were faster to make discriminations about these images when the type of object matched their expectation. fMRI data reveal that this priming was associated with anticipatory increases in object-specific visual cortex, even in the absence of object-specific visual information. Expecting a face evoked increased activity in several face-selective cortical regions including the fusiform gyrus, superior temporal sulcus, and inferior occipital cortex. Conversely, expecting a house produced increased activity in parahippocampal regions. Brain regions associated with expecting faces and houses are contained within those associated with the perception of faces and houses, suggesting that visual anticipation involves similar mechanisms as involved in perception. Visual expectation leads to 'seeing' what we expect to see.

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36.308 **Object attention in extended objects has few effects on accuracy**

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Object attention theory claims that attention is allocated to objects, or spatial regions delimited by object boundaries. One influential object attention paradigm measures the effects of cuing one region of an extended object demarked by an outline on the reaction times to onset detection at the cued location, another location within the object, and a distance-matched control location in separate object (Egly, Driver, Rafal, 1994). However, reaction times in such paradigms may be affected by criterion or bias shifts as well as changes in discriminability. This study measures full psychometric functions for orientation discrimination in a cuing paradigm to examine object attention effects on location cuing in zero and high external noise. Two vertical (or horizontal) rectangular objects marked by outlined edges encompassed two locations each (i.e., top and bottom). One end of one object was peripherally pre-cued, and observers reported the orientation of a Gabor patch in one of the four locations indicated by a report cue; the precued location was tested on 5/8 of the trials, and each of the others on 1/8 of trials. Gabors of varied contrasts appeared either in high external noise (masked) or in no noise. We also tested a four-location design without the rectangles. There was a large benefit for the precued location in the object attention experiment, similar to that found in the four-location design (see Dosher & Lu, 2000; Lu & Dosher, 2000). The within object uncued position showed very small accuracy benefits relative to the between object control in zero noise and no reliable benefit in high external noise, although one of four subjects showed an effect. Any effects of object attention on accuracy are small in relation to spatial cuing effects. Most reported object attention experiments use simple response times, where voluntary changes in criterion may be important.

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36.309 **Effects of Object Structure on Object-Based Attention**

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Since an initial demonstration by Duncan (1984), many studies have found that it is easier to divide attention between two features belonging to the same object, than between two features of different objects—i.e., a "same-object benefit" (SOB). However, other studies, notably by Davis and colleagues (e.g., Davis & Holmes, 2005), have consistently found the opposite effect—i.e., a "different-object benefit" (DOB). We have replicated both effects repeatedly in our laboratory (e.g., Burnham & Neill, 2006), with the critical variable appearing to be the shape and/or complexity of the objects. Whereas most experiments finding SOB have used simple rectangles, experiments finding DOB have used more complex U-shaped objects. Our current experiments are designed to explore what object characteristics are necessary for either SOB or DOB to occur. Most SOB and DOB experiments have emphasized reaction time to clearly visible target stimuli. We have begun to test SOB or DOB for judgments of degraded (masked) stimuli, with Signal-Detection Theory (SDT) analyses of accuracy. In a recent experiment, we randomly intermixed trials with pairs of rectangles and trials with pairs of U-shapes. Subjects made unspeeded same/different judgments of two letters (E or F), briefly presented in ends of either the same object or different objects (equated for physical distance). Surprisingly, U-shapes yielded SOB in discriminability ($d' = 1.54$ vs. 1.40) virtually identical to rectangles ($d' = 1.58$ vs. 1.40). ANOVA yielded a highly significant main effect of same- versus different object, $F(1,27) = 55.63$, $p < .001$, but there was no interaction with shape, F(1,27) = 1.29, p > .26. Because this is the first experiment in which we (a) randomized shapes over trials, and (b) measured accuracy of unspeeded responses, we are now testing accuracy when the shapes are blocked, and (conversely) reaction time when the shapes are randomized.

36.310 **The effect of awareness on hemispheric asymmetries in object-based processing**

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Research has suggested that object-based processing is lateralized more to the left than right hemisphere. Independently, Breitmeyer and colleagues have observed that object-based processing varies with awareness. The present study integrated these findings by investigating whether hemispheric lateralization for object-based processing changes as a function of awareness. While participants fixated a centrally located cross, two stimuli were consecutively presented in the same location to either the left or right visual field. Both the prime and target stimuli could be one of four color/shape combinations (blue/square, blue/diamond, green/square, green/diamond) creating three congruency conditions (all-congruent, part-congruent, all-incongruent). To manipulate the participants' awareness of the prime, the stimulus onset asynchrony (SOA) was either 50ms (unaware) or 250ms (aware). SOA was blocked, while congruency was randomized within each block. Reaction times were measured and a main effect of congruency was found, indicating interference by the priming stimulus as expected. Following the methodology developed by Breitmeyer and colleagues, expected part-incongruent RTs were estimated by averaging the observed RTs for the all-congruent and all-incongruent conditions. It was predicted that if the two features of the targets (form and color) were being processed as objects (i.e. conjoined), the RTs for the part-congruent pairs would show more interference than a neutral prime. The RTs for the observed part-congruent condition should then be significantly larger than the expected part-congruent RTs. Analyses were conducted comparing the expected and observed part-incongruent RTs at the two SOAs for the left and right hemispheres. A significant difference was found when comparing the expected and observed part-incongruent RTs for the 250ms SOA when stimuli were presented directly to the left hemisphere. This result is consistent with previous research showing that object-based processing is associated more with left hemisphere function than right, but suggests that lateralization occurs only when objects enter awareness.

36.311 **Attention increases the perceived strength of illusory contours**

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Carrasco, Ling and Read (2004) reported that transient (exogenous) covert attention increases the apparent contrast of attended stimuli relative to unattended stimuli. Others have proposed that attention increases the strength of polarity-independent orientation-sensitive representations (Wede & Francis, 2007; Suzuki & Grabowecky, 2003). A procedure similar to Carrasco et al. (2004) was used to test the effect of attention on the perceived strength of polarity-independent illusory contours. Four inducing elements, composed of four concentric circles with one quadrant of arcs shifted out of phase with the circles, created a Kanizsa-like illusory square. The strength of the illusory contour was varied by manipulating the phase angle (0-180) between the arcs and circles. A standard (108 degree phase angle) stimulus was paired with a test stimulus (0-180 degree phase angle), and briefly presented on either side of fixation. Before presentation of the inducing elements, a cue was presented at the location of the test stimulus, the standard stimulus, or at fixation. Participants reported which stimulus appeared to have contours with the highest clarity. Psychometric functions expressing the likelihood of choosing the test stimulus over the standard stimulus were obtained, as a function of the phase angle. The results showed that cueing the test stimulus reduced the phase angle required to match the standard stimulus, effectively increasing the strength of the illusory contour. With a neutral cue, participants were at chance when the two stimuli were identical. The results are consistent with the idea that attention modifies the strength of polarity-independent orientation-sensitive mechanisms in visual cortex (Wede & Francis, 2007; Suzuki & Grabowecky, 2003).

36.312 **Feature binding through anticipatory inhibition**

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The present study investigates the binding of features when active inhibition is applied to one dimension of an attended non-target object. In a series of experiments, participants made speeded responses to the color (red vs. green) or orientation (left vs. right) of a target on different trials. The target was preceded by a two-dimensional negative cue whose relevant dimension matched the target response on 33.3% of the trials. Of particular interest was whether the irrelevant dimension of the cue would be inhibited along with its relevant dimension, and whether inhibition would be applied at a feature level (with the individual features unbound) or at an object level (with the individual features bound).

The results show that participants' reaction times were influenced by both the relevant and irrelevant dimensions of the cue, suggesting that inhibition was applied to the object features regardless of their task relevancy. Furthermore, the inhibitory effect of the irrelevant dimension was observed only when the cue and target could be perceived as the same object, suggesting that inhibition was applied at an object level. The results are interpreted with reference to the theoretical frameworks of object files (Kahneman, Treisman, & Gibbs, 1992) and event files (Hommel, 1998).

Color Perception

36.313 **Unique hue isochromes in the equiluminant plane**

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Each chromatic hue is generally specified by the proportions of four unique hues (R, G, Y, and B) it contains. These proportions have been mainly established for spectral colours. We determined them for non-spectral colours of different excitation purity. Specifically, we have established isochromatic curves (isochromes) in the equiluminant plane for three trichromats. By isochrome we mean a set of points in the equiluminant plane which have the same amount of one of four unique hues. For example, a R-isochrome is a curve in the equiluminant plane all points of which represent colours having the same amount of unique red.

Observers were presented two rectangular patches on the CRT monitor driven by the VSG 2/5 graphical board. Both patches were spatially homogeneous in colour and surrounded by a neutral background. One patch was a reference stimulus. As reference stimuli, we used four unique hues preliminary established individually for each observer. The second patch was a variable stimulus adjusted by observers so that it looked as having the same amount of the unique hue as the reference stimulus. In a single trial an observer could change only the excitation purity of the variable stimulus, its dominant wavelength being fixed. Throughout the experiment the dominant wavelength varied at 10-15 levels (depending on the unique hue).

The isochromes were found to be essentially nonlinear. If one interprets isochromes as the equal-response curve of the channel producing the unique hues, then it follows that these channels are non-linear. Moreover, we found symmetry between neither R- and G-isochromes, nor Y- and B-isochromes. It follows that, contrary to the general view, the channel producing the unique hues are unipolar, i.e., non-opponent.

36.314 **Simultaneous Color Contrast, Afterimages and Metameric Intransitivity: Novel Effects and Explanation of Previously Enigmatic Results**

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While many features of simultaneous color (and brightness) contrast (SCC) and negative and positive afterimages (NAI, PAI) have been known for half a millennium, even simply stated questions remain unexplained (e.g., Anstis, Rogers & Henry 1978). We discuss novel and underappreciated properties and effects of SCC, PAI and NAI, and implications for understanding neural mechanisms underlying these phenomena. In particular, we develop displays of test patches which look the same but have grossly different afterimages, and, conversely, which look very different but have identical afterimages (metameric intransitivity). These effects are based on the findings that SCC has a time course, that the PAI and NAI can be visible simultaneously and that these afterimages can obscure results of vision experiments. When at least one background is white or near-white it is not possible to match the test patch colors merely by adjusting their brightness, possibly due to slightly unequal number of color receptors or associated higher order neurons. We emphasize the underappreciated effect that SCC does not cause the test patch to take on the surround's complementary color, rather the common color is "pulled out" from the surround and test patch. We derive semi-quantitative curves for the strengths of SCC, NAI and PAI and use these to explain previously enigmatic results (ARH, 1978) and produce the dissociations between image and afterimage metamers. Furthermore, we show that the Munker color effect can be obtained solely from grouping effects—and does not depend on geometry—of a group of colored discs on a different color background inducing a change in the color of a group of test discs. We use this grouping version to clarify the effect of the inducing stimuli in the Munker, White and inverse White effects, leading to the explanation of a novel inverse Benary effect.

36.315 **Switch color afterimages depend on the luminance of the viewing surface**

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Using a two-stimulus afterimage procedure, VanHorn and Francis (VSS 2007) reported on a new type of color afterimage. When observers viewed two orthogonal bar gratings in sequence they reported seeing an afterimage that was the same orientation as the first image. Further, observers reported that the color of the bars in the afterimage had switched from the color of the bars in the first bar grating of the inducing sequence. When the first bar grating included blue and black bars, observers often reported that the afterimage contained black and blue bars with the colors in switched positions relative to the inducer. On other trials observers reported seeing a negative color afterimage rather than a switch afterimage. We now report that the probability of seeing a switch or negative afterimage depends on the intensity of the viewing surface. We varied the luminance of the viewing surface and asked observers to report on the afterimage color of one of the afterimage bars. Switch afterimages were reported more often when the luminance of the viewing surface was low, while negative afterimages were reported more often when the luminance was high. The role of viewing surface luminance is similar to its role for positive afterimages, which are more common when the viewing surface is dark (Robertson & Fry, 1937; Howard, 1960).

36.316 **Color contrast effect under natural and unnatural viewing conditions**

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We usually have good color constancy in natural environments where we can easily recognize the structure of a space and illumination. In our previous study, we have demonstrated the effects of a natural and an unnatural viewing condition on color constancy. (Mizokami & Yaguchi, 2007 ECVP). Observers judged a color of a test patch placed either in a front or a back room. Two rooms were connected by a window and illuminated by reddish and white lights, respectively. The immediate surround of the patch was always the white wall of the back room under white illumination. Results showed a loss of color constancy under the unnatural viewing condition where the spatial structure was distorted by a kaleidoscope-type viewing box, suggesting the importance of naturalness and spatial factors. We also found a strong contrast effect by the immediate surround, but it was not clear if it was due to a local contrast or the 'white' illumination of the back room became a strong anchor.

In this study, we examined how color constancy and color contrast were changed by a variety of immediate surround conditions under the natural and unnatural viewing conditions to find factors affecting the appearance of a test patch. We tested the combinations of white, reddish, and green illuminations as well as different background colors. The results showed stronger local contrast effects on the color judgments of the test patches under the unnatural viewing condition than the natural viewing condition in all combinations of illumination color. They suggest that color appearance is not determined by merely a local contrast but the color of illumination under a natural viewing condition, whereas it strongly relies on the immediate surround in the case of an unnatural condition that we are not able to obtain the accurate recognition of a space and illumination.

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36.317 **What L/M cone-signal pooling is consistent with the Rayleigh matches of carriers of deuteranopia?**

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PURPOSE: A deuteranope's mother and daughter are obligate carriers of deuteranopia, who have one defective and (in most cases) one normal X chromosome. The normal array has both L- and M-photopigment genes (L1 and M1); the defective array has an L-photopigment gene (L2), which is not necessarily the same as the L1 in the normal array. According to Lyonization (Lyon, 1961), a female carrier's defective gene is expressed so she may have more than two types of L/M photopigments (for example, L1, M1 and L2). An open question is how a deuteranopic carrier's third pigment in the L/M range (L2) contributes to the neural signals encoding color. Carriers' Rayleigh matches are known to have a midpoint within the normals' match range; and carriers' Rayleigh-match range can be normal or enlarged (Pickford, 1944; Krill & Schneiderman, 1964; Jordan & Mollon, 1993). Here, a model considered how the signal from cones with the L2 pigment pools with the signal from cones with the L1 or M1 pigment. The model predicted individual differences in Rayleigh-match midpoint and range for carriers of deuteranopia.

METHODS: The model determined carriers' Rayleigh matches based on three different assumptions about the signal from cones with the L2 pigment: it pools with the signal from cones with (1) only the M1 pigment, (2) only the L1 pigment or (3) either the M1 or L1 pigment, unselectively. L2 spectral-sensitivity peak, L2 optical density, and the relative number of L1, L2 and M1 cones were varied in the model.

RESULTS AND CONCLUSIONS: The model predicted typical deuteranopic carriers' matches (that is, midpoint within the color normals' range and match range normal or enlarged) only under the assumption that the signal from cones with the L2 pigment pools unselectively with the L1- and M1-cone signals.

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36.318 **The influence of object identity on lightness constancy**

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Lightness constancy refers to the visual system's ability to detect the same grey shade regardless of current light intensity. A typical paradigm involves the comparison of two objects of the same shade placed under different illumination levels. Some failure in constancy is usually observed. In an attempt to stress object identity, we have recently developed a novel paradigm in which a lightness match is taken in one illumination and then the target is relocated to another illumination for the second match. Even here, there is still failure in constancy. In a previous study (Zdravkovic, 2006), one grey shade was used for the first match and a different grey shade was used for the second match; observers were essentially tricked into thinking that only a single object was presented. The second match varied as a function of the shade of the first target. That is, observers misperceived the second shade, making a match in the direction of the first shade. Rather than simply demonstrating constancy failure, these results illustrated how the strength of constancy could be measured. Using the same paradigm, two new studies were designed to investigate the relevance of context on the strength of constancy: illumination in the first experiment and background in the second. These two manipulations were expected to produce opposite results. Reduction of the illumination difference between the two target levels should increase constancy, while a decrease in background articulation should decrease constancy. In the first experiment the illumination difference was reduced (from 1:13 in our original experiments to 1:2.) and there was no failure in constancy. In the second experiment articulation of the background was reduced. In all previous experiments the back wall was covered with different grey shades, here it was plain black. As expected, there was significant failure in constancy.

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36.319 **Impossible transparency becomes possible also without stratification indexes: a new example of illusory transparency due to motion**

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Two static surfaces need stratification indexes to be perceived as overlapped and plausible colors combination to be perceived as transparent. Motion leads to perceive transparency also when colors are implausible. However, the static presentation of the same stimulus will be perceived as two non-transparent overlapped figures because of the presence of stratification indexes (Hupé and Rubin, 2000). In this study we show a pattern where, in static presentation, no indexes of stratification are presented resulting in a perception of coplanar non-transparent areas both when colors combination is implausible or plausible with transparency perception. Nevertheless, the introduction of motion still leads to a perception of stratification and transparency in both cases. Stimuli consist in two movies with a horizontal rectangle composed by three vertical rectangles changing their widths during time. The two movies (plausible or implausible transparency) differ each others only because of the greyscale colors filling the vertical rectangles. In the plausible condition, colors combination was plausible with the interpretation of the pattern as two squares in which one square is transparent and slowly covers and discovers a second square. In the implausible condition, colors combination was absolutely implausible for this kind of perceptual interpretation. Ten participants observed a randomised series of the frames composing the two movies conditions in static presentation. All participants spontaneously reported, for all frames, to perceive three vertical rectangles composing an horizontal rectangle: no transparency or stratification were perceived, also when colors combination was plausible with transparency. After that, the same subjects observed the two movies and for all of them transparency and stratification was immediately perceived also when colors combination was implausible with transparency. These results show how transparency and stratification is perceived in a dynamic stimulus also if stratification indexes and plausible colors combination are not present.

36.320 **A Microphotogoniometer for the Measurement of Gloss and its Correlation with Visual Perception**

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A Microphotogoniometer (MPG) has been developed reporting physical gloss measurements that correlate well with human psychometric responses. Print gloss measurements are typically performed through integration of specular, un-polarized light within an aperture window at a given incidence angle. The later is often chosen depending on the reflector properties. Although such measurements are robust and well accepted by the industry, they often find poor correlation with visual perception.

This instrument allows for the measurement of polarized specular gloss at different surface angles and constant incidence angle. Reflectance data is summarized in terms of a Bidirectional Reflection Distribution Function (BRDF) and then parameterized into several independent gloss components. These components contain information about both surface and material properties and provide additional degrees of freedom for both understanding gloss and gloss metric development.

A comparison of printed and un-printed inkjet photographic media gloss measurements by the MGP and a traditional gloss instrument is presented. Then, a psychometric analysis is employed to compare both techniques. Material and surface properties and their impact on gloss are also discussed.

36.321 **Perception of the diffuseness of the light source and of the number of light sources in photographs of real objects is predicted by image statistics regardless of shape and material of the objects**

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Introduction: Previously we have shown that human observers use mostly lower order features like the average direction of the light source to determine whether two objects are illuminated in the same way. In this experiment we varied the diffuseness of the light source and the number of light sources while keeping the average direction of the light constant, in order to find out whether these aspects of the light field can be used effectively.

Methods: We chose three objects from the ALOI database (Geusebroek et al. ,IJCV, 2005), a teapot, an orange and a tennis ball. The objects in the database are photographed with light sources from five different directions. We combine these images with different weights to create our stimuli, either with a single light source that varies in diffuseness in three steps, or with two light sources that vary in their separation in three steps. Observers are presented with an orange, a teapot and a tennis ball on every trial, and have to indicate which of the three objects is illuminated differently from the other two (odd-one-out paradigm). We used all possible combinations of the six light source conditions.

Results: Although observers complained that the task was difficult, their performance was nevertheless significantly above chance for most combinations. Moreover, results could also be predicted fairly well by the average pixel differences between two stimuli of the same object, suggesting that observers were able to disregard the differences in the image due to the difference between shape and form of the objects, and focus on the differences caused by the change in illumination.

Conclusion: Observers are able to extract information about diffuseness and number of light sources from a scene, in spite of the large differences in shape and material of objects.

36.322 **Neural Pathways of Induced Steady Color Shifts Caused by Temporally Varying Context**

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Purpose & Method: When a field surrounding a physically steady central region is slowly modulated in chromaticity over time (<~3 Hz), the color appearance of the central region also varies. At higher temporal frequencies (> ~3 Hz), modulation of the surround remains visible but the central region appears steady (De Valois et al., 1986). Further, modulation between ~3 – 20 Hz along the l or s axis of the MacLeod-Boynton color space (time-average chromaticity metameric to equal energy white) shifts the steady appearance of the central region toward redness or yellowness, respectively (D'Antona & Shevell, 2006). This study examined whether the induced steady color shifts occur independently in l and s pathways. If so, induced color shifts with modulation along only l or only s can determine (by vector summation) induced color shifts with simultaneous modulation along both the l and s directions. Further, changing the relative phase of simultaneous l and s temporal modulation by 180°, should not influence the color shift. These predictions were investigated by square-wave modulation of surrounds at 6.25 Hz along the l axis alone, the s axis alone, or along intermediate axes. Induced colors were measured using achromatic cancellation. Results & Conclusion: Shifting the relative phase of simultaneous l and s modulation caused sharply different induced steady color shifts. Further, color shifts from simultaneous modulation along l and s axes were not a simple combination of the shifts from modulation along only the l or s axis. Independent neural responses in l and s pathways cannot explain these findings. The measurements indicate a contribution from a cortical mechanism sensitive to the specific chromatic axis of modulation.

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36.323 **Colour dissimilarities under neutral light sources differing in intensity measured using two competing methods**

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In previous work (Logvinenko & Maloney, P&P, 2006), we asked observers to rate the dissimilarity of pairs of achromatic surfaces in simple scenes illuminated by neutral lights differing in intensity. We found that log surface albedo difference and log lighting intensity difference contributed additively to rated dissimilarity but that the surface contribution was greater, a form of partial lightness constancy. Here we (a) extend these results to dissimilarity of coloured surfaces under neutral illuminants differing in intensity and (b) compare two methods for measuring perceived dissimilarity, quadruple comparisons and dissimilarity ranking. In quadruple comparisons observers judge which of two illuminant-surface pairs exhibits the greater dissimilarity (forced choice). In dissimilarity ranking observers assign a numerical ranking to each illuminant-surface pairs.

Five normal trichromatic observers took part in the experiment. A stimulus display consisted of 3 identical sets of 7 Munsell papers (5R4/14, 5YR7/12, 5Y8/12, 5G6/10, 10BG5/8, 5PB5/12 and 10P5/12) illuminated independently by 3 light sources the intensities of which were 6, 110 and 2100 lux. The experiment was divided into two parts. In the first part, dissimilarities between the seven Munsell papers for each of the three illuminations were evaluated by using a method of quadruple comparisons. Each pair of pairs was evaluated five times for each observer. Then, in the second part, dissimilarities between Munsell papers illuminated by dimmer lights (6 and 110 lux, respectively) were evaluated by numerical ranking using the dissimilarities under the brightest light as anchors. We compared non-metric Multi-Dimensional Scaling solutions for the two methods. Procrustes statistics (a standard method for comparing spatial configurations) were close to zero. This justifies the use of the ranking method in measuring colour dissimilarity. We conclude that on average the dissimilarities between Munsell papers decreased with decreasing light intensity.

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36.324 **Categorical color perception in natural scenes under different illuminants**

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Perceiving surface colors categorically may help in identifying and recognizing objects in a scene. Although often investigated with abstract colored patterns, it is unclear how well categorical color perception is maintained in more naturalistic environments, such as natural scenes, with varying natural illuminations, as in everyday life. To address this issue, a categorical color-naming experiment was performed with simulations of hyperspectral natural images presented on color display, under daylight of correlated color temperature either 6500 K or 25000 K, each of duration 1 s. A test surface in the image, a sphere physically inserted in the scene, was covered with a Munsell color drawn from the category subsets of brown, pink, and purple, each comprising approximately 60 colors. The test-surface color varied from trial to trial, and each category subset was tested in each experimental session. Observers had to name the color of the test surface by pressing one of nine computer keys labeled: red, green, blue, yellow, pink, purple, brown, orange and neutral (black, gray, or white). The positions of observers' focal colors were determined by the peaks of the smoothed distributions of their naming responses plotted in CIE 1976 (u', v') space. To quantify the effect of illuminant, a focal-color "constancy" index was computed by a comparison of the focal-color shift with the ideal reflected-color shift due to an illuminant change. As with the standard color-constancy index used with e.g. asymmetric color matching, perfect constancy corresponds to 1 and perfect inconstancy to 0. Focal-color constancy reached approximately 0.7 for pink and purple, and 0.2 for brown. Although not as good as traditional measures of constancy, categorical color perception appears to be more robust than expected under illuminant changes, and may provide a useful anchor for surface-color judgments in natural scenes.

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36.325 **Colour constancy for real 3D and 2D scenes under typical and atypical illuminant changes**

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Previous studies comparing colour constancy across diverse illumination changes have drawn an inconclusive picture as it is not yet firmly established if typical illumination changes, which are likely to occur during a daily routine (e.g. change between daylight and tungsten), lead to higher levels of colour constancy than atypical ones.

Using a real surface matching task we investigated if either (a) the nature of illumination change (typical vs atypical) or (b) the learning illuminant had an influence on observers' colour constancy performance. For (a) observers learned a real surface colour under daylight and matched it either under tungsten (typical change) or a purple illuminant (atypical change). For (b) learning took place either under the tungsten or the purple illuminant and matching was always performed under daylight.

For all four experiments surface colours were either learned as part of a three-dimensional (3D) or a two-dimensional (2D) setup. We chose a mixed-design with the four illumination changes as between-subject factors and the two learning setups (3D/2D) as within-subject factors. In total, twenty-eight colour normal observers participated. After learning a real surface colour for 20 s, an illumination change occurred and observers adapted for 2 min to the new illuminant before matching, which was always done in a 2D setup. Six different target colours were tested.

The results showed no evidence that observers performed better for typical than atypical illumination changes nor that the learning illuminant had a significant effect on observers' performance. However, learning real surface colours as part of a 3D setup significantly improved observers' colour constancy performance. We conclude that human colour constancy is able to cope with a wide variety of illuminant changes and benefits from the additional cues available in a 3D setup.

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36.326 **The structure of color space is largely invariant under illuminant changes**

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Color constancy is often measured using asymmetric matching or achromatic adjustments. These methods are accurate but have limitations: achromatic adjustments allow the characterization of only one point in color space, and while asymmetric matching overcomes this limitation, measuring many points in color space is time consuming. Color naming allows quick sampling of a large portion of color space and the direct measuring of color appearance, making it a powerful tool for studying color constancy when coupled with appropriate data analysis methods. We asked observers to classify Munsell chips simulated on a monitor varying in hue, chroma and value to one of nine color categories under a neutral and four chromatic illuminants. Category boundaries were fitted to the naming data in order to determine the effect of illuminant change on color categories and on the convergence point of the boundaries. Observers were fairly consistent in their classification performance: 73% of the chips were classified in the same color category under four of the five illuminants and 43% of the chips under all illuminants. The chips that were categorized most consistently fell closest to category centroids and formed clusters in color space that were close to the unique hue loci. The fitted category boundaries and convergence points were highly similar under all illuminants, and color constancy calculated from the achromatic points was close to 90%. The convergence points were slightly shifted away from the direction of illuminant change, revealing incomplete adaptation to the illuminant. This undershoot was small, however, when compared to the change in the color signal from the surfaces under illumination changes. In conclusion, the classification of Munsell chips was based to a large extent on their reflectance rather than on the overall color signal, this being particularly clear for chips close to the loci of unique hues.

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36.327 **Searching for variegated elements**

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Background: The characteristics of chromatic mechanisms mediating suprathreshold color vision still are unclear. In this study, variegated elements were used in a visual search task to investigate how the visual system processes multiple elements that are chromatically heterogeneous.

Methods: A forced-choice accuracy visual search task was used. Twelve variegated search elements, each 0.73x0.73 deg consisting of 64 small colored squares, were presented as a 200 msec flash. In half the trials, one of the elements was a target. Difference thresholds were estimated for variegated targets that differed from the variegated distractors in their space-average chromatic mean along the so-called cardinal color directions. The amount of within-element chromatic heterogeneity (chromatic variance) also was systematically varied to estimate the underlying mechanisms' sensitivity. Specifically, five different levels of within-element chromatic heterogeneity (including a homogeneous condition in which both target and distractor elements were uniform in color) were tested for each of the four target chromaticities. Within a level of heterogeneity, both target and distractors contained the same amount of heterogeneity, expressed along the same chromatic direction (e.g., red-green variegated distractors with a chromatic mean at "white" and a pink-red variegated target).

Results: Indices of detectability corresponding to 75% search performance were estimated from psychometric functions for each target chromaticity and each level of within-element chromatic heterogeneity. Slopes relating threshold as a function of within-element chromatic heterogeneity were taken as estimates of the mechanisms' sensitivity. These slopes described the measurements well and were similar across chromatic targets and observers.

Conclusions: Search for variegated elements were performed efficiently as evidenced by the relatively shallow slopes relating search performance to the amount of within-element chromatic heterogeneity. Similar slopes obtained for the different chromatic directions suggested similar sensitivity along the so-called cardinal directions.

36.328 **Perception of neon color spreading in 3- to 6- month old infants**

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Although lots of studies about neon color spreading have been reported, there are few studies about the early perceptual development of it in human infants. The aim of this present study was to explore the perceptual development of neon color spreading in infants.A total of 28 infants, aged 3-4 and 5-6 months, participated in the present study. There were two conditions (experimental condition vs. control condition), and each infant participated in both conditions. In the experimental condition, two kinds of stimulus were presented side by side: an Ehrenstein neon color spreading pattern and a non-neon color spreading pattern. The latter was made by reversing the color arrangement of the Ehrenstein neon pattern. In the control condition, we separated the differently colored parts of the Ehrenstein neon color spreading pattern and the non-neon color spreading pattern in the experimental condition. Each experimental condition consisted of 2 trials. In each trial, stimulus was presented for 15 s. In this paradigm, we infer that if infants could perceive neon color spreading, they would show a preference for the neon pattern only in the experimental condition. The current results showed that the 5~6-month-old infants had a significant preference for the neon pattern, but the 3~4-month-old infants did not. Neither age group showed preference in the stimuli of the control condition. These results suggest that the 5~6-month-old infants could perceive neon color spreading.

36.329 **Categorical discrimination of colour**

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Colour vision leads to the conception of linguistically delimited colour categories that enable us to communicate the reflectance properties of objects. The question arises whether this demarcation of the continuous colour signal implies an actual stepwise variation in colour perception, a phenomenon that has been called categorical perception. In this case the categorization of colour might be inherent in the low-level perceptual processes that allow the discrimination of different wavelength combinations. To answer this question we investigated the relationship between discrimination thresholds, reaction times to color differences, and colour categories for different hues of approximately equal saturation along a color circle in the Derrington-Krauskopf-Lennie (DKL) colour space. If there is categorical perception on this level of visual processing one would expect a reduction of discrimination thresholds at the category borders. In the first experiment we determined the boundaries and transitions between the colour categories green and blue individually for each observer. We measured the differential decision boundary between these two categories and the probabilities of colours to be included or excluded in either of the two categories. In the second experiment we used a staircase technique to measure discrimination thresholds along the transition between the two categories. These discrimination thresholds can be considered as a local metric of colour space that is independent of the particular colour space in which they are measured. Therefore we used the discrimination thresholds to determine equally distant stimuli above threshold. We measured reaction times for discriminating these stimuli within and across the borders of green and blue. We found no reduction of discrimination thresholds at the category boundaries. However, reaction times seem to be sensitive to the transition of colour categories.

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36.330 **Diversity in English color name usage**

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Background: A striking feature of color naming in the World Color Survey (WCS) (www.icsi.berkeley.edu/wcs) is the great diversity among the color vocabularies of informants speaking each of these unwritten, third-world languages. In this project, we examined English speakers to determine whether this prominent diversity in color naming applies to a written, Indo-European language.

Methods: We collected free color-naming data on educated native English speakers (N=23) using the same 330-color stimulus set and the same instructions as were used for the WCS. Then we followed up with color names restricted to the 11 English "Basic" Color Terms (BCTs).

Results: English-speaking subjects showed remarkable diversity in their usage of color terms. The average pair-wise similarity under restricted instructions was 0.80 ±0.04, reflecting variations in the locations of boundaries between BCTs. Average similarity under WCS instructions dropped to 0.68 ±0.06 (85th percentile of the WCS, which averaged 0.54 ±0.13), reflecting non-BCT (nBCT) usage. Subjects averaged 8 nBCTs (males averaging fewer color terms than females, $p<0.02$). The most common nBCTs were peach (N=19) and lavender (N=15), followed by maroon and teal (N=13). Peach and lavender named desaturated subdivisions of orange and purple, respectively. Desaturated subdivisions for green and blue were not observed. Other nBCTs intruded between BCTs: for example, turquoise and teal appeared between green and blue. In general, nBCTs were reminiscent of color terms in the WCS, where both subdivision and intrusion are common.

Discussion: Our results indicate that the low concordances observed in the WCS are a general feature of world languages, not restricted to unwritten languages spoken far from the influence of Western culture. We do not know why pink is a BCT, used by all speakers of English, whereas peach and lavender are not, or why no language (in the WCS or elsewhere) has a one-word term for *pale-green.

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36.331 **Color Naming Based on Clinical Visual Condition: A Surprising Interaction**

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Purpose: Color naming procedures usually involve the presentation of a stimulus that varies in appearance (based on chromatic or achromatic properties). Berlin and Kay (1969) have noted that well-developed languages seem to contain precisely eleven basic color terms. For the purpose of exploring how the phenomenological color world of clinically diagnosed vision-altered patients exemplifying various forms of color alterations matches that of color normal observers, and to assess receptor sensitivity in relation to one's description of color, a color naming procedure was utilized.

Procedure: Subjects (n=10) exemplified altered color vision and best-corrected visual acuities of 20/100 to 20/600 in both eyes. Color vision deficiencies were detected with Ishihara Color Plates. Subjects were tested with a set of color chips and color categories were assessed using a pallet of nominal color regions consisting of 11 colors- red, green, yellow, blue, orange, purple, brown, pink, white, black, and gray. Control subjects (n=10) were assessed with the same stimuli and procedures.

Results: Data for color naming under incandescent and natural lighting conditions were collected. Although the regions chosen by our subjects for the 11 basic color terms were quite large and slightly shifted, they were in rough agreement with control subjects.

Discussion: Despite the fact that subjects show reduced visual acuity and altered color vision they show consistency in naming colors and characteristic shifts and confusions. These data imply that, despite their inability to pass standard color vision tests, these patients color naming abilities are remarkably intact. It is likely that our subjects are making use of possible learned cues and segmentations to demonstrate a fairly accurate color naming ability despite evidence of profound color loss. Color categorization data collected under both incandescent and natural lighting conditions complement one another. These data suggest a good degree of color constancy for our subjects.

36.332 **The color of music**

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We investigated the relations among color, music, and emotion for the 37 colors of the Berkeley Color Project: saturated, desaturated, light, and dark shades of red, orange, yellow, yellow-green, green, blue-green, blue, and purple, plus white, black, and 3 grays. To study color/music relations, participants viewed all 37 colors while listening to 18 orchestral selections in major and minor keys by Bach, Mozart, and Brahms that had slow, moderate, and fast tempos. For each selection, participants chose the five most-consistent and the five least-consistent colors. Across composers, faster tempos and major keys were both associated with brighter, warmer, more saturated colors than slower tempos and minor keys. To determine whether affective responses might mediate these color/emotion associations, we also studied the relation between the color samples and emotion words and between the musical selections and emotion words. Participants produced color/emotion associations by rating the consistency between 16 emotion words and each of the 37 colors. Strong associations were found between many emotion words and colorimetric dimensions: e.g., HAPPY, LIVELY, and ENTHUSIASTIC with light-warm-saturated colors; SAD, DREARY, and UNENTHUSIASTIC with dark-cool-desaturated colors; STRONG and AGGRESSIVE with warm-saturated colors; and WEAK and SHY with cool-desaturated colors. Participants also produced music/emotion associations by rating the consistency between each emotion word and each of the 18 musical selections. We found a strong link between the affective response to musical selections and the affective response to the corresponding chosen colors. Specifically, there was a strong positive correlation (.93) between the ratings of emotional associations to the 18 musical selections and the ratings of emotional association to the colors people chose as most/least consistent with the same musical selection. This finding suggests that affective response may mediate the relations we found between color and music.

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

36.333 **An EOG-assisted Saccade-contingent Color Breakup-free Display**

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This paper presents a contingent field sequential display that inhibits color breakup on-the-fly when saccadic eye movement is detected. On field sequential displays, which synthesize colors in the time domain, the color breakup phenomenon occurs when the three primary components of the same object project onto different locations of retina upon saccadic eye movement. While saccadic suppression inhibits the luminance channel, the rainbow-like chromatic signals are not suppressed and become the major artifacts of field sequential displays.

The project goal is to build a saccade-contingent display that switches between two modes. The display functions normally when the viewer gaze is in fixation or smooth pursue. Once a saccade is detected, the display immediately reduces the image chroma to the threshold that color breakup is not perceivable until the saccade finishes. The saccadic eye movement is detected by a remote battery-powered electrooculogram (EOG) sensing circuit, which includes operational amplifiers, low-/high-pass filters, notch filters, and infrared LEDs. The saccade event is conveyed via the infrared beams and received by a local infrared sensor. An FPGA board was used to drive the infrared sensor and modify the image. The chroma is reduced by adjusting the red, green, and blue primaries from LED backlights. Each primary can be mixed with the other two primaries such that the chroma is reduced while the luminance is increased.

To find the threshold of perceiving color breakup, we designed a saccadic display, which is a 32x1 linear red-green LED array driven by FPGA. Each row of the given image is displayed by the linear LED array sequentially. The whole image will be perceived only on a synchronized saccade. We used the EOG circuit to trigger the display when a saccade is detected.

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URL: color.di.nctu.edu.tw

Perceptual Organization: Contours

36.334 **Grouping of Shape by Perceptual Closure: Effects of Spatial Proximity and Collinearity**

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Time course of grouping of shape by perceptual closure as a function of spatial proximity and collinearity between the closure-inducing fragments was examined in three experiments using primed-matching. When only closure was available, early priming of the global shape was observed for spatially close fragments, but not for spatially distant fragments. When closure and collinearity were available, the global shape of both spatially close and spatially distant fragments was primed at brief exposures. These results indicate that spatial proximity is critical for the rapid grouping of shape by perceptual closure in the absence of collinearity, but collinearity facilitates the rapid grouping of shape when the closure-inducing line segments are spatially distant. These findings suggest a rapid computation of collinearity between closure-inducing line segments that is insensitive to spatial proximity within a certain range. This fast-occurring mechanism enables efficient image descriptions and apparently is crucial for a fast, reliable interpretation of the visual scene. The results also showed, however, that stable priming effects of the global shape over time were observed only when the closure-inducing fragments were collinear and spatially close, suggesting that maintaining a stable representation of shape beyond the first stages of visual processing depends both on spatial proximity and collinearity between the closure-inducing fragments.

36.335 **Misalignment Constraints on Visual Interpolation**

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Problem: Some geometric constraints on contour interpolation have been shown to be largely scale-invariant (Banton & Levi, 1992; Shipley & Kellman, 1992). Kellman & Shipley (1991) hypothesized that the constraints of contour relatability may include a small tolerance for misaligned parallel edges that is not scale-invariant. Earlier we reported data suggesting that this tolerance is constant in retinal terms, rather than scale-invariant (Hilger & Kellman, 2005). Here we report more comprehensive studies of the relation of contour interpolation to retinal misalignment. We used different stimulus types (step-edges vs. Gabors) and misalignment methods (element misalignment vs. phase misalignment).

Methods: Tolerance for misalignment was tested in a two-interval forced-choice path detection paradigm (Field, Hayes & Hess, 1993). Targets were paths of nine spatially separated contour segments that were collinear or misaligned to varying degrees relative to the axis of global path alignment. Paths were presented in noise consisting of 247 identical contour segments, randomly oriented. The amount of retinal misalignment was manipulated within subjects while the inducer type (step-edge or Gabor) and misalignment type (element misalignment or phase misalignment) were varied between subjects.

Results: Element-misaligned stimuli largely confirmed a retinal tolerance, with interpolation effects disappearing by about 16 min. Both step-edge and Gabor stimuli showed similar absolute performance levels and similar decreases with increasing misalignment, falling to chance between 12-16 min. In contrast, phase-misaligned Gabors (with aligned envelopes) showed superior performance overall and a slower decline in performance with increasing misalignment compared to element-misaligned stimuli.

Conclusions: Tolerance for misalignment in the interpolation of edges is determined by a retinal metric, decreasing gradually up to 12-16 min. This tolerance is largely identical for both illusory edges and Gabor-based paths. Other aspects of an array, such as perfectly aligned envelopes, may increase this tolerance in a search-based task.

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36.336 Contour interpolation and lightness induction mechanisms interact to produce classification image features in a shape discrimination task

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Purpose. Recent classification image (CI) studies have revealed the important role of pixels near interpolated contours in the perception of illusory shapes. However, it is unclear if the direction/magnitude of this influence owes only to contour interpolation, or at least partly to induced surface lightness.

Method. We addressed this issue by having subjects discriminate fat and thin noise-corrupted rectangles, the tops and bottoms of which were connected by illusory contours or luminance-defined contours. Inducers were either all black, all white, or mixed (half black / half white). Within twenty days, two naïve participants each performed 10,000 trials for each of the six polarity/contour pairings. An additional twenty naïve subjects each performed exactly 200 trials of the six conditions. A Quest staircase adjusted inducer contrast to yield 70% performance for each observer.

Results. First, CIs deriving from the white and black inducers had features of opposite polarity, and the mixed inducers produced the weakest CI features. Second, we used the average noise field of one response category with the mixed inducer as a baseline condition, and compared it with the average noise field of the alternative response category with either the white or black inducers. In the illusory condition, the resulting CI revealed a lighter and darker center region when the inducers were black and white, respectively. Finally, for both illusory and luminance-defined contours, thresholds with mixed inducers were lowest.

Conclusions. These results suggest that a) dominant CI features (direction/magnitude) systematically depend on inducer polarity; b) the luminance of the central surface of illusory shapes affects discrimination, despite being far-removed from contours; and c) shape discrimination is more efficient when lightness induction is reduced, perhaps by causing greater reliance on contours. These findings, taken together, indicate that contour interpolation and lightness induction mechanisms interact to produce fat/thin CI characteristics.

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36.337 Figural constraints on contour discontinuity detection

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In this study the effect of figural goodness on the detection of contour discontinuity was investigated. Two oposite hypotheses of goodness effect were evaluated. The Assimilation hypothesis: good figures are more tolerant to the contour degradation than the poor ones (e.g. a circle with a small gap on its contour is perceptually categorized as a circle, not as an arc). The Sensory detection hypothesis: good figures are more sensitive to the contour degradation than the poor ones (e.g. the small gap on a contour of a circle is easier to detect than the gap on an ameboid figure). In this study the dimension good-poor was defined through four stimulus dimensions: symmetric-asymmetric, simple-complex, compact-disperse and oval-sharp (good figure is an aproximation of a circle, i.e perfect symmetric, simple, compact and oval form). According to these dimensions the pairs of figures were generated. Each figure had its complete contour and incomplete contour (small gap) version. Twenty subjects were asked to judge whether the presented figure had a gap (visual search task: the gap was a target). RT was recorded. The analysis of variance indicated the significant effect of completness: the gap was detected faster in an incomplete than in a complete contour condition. The effect of the factor stimulus dimension and the interaction dimension x completness were significant. Partial analysis has shown sigificant effects of the dimension simple-complex: the gap was detected faster in simple than in complex figures. The effect of the dimension symmetric-asymmetric was marginally significant: the gap was detected faster in symmetric than in asymmetric figures. These results are in line with the Sensory detection hypothesis suggesting that the contour discontinuity is detected faster on good than in poor figures.

36.338 Connection structures underlying human contour integration

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Contour integration is believed to be an important step in human visual processing and object recognition, and has been shown to be performed very efficiently by the visual system.

We modeled contour integration using a Bayesian neural network. In this model the connection structure is given by an association field, a probability density describing the link probability between different edge elements. To evaluate the model we compared its predictions to human contour detection performance. Stimuli consisted of curvilinearly aligned contour elements which were drawn from an association field and a background of randomly oriented Gabor patches. Hence one would expect the model to perform most accurately when using the same connection structure for detecting the contour as was used to create the contour.

However, this would mean that the connection structure employed by the human brain had to change with the statistical properties of the contour while one might expect that the brain uses only one connection topology which is learned from visual experience and hence might be adapted to the statistical structure of natural images.

We analyzed several possible connection structures including the ideal association field for each single stimulus, connection topologies resembling the contextual interactions found in electrophysiology, and an association field extracted from natural images. In addition we looked at different association field symmetries and ranges.

As human contour detection performance was reached with several association fields, we compared correlations between human contour detection errors and errors by the model on a trial to trial basis. While the association field used for contour generation leads to highest performance, this correlation analysis suggests that the brain uses a single unidirectional association field linking edge elements in only one direction, rather than stimulus adapting association fields or bidirectional association fields which allow contours to abruptly change directions.

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36.339 Spatial localization of interpolated contours

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Perceptual completion connects regions belonging to the same object but physically disconnected in the retinal image; a process of fundamental importance to visual scene analysis and object perception alike. We manipulate the distribution of contrast polarity reversals in inducing configurations to probe the mechanisms underlying different forms of perceptual completion. Novel configurations compatible with modal or amodal completion are equated in the structure of local features and the spatial distribution of local luminance relationships provides the only cue for the different depth relationships associated with modal and amodal completion. Use of these stimuli eliminates the confounding factors and interpretational difficulties related to differences in local structure in traditional configurations used to study modal and amodal completion.

Here, we directly compare the time course (50-300 ms) of spatial localisation of modally and amodally interpolated contours in two variants of a dot-probe localisation task. In a traditional version of this task, the dot always appears in a specified, fully predictable location (e.g., always close to the top contour in a Kanizsa square configuration). We developed a modified ("global") version of this task, where the dot can appear close to any of the four contours. Positional certainty of a dot-probe's appearance in the traditional task affords reliance on the position of the nearest inducers whereas a global task depends more on the use of interpolated contours. While there was no difference in spatial localisation performance between modally and amodally completed contours with the traditional task, significant differences were observed with the global dot-localisation task. Modally completed contours were localised faster and more accurately than amodally completed contours. These results challenge the assumption that the boundary interpolation system depends solely on the geometrical spatial alignment of inducing fragments. Instead, they suggest that boundary interpolation depends on the spatial distribution of local luminance relationships.

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36.340 **Contour and surface integration behind moving occluder**

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The visual system represents partly occluded objects as completed forms. Partly visible edges and surface features are integrated, and the visual interpolation is achieved when the visible edges are relatable (Kellman & Shipley, 1991). We examined in previous experiments how visual interpolation processes allow observers to derive representations of objects from spatially and temporally fragmented information (Unuma, Hasegawa, & Kellman, VSS 2006, 2007). Our experiments provided some evidence for spatiotemporal interpolation and the temporal limits of the Dynamic Visual Icon (Palmer, Kellman, & Shipley, 2006) in object perception.

Here, we tested the temporal characteristics of contour and surface integration processes using a shape discrimination task with a moving occluder. Temporal thresholds in a contour-integration condition were compared with those in a contour and surface-integration condition. Illusory-contour squares and a large occluder with a small window were presented to observers. The occluder rotated in front of the illusory square and the speed of rotary motion was manipulated. The method of constant stimuli was used. Psychometric functions for discrimination of the shape wee measured as a function of presentation cycle of inducing figures.

Results showed that accuracy increased with increasing presentation cycle, and that estimated temporal limits of the visual buffer in the contour-integration condition were shorter than those in the contour and surface-integration condition. These results support the notion of the Dynamic Visual Icon. Further, our study indicates that the temporal limits of surface integration processes differ from those of contour integration process.

URL: http://www.kgwu.ac.jp/sinri/unuma/index.htm

36.341 **Spatial averaging of afterimages between contours**

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After fixation on a colored surface, negative afterimages can be seen on a white test surface. Using multi-color stimuli, and both subjective reports and quantitative matching methods, we found chromatic afterimages that averaged spatially between areas marked out by black contours in the white test field (van Lier & Vergeer, ECVP 2007). Thus, one and the same stimulus could elicit different afterimages at the same retinal location depending on the position of achromatic test contours presented after the colored stimulus. Depending on the specific color settings, these different afterimages may even be complementary in color space. In one experiment, we adapted to a plaid consisting of two transparently superimposed square-wave gratings, one grating of horizontal blue and yellow stripes, the other of vertical red and green stripes. Following adaptation, we examined the afterimage seen on a white test field. Results: thin black horizontal lines in the white test field yielded an afterimage consisting of yellow and blue horizontal stripes, whereas thin black vertical lines yielded an afterimage consisting of red and green vertical stripes. Several experiments show accumulating evidence both for averaging of afterimage colors between contours and for lateral inhibition (color induction) across contours. Instead of black lines, test fields contours could equally well be defined by second-order, equiluminous textures – the same color changes in the afterimages were observed. Our results are in line with both diffusive and non-diffusive models of perceptual filling-in for real colors, since in both types of models the process of perceptual filling-in can be blocked by boundaries. We argue that for the brain, afterimages are similar to real colors. For that reason, mechanisms driving filling-in of real colors should also be expected to be involved in the processing of afterimages.

36.342 **Spatio-temporal neuronal interactions as a basis for perceptual binding**

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Detection of low-contrast Gabor patches (GPs) is improved when flanked by collinear GPs, whereas suppression is observed for high-contrast GPs. The facilitation resembles the principles of Gestalt theory of perceptual organization. We propose a model for contour integration in the context of noise that incorporates a temporal element into this spatial architecture. The basic principles are: 1) The response increases with increasing contrast, whereas the latency decreases. 2) Activity-dependent interactions: facilitation for low and suppression for high activity. 3) The variance increases with contrast for responses, rates, and latency. 4) Inhibition has a shorter time-constant than excitation. When a texture of randomly oriented GPs is presented, the response to every element decreases due to fast inhibition between the neighboring elements, shifting the activity towards the range of collinear facilitation. Next, the slower excitation induces selective facilitation along the contour elements. Consequently, the response to the contour increases, whereas the variance of the rate and latency decreases, providing better temporal correlation between the contour elements. Thus, collinear facilitation increases the saliency of contours. Our model may suggest a solution to the binding problem by bridging between the temporal and spatial aspects of lateral interactions that determine the encoding of perceptual grouping.

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36.343 **Behavioral Evidence for the Perception of Kanizsa Illusory Contours in Pig-tailed Macaque Monkeys (M. nemestrina)**

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Illusory (subjective) contours as described by Kanizsa are readily perceived by most human observers. Many investigations into the neural correlates of illusory contour perception are conducted in non-human primates. These neurophysiological studies presuppose that non-human primates "see" the illusory contours evident in human perception. However, there is no definitive behavioral evidence to support that supposition. The purpose of this study was to quantitatively investigate whether macaque monkeys (Macaca nemestrina) in fact show evidence for Kanizsa illusory contour perception.

Using a zero-delay similarity matching-to-sample (S-MTS) procedure, two juvenile monkeys were initially trained on an orientation discrimination with simple forms. They were then transferred to a combined S-MTS + visual search procedure where the potential matching stimuli were "hidden" within one of two fields of random non-contour inducing "pacman" elements; the subject's task was to correctly identify the field that contained the match. Using the same procedure, subjects were then tested with six contour-induced Kanizsa illusory shapes as potential matches, which were embedded in the fields of random elements. Both subjects reached the criterion performance level of 80% or better with the six illusory shapes demonstrating clear evidence of Kanizsa figure perception. We also measured thresholds for performance on this task by varying the support ratio for the illusion. Thresholds for each subject (S1: 27% and S2: 41%) were similar to those obtained in 8-month old human infants (37%) as well as human adults who are typically not tested with support ratios below 25%. These results provide the first quantitative behavioral evidence that monkeys perceive Kanizsa illusory contours similarly to humans. In addition, we show that they can use illusory forms to discriminate shape and orientation. Finally, these findings enhance our understanding of the similarities in visual perception between macaque monkeys and humans, strengthening the justification for studies of shape and boundary processing in macaques.

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36.344 **Photographic Exploration of Illusory Contours**

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Many variations of illusory or subjective contours have been devised, and these have clarified the nature of these figures and the conditions that lead to them. However, most of the stimuli have been produced by drawings that have used limited palettes. In contrast we used photographs to produce stimuli in a variety of different ways to assess whether strong illusory contour effects would result. Stimuli like those commonly used (e.g. a circle with a pie shape missing) were made and then photographed. Illusory contours were present when the stimuli were photographed at an angle, when the different circles were placed on steps and different distances, and when the circular pieces were at right angles to each other. Illusory contours resulted when actual apple pies with missing pieces were used. And illusory contours resulted in many cases when photographs formed both figure and ground. We show examples in which the illusory contours are both weaker and stronger and discuss some of the factors that affect illusory contours in photographic situations.

URL: perceptualstuff.org

36.345 **Random and systematic effects of neural noise on low-level and high-level pattern vision**

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The visual system never perfectly represents the physical world. Rather, neural noise sometimes perturbs perception of simple shapes, especially when they are viewed briefly. Neural noise can randomly influence perception, but may also systematically distort perception, as in feature exaggeration. We examined these random and systematic influences of neural noise on curvature perception when short contour segments were presented alone (primarily involving low-level processing) and when they were embedded as the mouths within schematic faces (involving high-level object processing). Inverted-and-scrambled versions of the faces were used to control for a potential effect of crowding. To detect perceptual noise with high sensitivity, we used a procedure developed by Baldassi, Megna, and Burr (2006) in which brief presentations were comprised of an array of straight segments with either one curved target or no curved targets. The task was to report the curvature of the segment that appeared most curved using a magnitude-estimation procedure. Random noise was estimated as the variance of the reported curvatures for displays where curved targets were absent. Curvature exaggeration was measured as the average difference between the reported curvature and the actual curvature of the target. Random noise in curvature perception was greater when segments were presented within faces or inverted-scrambled faces compared to when they were presented alone, suggesting that crowding increased random perceptual noise. Curvature exaggeration, in contrast, was substantial when segments were presented alone or within inverted-scrambled faces, whereas exaggeration was weakest (reduced by ~40%) when segments were presented within faces. This pattern of curvature exaggeration may reflect the possibility that systematic exaggeration is beneficial in low-level processing because a unique feature may become more salient, but could be harmful in high-level processing because perceptual exaggeration of facial expressions may lead to socially inappropriate responses.

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Sunday, May 11, 2:30 - 6:30 pm
Poster Session, Royal Palm Ballroom 6-8

Motion: Space and Speed
Perception and Action: Goal Directed Movements
Reading

Motion: Space and Speed

36.401 **Analysis of shape-dependent specular motion - predicting shiny and matte appearance**

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Previously, we found that observers, when viewing movies of rotating specular superellipsoids of varying corner-roundedness, perceived more-rounded shapes as less shiny than cuboidal shapes. Here we investigate which properties of the stimuli predict observers' percepts.

Our analysis is based on the observation that rotating specular cuboidal and ellipsoidal shapes give rise to image velocity distributions that differ in their characteristics. Image sequences of objects that are perceived shiny tend to have bimodal velocity distributions, with one of the velocity components ("slip") opposite to motion of surface points on the object, whereas matte-perceived objects have velocity distributions dominated by the motion of the surface points.

To quantify this observation we analyzed the motion information in the stimulus image sequences using steerable spatio-temporal filters. Using linear discriminant analysis, we show that filter responses can be used to correctly classify stimuli as shiny or matte, and show good agreement between these classification results and the observers' ratings of shininess.

To better understand the origins of this motion information, we investigated the relationship between specular flow and shape analytically. We found 1) that specularities appear to flow along the directions that the surface's curvature gradients moved during object rotation. 2) Consistent with our qualitative observations, we find that the image velocity distribution of a specular feature on a rotating shiny object transitions from unimodal to bimodal as the shape of the object varies from ellipsoidal to cuboidal, which may account for the misperception of material in ellipsoidal objects.

Taken together our findings provide an account of how material percepts can arise from image velocity patterns, and what physical properties of objects give rise to these patterns.

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36.402 **Motion perception driven by inferred shape properties**

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To examine whether the visual system performs motion computations after extracting shape, we measured accuracy for detecting direction of rotation defined by shape axes.

Random shapes consisting of 20 dots along evenly spaced radial spokes extending from a center were generated by distorting a 4 deg circle with Gaussian noise of Mean 0.0 and SD 3.8 or 12.7 min along the spokes. Half of the shapes were bilaterally symmetric. Shapes were rotated at 12.5, 5.6 or 3.6 Hz in ten sequential 18^o turns. Hence the dots always fell on the same spokes with each dot moving inward or outward. The observers' task was to indicate the direction of rotation. To quantify sensitivity to global motion in the presence of noisy local motion, Gaussian perturbations were added after each turn to each dot's eccentricity along its spoke with Mean 0.0 and SD 0.0, 2.5, 5, 10, 20 or 40 min. On half of the trials, the dynamic noise was constrained to be bilaterally symmetric.

At low noise levels, discrimination of rotation direction was almost perfect, ruling out decisions based on pooling local motion signals extracted from nearest correspondences. With increasing asymmetric noise, accuracy decreased monotonically for all shapes and speeds. This performance could be explained by a winner-take-all choice between templates for global rotation, expansion, contraction and translation applied in parallel to the candidate local motions of all dots. This model, however, could not account for the effect of symmetric noise on accuracy, which formed a U-shaped function: decreasing accuracy for small noise levels but increasing accuracy for larger levels. Since a different symmetric shape was presented on each frame, the advantage for symmetry could only arise if the observer extracted each axis of symmetry and perceived the direction of rotation of the inferred axes.

36.403 **Exploring the spatiotemporal properties of fractal rotation**

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Motion perception of first- and second-order stimuli has been proposed to be mediated by separate mechanisms. Whereas luminance-based stimuli are analyze by energy-based motion detectors, uncertainty remains as to the mechanisms involved in the processing of second-order stimuli.

The aim of this experiment was to determine the nature of mechanisms accounting for detection of fractal rotation (Benton, O'Brien & Curran, 2007) in comparison with those responsible for first-order rotation. To reproduce such a stimulus, a rotating oriented filtered noise pattern was used, in which orientation varied from frame to frame. Noise was resampled for each frame. This stimulus should be invisible to first-order motion sensitive mechanisms considering the absence of energy movement. Rather, rotation is the only local cue available to motion detectors. Hence, motion perception would be based on the analysis of spatial structure, more specifically the orientation change over time. In comparison, we have used another stimulus composed of a single rotating oriented filtered noise frame where motion is detected by first-order sensitive mechanisms.

First, we measured the temporal response of fractal rotation. Contrast thresholds were measured using a direction discrimination task at various temporal frequencies. First-order rotation was found to be band-pass, whereas fractal rotation was low-pass, as previously reported for contrast-, polarity- and spatial length-modulated motion. Hence, fractal rotation has second-order mechanism properties.

Second, the nature of mechanisms responsible for detection of fractal rotation has been explored using a known paradigm where different energy levels are used by changing velocities (Seiffert & Cavanagh, 1998). Sensitivity to first-order stimuli is expected to change proportionately with energy levels while sensitivity to second-order properties is not. Results suggest a velocity-based mechanism account for perception of first-order motion but not for fractal rotation. This implies second-order mechanisms are sensitive to change of spatial orientation structure over time.

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36.404 **Motion of motion-defined pattern does not induce spatial mislocalization**

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The luminance-defined (LD) motion influences the perceived position of a moving object itself (Kinetic edge effect, Ramachandran & Anstis, 1990). However, little is known about the perceived position of more complex motion. In this study, we investigated the perceived position of motion-defined (MD) motion stimuli. In the experiment, observers viewed LD or MD motion displayed in a rectangular patch at the center. Both stimuli consisted of random dots and were surrounded by a dynamic random-noise field. The dot luminance in the LD stimuli was modulated to generate a square-wave pattern. The dots in the MD stimuli moved either upward or downward to generate a motion-defined square wavepattern. The modulation wave was shifted leftward or rightward to generate horizontal LD/MD motion. Two white wire-frame rectangles were displayed above and below the motion patch, and served as references. The horizontal offsets between the motion patch and the references were varied randomly across trials, and observers were asked to judge the direction of the offset. We pooled data from each subject and estimated the point for each motion direction condition where the perceived position of the central patch is aligned with the references. The perceived offset was estimated as a half of the distance between the estimated points in two motion direction conditions. Consistent with previous findings, we obtained a significant kinetic edge displacement for the LD stimuli with the effect size being several arc minutes. However, no significant displacement was found for the MD stimuli. The same pattern of results was found even when the observers accurately (around 95%) judged the direction of MD motion concurrently with the main position judgment task. Our results show that the activation of higher-motion system, at least in this particular case of MD motion, does not influence the position coding of a visual object.

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36.405 **The transient temporal processing system contributes to motion perception in a static figure**

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The Rotating Snakes is a dramatic illusion of motion perceived in a static figure (Kitaoka & Ashida, 2003), which is comprised of luminance-defined micropatterns: black, dark-gray, white, and light-gray. Murakami et al. (2006) demonstrated that the illusion had a positive correlation with fixation instability and suggested the model that the biphasic nature of the temporal impulse response function is a prerequisite for the illusion. Previously, we tested this model by changing the retinal illuminance, thereby indirectly changing the shape of the temporal impulse response function from biphasic to monophasic (Hisakata & Murakami, 2007 VSS). The strength of illusion decreased with decreasing retinal illuminance. In this study, we aimed to ensure the expected change in the impulse response with retinal illuminance. We used the double-pulse method (e.g., Burr & Morrone, 1993) to measure the temporal impulse response at several retinal illuminances. The two successive Gabor patches (horizontally oriented, 1 cpd, sigma 1.79 deg) were presented at 12 deg to the left. For 16 SOA conditions and two Gabor-phase conditions (in-phase or out-phase), contrast sensitivities were measured. Based on the measured sensitivities, temporal impulse response functions were estimated by a standard protocol. As a result, the shape of the impulse response indeed changed from biphasic to monophasic within the range of illuminances we previously used (2007 VSS). We also confirmed that the visibility of high spatial-frequency components in the illusory figure was not compromised under dark illuminances, and that intermediate contrasts (as in dark-gray or light-gray regions of the figure) were detectable. We conclude that some transient temporal processing system is necessary for the illusion, and argue that the same mechanism may also be involved in the processing of retinal-image motions with fixation instability. We will discuss the validity of several models for the Rotating Snakes or other peripheral drift illusions.

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36.406 **Effects of Spatial Cue Timing and Relevance on Representational Momentum**

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In representational momentum (RM), memory for the final location of a moving target is displaced in the direction of motion (for review, Hubbard, 2005). Previous experiments found inconsistent effects of manipulating attention on RM; Hayes and Freyd (2002) presented an additional task during target presentation and found increases in RM with decreases in attention to the target, whereas Kerzel (2003) presented a distractor after target presentation and found decreases in RM with decreases in attention to the target. The current experiments address these differences by presenting a spatial cue and varying the (a) timing of cue presentation and (b) relevance of the cue for target localization. Participants viewed implied horizontal motion of a target, and a spatial cue was visible in one-half of the trials. In Experiment 1, the cue was visible during target presentation, and in Experiment 2, the cue was visible during the retention interval between when the target vanished and a probe appeared. The cue was relevant (i.e., indicated where the target would vanish [Exp. 1] or had vanished [Exp. 2]) or irrelevant (i.e., was above or below the path of target motion). RM occurred in all conditions, but was less when a cue was visible than when a cue was not visible. In Experiment 1, decreases in RM were larger with relevant cues than with irrelevant cues; in Experiment 2, decreases in RM were larger with irrelevant cues than with relevant cues. The decrease in RM when cues were visible in both Experiments 1 and 2 suggests differences between Hayes and Freyd (2002) and Kerzel (2003) do not reflect differences in the timing of their attention manipulations. Effects of cue relevance are consistent with existence of a non-modular (cognitively penetrable) component of RM, but the presence of RM when relevant cues were visible during target presentation or during the retention interval is consistent with existence of a modular (cognitively impenetrable) component of RM.

36.407 **Support for a postdictive account of the flash-lag effect**

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In the flash-lag illusion, the location of a moving object aligned with a flashed stimulus is misperceived ahead of the flash. Two explanations have been offered. Nijhawan (Nature, 1994) proposes a predictive theory, which claims that the visual system corrects for transmission delays by using the motion of the object before the flash to extrapolate its position at the time of the flash. In contrast, Eagleman and Sejnowski (JoV07) have suggested a postdictive theory that argues that the motion of the object after the flash biases the perceived position of the object at the time of the flash. The postdictive theory correctly predicts that the flash-lag effect is not observed when the moving object disappears at the time of the flash. In order to account for this, the predictive theory requires an additional assumption, that a transient signal on the moving object at the time of the flash will override the extrapolation, yielding a veridical percept. To test this assumption, we presented moving items with three types of transients occurring at the same time as the flash. The moving object was changed from black to white, reduced from 30% to 4% contrast, or reduced from 4% to 0% contrast (i.e. it disappeared). In the first two conditions, the flash-lag effect was just as strong as in a control condition with no transient signals. When the moving item vanished, however, the illusion was entirely absent, even though the transient signal generated by the disappearance of this moving low contrast object was much less than that generated in the previous two conditions. Transient signals per se do not disrupt the flash-lag effect. Rather, the disappearance of the moving object, and the subsequent lack of motion signals, eliminates the effect. This finding contradicts the predictive account, but is consistent with a postdictive account.

36.408 **Non-reversed motion perception induced by the spatiotemporal reversal of apparent motion sequences**

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Apparent motion between two or more stimuli cannot be perceived until the next stimulus is presented. This characteristic suggests that the representation of apparently moving objects is interpolated after the presentation of the subsequent stimulus. In order to investigate whether or not representation is capable of affecting physical spatiotemporal properties, we investigated apparent motion perception in a situation involving the spatiotemporal reversal of motion sequences. Our apparent motion display comprised five stimuli (0.4 × 0.8 deg each) horizontally aligned with a gap of 0.4 deg. The stimuli were presented sequentially. The durations and interstimulus intervals (ISIs) were 13.33 ms (30 deg/s). Our participants reported the motion direction of the last two stimuli (the test sequence). We discovered that, even when the spatiotemporal orders of the test sequence were reversed, the motion direction perception of the test sequence was consistent with the three stimuli (the prior sequence) presented first. This "misperception" did not occur in the absence of the prior sequence. We replicated these findings when the fourth stimulus contained a vertical offset. Further, we confirmed that the prior sequence comprising only one stimulus (three-point apparent motion display) was sufficient to produce the misperception of the test sequence; this effect reached a ceiling when the prior sequence contained two or more stimuli. Moreover, the perceived motion direction of the test sequence could not be altered by the apparent motion sequence of nearby objects. These findings suggest that the internal representation constructed after the presentation of all the stimuli would make the spatiotemporal reversal of motion sequences unaware. Moreover, it was revealed that the perceived speed of motion with the test sequence reversal was faster than that without the reversal. This suggests that, different from motion direction perception, velocity perception could be rather affected by the reversal.

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36.409 **Isodipole textures in spacetime: a novel non-Fourier and reverse-phi motion stimulus**

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Early motion processing is generally considered to be carried out by "first-order" (Fourier) and "second-order" (non-Fourier) mechanisms. The former extracts motion when pairwise spatiotemporal correlation of luminance signals is present. The latter extracts motion under other circumstances, and is often modeled as local nonlinear pre-processing, such as flicker detection, followed by spatiotemporal correlation.

To further investigate the computations underlying early motion processing, we created a novel set of spatiotemporal movie stimuli. Each frame of the movie is a black-and-white checkerboard. Colorings are determined by a recursive three-check "glider" rule: within the three checks of the glider, the total number of black checks must have a particular parity (even or odd). That is, each check of the movie is calculated from two previously determined checks, of which at least one is from an earlier time frame. This is similar to "isodipole" texture generation, except that here the recursion rule operates in space and time, rather than just space.

We determined the motion percepts elicited by 6 pairs of stimuli. Within each pair, the spatiotemporal configuration of the recursion rule was the same, but parities were opposite. The results were highly consistent across 5 subjects: 5 out of 6 pairs of stimuli were judged as moving in a definite direction (two-alternative forced choice). For 4 of the 5 pairs, changing parity reversed the apparent motion (reverse-phi motion).

These stimuli have no spatiotemporal correlation at second-order, and, moreover, there is no second-order correlation between the locations of checks that flicker, or the presence of edges. Thus, motion cannot be extracted by pairwise spatiotemporal correlation of image luminance, or of derived local features (flicker or edge). However, motion can be extracted by correlation of a derived feature at one position with luminance at another position, i.e., crosstalk between standard first-order and second-order mechanisms.

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36.410 **Possible mechanisms for pedestal effects on speed perception**

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Previous research has demonstrated that the superimposition of a static pattern on a moving one produces an increase in the apparent speed of motion. The purpose of the current experiments was to investigate the mechanism underlying this increase in perceived speed. In Experiment 1, we investigated the effects of static grating (pedestal) and drifting grating (target grating) spatial frequency on the perceived speed of the target grating. The results show that both target and pedestal grating spatial frequency have an influence on the increase in perceived speed. The results suggest a spatial frequency tuning of the speed effect where the optimal pedestal spatial frequency changes as a function of target grating spatial frequency. In Experiment 2, we measured the effects of the pedestal grating in monoptic (pedestal and target gratings presented to the same eye) and dichoptic (pedestal and target gratings presented to different eyes) viewing conditions and when the pedestal was coextensive with the target grating or presented adjacently to it. Adjacent presentation of the pedestal was not found to produce systematic increases in perceived speed. Further, whereas monoptic presentation of the pedestal and target gratings produced an increase in perceived speed similar to that observed in Experiment 1, no increase in perceived speed was observed in dichoptic viewing conditions. In Experiment 3, we studied the effect of temporal frequency on the increase in perceived speed. No change in the relative increase in perceived speed occurred with changing temporal frequency. We conclude that the effects of a static pedestal on the perceived speed of a target grating are mediated early in motion processing, at a stage sensitive to spatial frequency and prior to binocular integration.

36.411 **The perceived duration of motion increases with speed**

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It is known that a moving stimulus appears to last longer than a static one. To assess how duration overestimation relates to parameters such as spatial frequency (SF), temporal frequency (TF), and speed, we measured the perceived duration of drifting Gabor patches, with various combinations of SF (0.5, 1, 2, 4 c/deg) and TF (1, 2, 4, 8, 16 Hz) of the carrier sinusoid (tapered by a static Gaussian envelope). The physical durations were ranged within 0.3-1 s. In Expt. 1, we used the matching technique to determine the physical duration of the static patch that just appeared the same duration as the moving patch. As a result, we obtained overestimation ranging 110-160%, as an increasing function of TF and a decreasing function of SF. When data were replotted against speed, however, all data collapsed into a logarithmic increasing function of speed irrespective of SF and TF. In Expt. 2, we used the reproduction technique, in which the subject first observed a stimulus and then held a button for the same interval as the perceived duration. Again, overestimation was better described as a logarithmic function of speed, rather than SF or TF. These results apparently contradict the recent finding by Kanai et al. (2006), who noticed overestimation as an increasing function of TF, not speed, for a variety of stimulus configurations. We looked at the Fourier domain of their motion stimuli and ours and found that, whereas our Gabor patches contained a well confined frequency band centered at the desired frequency, Kanai et al.'s motion stimuli had strong DC component in SF power spectra leading to standing flicker. Therefore, we reconcile the apparent discrepancy by the conclusive remark: speed governs the illusion when drifting motion is dominant, whereas TF governs the illusion when flicker is dominant in the stimulus.

36.412 **Blur increases perceived speed**

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Rapidly moving stimuli appear blurred and this correlation between speed and blur may cause blur itself to be taken as a cue to apparent speed. To investigate the effect of visual blur on speed perception, subjects were asked to compare the rotation speed of a sinusoidal radial grating with that of a square wave radial grating. The gratings were presented consecutively for one-second intervals in the center of the display and subjects were asked to adjust the speed of the sinusoidal grating to match that of the square wave grating. Results showed that the sinusoidal grating is perceived to move significantly (15-20 %) faster than the square wave grating. In the second experiment, using sinusoidal gratings with different spatial frequencies, it was shown that increasing spatial frequency while keeping the speed constant increases the apparent speed. Therefore the relative slowing of the square wave grating (compared to sine wave) cannot be attributed solely to presence of higher spatial frequencies but is more likely a result of the alignment of frequency components that produces a sharp edge . These findings show that a blurred stimulus appears to move faster than a sharp stimulus of equal contrast.

36.413 **The role of explicit and implicit standards in speed discrimination**

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Five experiments investigated speed discrimination. Variations of the method of constant stimuli were used to obtain speed discrimination thresholds in Experiments 1, 2, 4, and 5, while the method of single stimuli was used in Experiment 3. The observers' thresholds were significantly influenced by the choice of psychophysical method and by changes in the standard speed. The observers' judgments were unaffected, however, by changes in the magnitude of random variations in stimulus duration. When an implicit standard was used, the observers produced relatively low discrimination thresholds (7.0 percent of the standard speed), replicating the results of McKee (1981). When an explicit standard was used in a 2AFC variant of the method of constant stimuli, however, the observers' discrimination thresholds increased by 74 percent (to 12.2 percent), similar to the thresholds obtained by Mandriota, Mintz, & Notterman (1962). A subsequent signal-detection analysis revealed that the observers' actual sensitivities to differences in speed were in fact equivalent for both psychophysical methods. The formation of an implicit standard in the method of single stimuli allows observers to make judgments of speed that are as precise as those obtained when explicit standards are available.

Perception and Action: Goal Directed Movements

36.414 **Shared Effects of Prior Information and Reward on Motor and Perceptual Choices**

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Introduction: Asymmetric prior probabilities and reward schedules induce systematic biases in sensorimotor choices; the proportion of more likely or valuable choices increases while response times for those choices decrease. However, it remains unknown to what extent perception may also be affected.

Methods: On each trial, two spots (diameter: 0.6 deg, peak luminance: 4.7 or 6.3 cd/m2) appeared on either side of fixation (±6 deg) against a noisy (SD: 8.2 cd/m2) background (mean: 37.6 cd/m2). Five observers (3 naïve) were asked to make a 2AFC saccadic choice to the brighter spot. For five observers, we biased this choice using asymmetric spatial probability (75% rightward or leftward); for two observers, we also used an asymmetric reward schedule (for a total of 7 cases). Upon saccade initiation, the spots and central cross were extinguished and the latter replaced by a test spot visible for 250 ms. Observers were then asked to report whether the earlier saccadic target or the later test pedestal was brighter in a 2IFC perceptual choice. We constructed oculometric curves and derived the saccadic point-of-subjective-equality (PSE) for favored and unfavored locations to quantify overall motor bias. We also constructed psychometric functions to quantify perceptual gain (the relationship between perceived brightness and signal strength) and uncertainty (the slope of the psychometric functions) at favored and unfavored locations.

Results: As expected, the experimental manipulations induced motor biases in all cases (mean PSE shift: 2.0 d' units). They also increased perceptual gain (mean: 21%) and uncertainty (mean: 11%) in a correlated manner ($r2=0.53$; $p<0.01$). Finally, the perceptual gain changes were correlated with the saccadic PSE shifts ($r2 = 0.36$, $p<0.01$).

Conclusion: Our findings are consistent with a neural mechanism in which motor and perceptual decisions share a common early weighting factor that scales both visual signals and their limiting noise.

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URL: http:snl.salk.edu~dlistonpercept

36.415 **Visuomotor planning cannot take advantage of conscious knowledge of future events**

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We examined whether or not conscious knowledge about the availability of visual feedback on an upcoming trial would influence the programming of a precision grip. Twenty healthy volunteers were asked to reach out and grasp objects under two viewing conditions: full visual feedback or no visual feedback. The two viewing conditions were presented in blocked, randomized, and alternating trial orders. Before each block of trials, participants were explicitly informed of the nature of the upcoming order of viewing conditions. Even though participants continued to scale their grip to the size of the goal objects which varied in size and distance, they opened their hand significantly wider when visual feedback was not available during movement execution. This difference was evident well before peak grip aperture was reached and continued into the grip aperture closing phase and presumably reflects the visuomotor system's ability to build in a margin of error to compensate for the absence of visual feedback. The difference in grip aperture between viewing conditions increased as a function of distance, which suggests that the visuomotor system can make use of visual feedback given enough time, even when that feedback is not anticipated. The difference in grip aperture between viewing conditions was larger when the visual conditions were blocked than when randomized or alternated. Importantly, performance did not differ between the randomized and the alternating trial blocks. In other words, despite knowledge of the availability of visual feedback on an upcoming trial in the alternating block, participants behaved no differently than they did on randomized trials. Taken together, these results suggest that motor planning tends to optimize performance largely on the basis of what has happened regularly in the past and cannot take full advantage of conscious knowledge of what will happen on a future occasion.

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36.416 **Perceptual and performance biases in action selection**

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When we see an object in the world, there may be a large number of different ways to interact with that object. This large 'visuomotor space' can be constrained through affordances (perceptually available object properties defining potential uses), task demands and the actor's intentions. The effects of perceptual biases can be modified by performance factors, such as a limb's end-state-comfort (ESC; Rosenbaum et al. 1990). We investigated how two other potential performance biases affected interaction with a perceptually under-constrained object: hysteresis (H) and minimal forearm rotation (MR). Experiment 1 found H and MR operating in adult participants who reached-to-grasp a doweling placed at different orientations either randomly or systematically (orientation changed by 30° every five reaches either clockwise or counter-clockwise). In the random condition, participants switched between pronation and supination depending on which required minimum forearm rotation, but a systematic reach history delayed the transition from pronation to supination in the counter-clockwise condition (and vice versa). This effect was more pronounced in 5-15 year old children. Experiment 2 placed ESC and MR in opposition. Participants reached-to-grasp a doweling at one of two initial orientations and rotated it clockwise or counter-clockwise by 180°. On half the trials, ESC could only be achieved at the expense of MR. Adults reliably acted to achieve ESC when reaching with their preferred hand (100% of trials but less so with the non-preferred hand at circa 80%). Younger children (5-8 years) and children with developmental coordination disorder (5-13 years) were primarily driven by MR and to a lesser extent H. Older children (9-13 years) showed a clear developmental trend towards adult behaviour. Thus, action selection is a dynamic process subject to numerous performance biases even in skilled adult participants. Importantly, the effect of performance biases on perceptually under-constrained objects varies with skill level and developmental status.

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36.417 **Learning and retaining visuomotor adaptation across time**

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Many studies have shown that the brain can learn to adjust movements to correct for altered visual feedback of the hand when reaching to targets. It is unclear how well brain can learn these adjustments when there are significant gaps in time between brief sessions compared to a single session and how long visuomotor learning is retained. How do delays in time affect learning and later retrieving a novel visuomotor mapping? In Study 1, participants adapted to altered visual feedback of the hand when reaching to visual targets in a single session of 100 trials and across five shorter weekly sessions of 20 trials each. In Study 2, another group of participants learned a similar visuomotor mapping across 200 trials and were retested on the same task 6-8 weeks, 2-3 or 5-6 months later. Results for Study 1 showed that participants had similar learning patterns for a single session compared to weekly sessions. We saw no significant difference in the overall learning rate, and the gaps between sessions did not lead to any loss of previous learning. This indicates that the brain does not need continuous reaching practice but rather it can adapt to this new visuomotor mapping with 7-day gaps between shorter reaching sessions. Preliminary results for Study 2 show that participants retained a substantial amount of visuomotor adaptation over time. We found that deviations in reaching were smaller when participants performed the same task 6-8 weeks after the first visuomotor adaptation session. Our results suggest that the learned visuomotor mapping may last over longer time frames of 2-3, and 5-6 months. We are currently collecting these data. Our results from Study 1 and 2 suggest that the brain is able to learn and retain visuomotor adaptations over time.

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36.418 **Predispositions to Approach and Avoid are Contextually Sensitive and Goal Dependent**

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We show that predispositions to approach and avoid do not consist simply of specific motor patterns but are more abstract functions that produce a desired environmental effect. It has been claimed that evaluating a visual stimulus as positive or negative evokes a specific motor response, extending the arm to negative stimuli, and contracting to positive stimuli. We showed that a large congruency effect (participants were faster to approach pleasant and avoid unpleasant stimuli, than approach unpleasant and avoid pleasant stimuli) could be produced on a novel touchscreen paradigm (Experiment 1), and that the congruency effect could be reversed by spatial (Experiment 2), and non-spatial (Experiment 3), response effects. Thus, involuntary approach and avoid response activations are not fixed, but sensitive to context, and are specifically based on the desired goal.

36.419 **Seeing all the obstacles in your way: The effect of visual feedback on obstacle avoidance**

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Human reaching behaviour displays sophisticated obstacle avoidance. Previous patient work has identified dorsal stream visuomotor processing as being integral to this ability (Schindler et al., 2004, Nature Neuroscience; Rice et al., 2006, Experimental Brain Research). Recently, we demonstrated that the obstacle avoidance system in normal participants is sensitive to both the position and size of obstacles (Chapman & Goodale, VSS 2007). A limitation in these previous studies was that reaches were performed without visual feedback, and were not made to a specific target (i.e. the target was a strip instead of a point). Many studies have shown that both the introduction of visual feedback and the order in which the feedback is received significantly alter performance in simple visuomotor tasks (e.g. Jakobson & Goodale, 1991, Experimental Brain Research). Thus, the present study was designed to compare obstacle avoidance when reaches were made to a discrete target with and without visual feedback (VF vs. NVF) under different orders of feedback availability. Twenty-four right-handed participants performed reaches in the presence of one, two, or no obstacles placed mid-reach. Three visual-feedback-order conditions were used: blocked (all VF trials occurred together, separate from NVF trials), alternating, and random. In addition to replicating the previous work, we showed that robust avoidance behaviour occurred when reaches were made to a specific target, and that visual feedback modulated this behaviour. Moreover, the order in which visual feedback was made available also had a significant impact; VF and NVF trials differed significantly across several kinematic measures – but only in the blocked condition. Performance did not differ between VF and NVF trials in the alternating or random conditions, suggesting that motor strategies are automatically adjusted by recent experience (Song & Nakayama, 2007, Journal of Vision) and are not affected by explicit knowledge about feedback availability on an upcoming trial.

36.420 **Visuomotor performance and visuomotor memory operate without conscious awareness of intrinsic target features**

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Binsted et al. (2007: Proc Natl Acad Sci USA) recently showed that unconsciously presented intrinsic target information (i.e., size) supports visuomotor control. In the present investigation, we sought to determine whether unconscious target information represents an evanescent or temporally durable visuomotor characteristic. To accomplish that objective, we used a variant of Di Lollo et al's (2000: J Exp Psychol Gen) four-dot masking paradigm. Participants were briefly (13 ms) presented an array of differently sized circles (1.5, 2.5, 3.5, 4.5, 5.5 cm). The array included a target circle identified by four red circles (i.e., four-dot mask) that surrounded but did not touch the target. During prime trials, the array and four-dot mask disappeared simultaneously, whereas during mask trials the four-dot mask remained visible for 320 ms after blanking of the circles array. Participants verbally reported the size of the target and in a separate set of trials pointed to the centre of the target. Importantly, reaches were cued in time with onset of the circles array or 1000 and 2000 ms following array presentation; that is, after a period of visual delay. Verbal reports of target size were accurate during prime but not mask trials. For reaching responses however, trajectories (e.g., reaction time, movement time, peak velocity) scaled in relation to the size of the target across prime and mask trials and regardless of whether reaches were cued in time with the array or following a period of visual delay. These results indicate that a conscious visual precept is not necessary to support motor output and that unconscious target information persists for up to 2000 ms of visual delay. As such, the present data provide a convergent view of a visual system that is largely unavailable to and unreliant on conscious awareness.

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36.421 **Estimates of performance in a visuo-motor task are accurate, but not after joint movement is constrained**

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Purpose. We routinely perform tasks while limited in our freedom to move, be it by carrying groceries or by an injury that prohibits normal use of a limb. Recent work indicates that we have access to accurate estimates of motor uncertainty in unconstrained movements (Maloney et al, VSS, 2006). Here we examine whether we can anticipate our movement uncertainty even when our freedom of movement is abruptly constrained.

Methods. Participants (n=7) made fast reaches (35 cm in 250ms) with their right index finger to touch a target (circular, 0.4 cm) on a horizontal touchscreen. Prior to each trial, participants estimated their chances (0-100%) of hitting the target. Participants performed three blocks: B1) 40 unconstrained trials, B2) 30 trials with an elbow constraint that fixed the joint at a 90^o angle, and B3) 30 unconstrained trials.

Analysis. We calculated across-subject averages of the endpoint errors in the last 20 trials of each block to estimate the objective probability Oi of hitting the target at asymptotic performance in Bi. We averaged subjective estimates over the same ranges to obtain corresponding subjective probabilities Si.

Results: Statistical tests indicated that O1=O2=O3: Participants had compensated for the constraint within the first ten constrained trials and showed only slight, and non-significant, improvements in the final post-constraint block. Participants accurately judged their performance before the constraint was imposed (O1=S1). However, S1>>S2=S3: Subjects' predictions of constrained performance in B2 and of post-constraint performance in B3 were lower by almost a factor of two than their objective performance.

Conclusions: Restraining the arm's degrees of freedom disrupted the ability to accurately estimate motor uncertainty and lead to a pronounced underestimation of objective performance. The finding has implications for motor impairments that are characterized by enduring losses in the freedom of movement.

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36.422 Perceptual Information for the Control of Walking-to-Reach

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Introduction: We examined perceptual information strategies for control of walking-to-reach. Previous research showed that people use a monocular tau-based strategy for the control

of walking to a target (Wann et al., 1996). Recently, we have shown that people also use a relative disparity tau-dot information strategy to control targeted reaching (Anderson & Bingham, 2007). To walking to a stop with soft contact of the hand at a target, multiple timing layers must be integrated and controlled including head-to-target velocity, timing of reach initiation, and hand-to-target velocity. The problem is that binocular tau information is not good at the larger distances entailed by walking and monocular tau information cannot be used to control reaching (Bingham & Zaal, 2005). Therefore, we propose that walking-to-reach entails a transition from monocular tau information for the control of walking to binocular tau information for the control of reaching. We manipulated the presence of monocular or binocular information under conditions of monocular or binocular viewing and analyzed walking and reaching trajectories to evaluate what information strategies might be used to control walking, reach initiation, and targeted reach trajectory.

Method: Eight participants walked briskly to a point-light or a glowing orb target in the dark and brought their hand or nose to a stop at the target. Hand location was specified by a point-light placed on the thumb. Movements were recorded using an OptoTrak. Diodes were placed on the participant's forehead, chest, and hand. Separation of the latter diodes indicated reach initiation.

Results: Results showed that participants used a monocular tau-dot strategy (Tau-dot ≈ -.5) to control walking (confirming previous findings) and used a binocular tau-based strategy to control reaching (confirming previous findings in studies of reaching).

Conclusion: Participants use a monocular tau strategy for control of walking but switch to a disparity tau strategy for control of reaching.

36.423 Do walkers follow their eyes? Further tests of the gaze-angle strategy for steering control

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What initiates a change in the direction of travel? In previous studies of goal-directed walking (Cinelli & Warren, VSS 2007), we found that an active head turn toward a peripheral light produced a small path deviation (~6cm) in the direction of the head. However, a passive head perturbation did not have the same effect, indicating that walkers do not simply follow their heads – at least when walking to a visible goal. Alternatively, the deviation might have resulted from attentional capture by a transient when the light was illuminated.

In the current study, we test which of four factors are sufficient to elicit a change in the direction of travel: (1) a steering synergy in which the eyes and head initiate a turn and the trunk and feet follow; (2) a saccadic eye movement without a head turn; (3) attentional capture by an external transient; and whether (4) a visible goal overrides such effects.

We dissociate these hypotheses by manipulating the following variables during walking straight toward a goal, while eye and head movements are recorded: (a) active head turn to peripheral light or face the goal; (b) saccade to peripheral light or fixate the goal; (c) respond to external transient or verbal command; and (d) goal or no goal. The results allow us to determine whether head turns, saccades, external transients, or some combination are sufficient to initiate a change in the direction of walking, and whether the presence of a goal overrides their influence.

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36.424 Comparing the impact of incorrect object identification on object use to the impact of incorrect action production on naming objects

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Past research on action production showed that object characteristics influence action production. In past experiments, Desmarais, Dixon and Roy (2007) taught participants to associate novel objects with novel actions, and to identify these novel objects with non-word labels. Specific objects were paired with specific actions, and findings revealed that people tend to confuse actions that are associated with similar objects more often than when these same actions are associated with dissimilar objects. Furthermore, when people produced an incorrect visual object identification and were subsequently asked to produce the action associated with the object they misidentified, they tended to produce the action associated with the incorrect name more often any other wrong action. However, in those previous studies, object naming always preceded action production, possibly enhancing the impact of object similarity on action production. In our study, we varied task order: half the participants named each object first before producing their associated action, and half of participants produced the action associated with each object before proceeding to its identification. We examined participants' visual identification and action production errors to see how often object identification and action production errors corresponded (i.e., how often an incorrect action followed its incorrect name, and how often an incorrect name followed its incorrect action). A Chi Square test for Independence revealed that which task was done first influenced the frequency of these corresponding errors. Though both task orders led to similar numbers of errors overall, corresponding errors occurred more often when naming was done first. Following an incorrect name, participants tended to follow with the incorrect action corresponding to that name; producing an incorrect action and following up with the incorrect name occurred less often. This suggests that naming objects before producing actions enhanced the impact of object similarity on action production.

36.425 Motor extrapolation of occluded spatiotemporal contours

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Purpose. When observers extrapolate occluded contours of constant curvature the extrapolated portions of the contours decrease in curvature with distance from the point of extrapolation (Singh & Fulvio, 2005, 2007). If an observer attempted to touch the occluded curve endpoint using his perceptual estimate, he would have failed. Consideration of everyday motor tasks within the environment, however, suggests that observers reach for partially-occluded objects accurately. We studied performance in a dynamic motor version of the perceptual task to test the hypothesis that different representations are used for extrapolation in the motor system.

Methods. Subjects attempted to touch a moving dot with their fingertip on a computer screen as it emerged (unseen) from behind an occluder. Dot trajectories could have one of two curvatures and two speeds. The occluder was a half-disk (two possible radii). At the beginning of each trial, a blinking dot signaled where the dot would begin its trajectory. On reach initiation, the dot traveled rightward toward the straight edge of the occluder and vanished. It was not shown emerging from behind the occluder. Subjects were rewarded for accuracy in the timing of their attempts to touch the dot where it would emerge from the far edge of the occluder. Reach trajectories, recorded with an Optotrak 3020, and the distribution of movement endpoints for each condition were analyzed.

Results: Because each start position could be continued as one of several dot trajectories, we analyzed the spatiotemporal reach trajectories to determine when subjects acquired information about substantial non-zero curvature in the dot trajectory. Despite similarities to perceptual performance for the zero-curvature trajectories, patterned deviations occurred for the non-zero curvature trajectories. For example, despite the usual speed-accuracy tradeoff for increased spatial variance with increased speed, we did not find strong evidence for the same increased variance with increasing occluder radius.

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36.426 **Sensitivity of visuomotor control to real and to illusory size**

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Evidence from neuroanatomical and neuropsychological studies supports the notion that different systems mediate visual control of action and visual perception. Yet, behavioral studies, including those who have focused on visual illusions, show a diverse pattern of results. In a first series of experiments we have attempted to disentangle – within the same paradigm – the effects of the real size and the apparent size of objects on action and perception. To this end, two objects of different sizes were presented within a size-contrast illusion, so that in most experimental trials the object that was perceived as the larger one was actually physically smaller than the other object. This design allowed us to focus on trials in which subjects have overtly decided that one of the objects is the smaller (or larger) of the pair, and to test whether or not the opening between the fingers of the grasping hand goes in the direction of this erroneous decision. The results showed that although subjects were affected by the illusion when making size decisions, the opening of their fingers reflected the real size differences between the objects. Thus, the real and apparent differences in the sizes of the objects had opposite effects on action and perception. These findings also indicate that visuomotor control may have enhanced sensitivity to real size. In a second series of experiments we examined this idea by focusing on the psychophysical function that links visuomotor control with size. Results showed that in the absence of illusory context, action and perception showed similar psychophysical functions for size. However, JND's (Just Noticeable Differences) increased with object size for perceptual estimations, but remained constant across different sizes when grasping the same objects. These findings suggest that qualitative differences exist in the way size is represented for visuomotor control and for perception.

36.427 **The Effect of Intention and Bodily Capabilities on the Perception of Size**

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Previous research has suggested that the intention to act can affect the perception of size. Vishton et al. (2007) found that the magnitude of the Ebbinghaus illusion decreases when the perceiver intends to grasp or touch the illusion. These results suggest that merely intending to act on an object, either grasping or touching, can affect the perception of its size. However, it is unclear whether this effect is specific only to the size perception of objects on which an action can be performed. For example, if an object is too large to be grasped, would size perception be affected by the impossible action of grasping?

In the present experiment, we addressed this issue by assessing the effects of action intention on the magnitude of the Ebbinghaus illusion in two different displays. In one display, the circles that comprised the illusion were too large to be grasped, and in the other display, the circles were much smaller and capable of being grasped.

We found that the intention to act on the large display (non-graspable) did not affect the magnitude of the illusion, while the intention to act on the small display (graspable) decreased the magnitude of the illusion. These results suggest that the effect of action intention on perception is constrained by the capability to perform the intended action. In both display conditions, we found that the illusion magnitude was negatively correlated with the participants' hand lengths but only when they intended to act on the illusion. These results suggest that the perception of the target's size in the Ebbinghaus illusion is scaled with respect to action intention and the observers' bodily capabilities (hand size) for the intended action of grasping.

36.428 **Reconsidering the role of action in perceiving the catchability of fly balls**

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Many visuomotor tasks require actors to make rapid decisions about different categories of action. For example, pedestrians must decide whether to cross the street in front of an approaching vehicle or wait until it passes; fielders must decide whether to catch a ball on a fly or let it bounce. In both cases, the actor's locomotor capabilities partly determine which actions are possible, and therefore must be taken into account. Previous studies suggest that people only know their locomotor capabilities when they are actually moving, and that stationary observers cannot reliably discriminate between actions that are within and beyond their limits. In one study, subjects made more accurate judgments of the "catchability" of fly balls when they were allowed to move for 1 s compared to when they were stationary. However, there were other differences between the Move and Stand conditions in this experiment that may explain why subjects were more accurate when moving. When we controlled for these differences in the present study, we found that stationary and moving subjects made equally accurate judgments. Fourteen subjects participated in the experiment, which was conducted in a large area virtual environment. Virtual balls were projected to one of four landing locations, crossed with four flight times. On judgment trials, the ball disappeared after 1 s and subjects indicated whether they could have caught the ball. On catch trials, the ball remained visible and subjects attempted to catch the ball. In separate blocks of trials, subjects made judgments while stationary or while moving. Judgments were equally accurate regardless of whether subjects were stationary or moving, suggesting that people do know their locomotor capabilities even when standing still. Judgments also became more accurate as remaining flight time decreased, suggesting that the ability to perceive possibilities for action improves as the task unfolds.

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36.429 **Intercepting moving targets: A little foresight helps a lot**

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Behavioral studies suggest that humans performing a fixed-heading interception task regulate velocity to maintain a constant bearing angle (CBA); that is, to null the change in the target's exocentric direction. This purely feedback-driven CBA strategy has been contrasted with a purely predictive strategy that requires the pursuer to predict the eventual time and location of the future interception point. However, there exists a continuum of possible strategies in between the purely feedback-driven CBA strategy and the purely predictive strategy that have yet to be considered. Our study is aimed at investigating these intermediate strategies in which the pursuer regulates velocity to null the change in bearing angle a short time into the future. Subjects sat in front of a large projection screen and watched computer generated displays that simulated linear self-motion over a textured ground plane. Simulated speed was controlled by adjusting a foot pedal, the position of which was mapped onto speed according to a first-order lag. A spherical target approached the subject's path from one of two angles, at one of two initial speeds, and along one of five potential trajectories with varying degrees of curvature. Human performance was compared with a model of interception behavior that, at each time-step t, produced the velocity adjustment that would minimize the change in bearing angle at time $t+\Delta t$, taking into account the target's behavior during that interval. By adjusting the parameter Δt, the model can simulate the full range of strategies between the purely feedback-driven CBA strategy ($\Delta t = 0$) and the purely predictive strategy (Δt = target's time-to-contact with the interception point). We found that the model most closely approximates the human data when Δt is at intermediate values, suggesting that subjects regulate velocity to null the change in bearing angle a short time into the future.

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36.430 **Baseball's Paradoxical Pop Up: Physics and Fielder Control Strategy Can Lead to Lurching**

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We describe how current baseball physics models predict a class of towering pop ups in which the ball trajectory is steep enough to exceed the angle of repose, resulting in upward curvature. When optical interceptive control strategies like Optical Acceleration Cancellation (OAC) and Linear Optical Trajectory (LOT) are applied to such trajectories they produce systematic vacillations in running paths. We refer to these fly balls as Paradoxical Pop Ups because they behave fundamentally differently than typical near-parabolic fly balls. Paradoxical Pop Ups comprise a unique set of trajectories that can exhibit discrete cusps and loops near the apex, and tend to be more symmetric than typical. These trajectory abnormalities appear to misinform the typically robust optical control strategies used by fielders, which can lead to systematic lurching, especially when the pop up is headed to land near the fielder. It is useful for perception-action modelers to be aware of these deviant cases given that a number of research laboratories that study interception currently use near-parabolic models of ball trajectories in lieu of direct location measurements. In short, current perception-action research may benefit from more accurate physical modeling. In the case of fielders pursuing paradoxical pop ups, some of their dancing around can be well explained as a combination of bizarre trajectories and misguidance by the normally reliable optical control strategy, and is likely not due odd wind conditions, too much chew tobacco, or apparent fielder error. Behaviorally, even professional baseball players occasionally find it difficult to gracefully approach these seemingly routine pop-ups, and former Major League infielders confirm that their experiences agree with our predictions.

36.431 **Preserved visual abilities following large bilateral lesions of the occipitotemporal cortex**

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MC is a 38-year-old woman with large bilateral lesions of occipitotemporal cortex, including almost the entire ventral stream and sparing only a tag of tissue in the rostral calcarine cortex. Formal and informal testing revealed that MC has some preserved motion perception (Riddoch phenomenon) and is able to track moving targets. Although MC reports seeing colour, formal testing revealed that she cannot correctly identify (or discriminate between) different hues or visual textures. MC can identify simple geometric shapes, even large letters, although there is a strong suggestion that she does this by using 'tracing' strategies, either explicitly with her finger or implicitly with eye and head movements. With more complex shapes, her performance plummets; she cannot recognize line drawings (or real exemplars) of familiar objects. Despite the fact that MC cannot distinguish between rectangular objects with the same surface area but different dimensions, when she reaches out to pick up such objects, she shows in-flight grip scaling. Moreover, her grip scaling for these objects (but not her manual estimation of their size) was significantly improved when the objects were strobe-illuminated at a temporal frequency of 4Hz. When picking up objects of varying shape, MC made subtle in-flight adjustments of her finger and thumb to ensure that she acquired the object using stable grasp points, even though she could not distinguish between pairs of these same objects. MC also showed evidence that she could detect obstacles when walking over them or when reaching out to objects. She is also able to intercept a tennis ball rolled towards her. All of this suggests that the visual perception of motion and the visual control of a broad range of actions can occur without input from the ventral stream or early visual areas, including (perhaps) primary visual cortex (Goodale et al., VSS 2008).

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Reading

36.432 **What is the visual word form area encoding? An adaptation study contrasting handwriting with word identity**

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Neuroimaging studies have shown that when subjects view written words, there is activation in the fusiform gyrus, more on the left than on the right, in an area called the 'visual word form area' (VWFA). In patients, lesions of the left medial occipitotemporal cortex are associated with alexia, whereas lesions of the right medial occipitotemporal cortex are found in some prosopagnosic patients, some of whom also have problems identifying handwriting. These observations suggest that encoding handwriting from written material may occur in the right fusiform cortex, whereas encoding word forms may occur in the left fusiform cortex.

To test these hypotheses, we performed an fMRI adaptation experiment in 11 subjects. Functional localizers, one using a contrast between faces and objects and another using a contrast between English and Korean words identified the right fusiform face area (FFA) and the bilateral VWFA respectively. The adaptation run was a block-design consisting of three different experimental conditions; one containing different words in different handwriting, a second containing the same word in different handwriting, and a third containing different words in the same handwriting.

Contrary to expectations, we found a significant adaptation for handwriting ($p<.021$) but not for word identity in the left VWFA, and a trend to adaptation for handwriting ($p<.065$) but not word identity in the right VWFA. No significant adaptation effects were found in the right FFA.

These findings raise questions about whether the VWFA encodes word forms invariant of the script in which they are written. Rather than this invariance, they show a sensitivity of the VWFA to script form that is independent of word form.

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36.433 **The visual cortical 'word form area' is selective for high spatial frequencies in humans but not monkeys**

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Neuroimaging and neuropsychological evidence suggests a specific module in the human ventral cortical stream, called the word form area (WFA), which responds selectively to visually presented word forms. This region is consistently localized adjacent and lateral to the left posterior FFA. However, since humans have used written language for only ~7000 years, it is unlikely that a novel cortical module evolved during that time. Instead it has been suggested that the WFA may reflect top-down processes activating a pre-existing module, which is tuned to relevant lower level cues.

To test this, we presented images of faces and places to human subjects and awake rhesus macaques, in a blocked-design fMRI experiment. The stimuli were either highpass-filtered, lowpass-filtered, or unfiltered for spatial frequency (SF). Results in humans showed selective activation in response to high SFs in the area reported as WFA. The functional signature of this area thus includes a specialization for high SF, which is crucial for perceiving (and presumably processing) letters. However, the high SF regions are bilateral, whereas the WFA is reported to be largely unilateral.

Nevertheless, extensive fMRI tests in two awake monkeys showed no homologue of the WFA. This is notable because it is increasingly unusual to not find monkey homologues of known cortical areas in humans.

We conclude that the WFA is coextensive with, or built up from, a pre-existing cortical area that is activated selectively by high SFs, even using non-word stimuli. No such cortical area appears to exist in monkeys, when tested with the same visual stimuli that elicit WFA activation in humans.

Therefore, it appears that a specific area/module has evolved in the human cortex in the past 25 million years, which is used for, but not exclusively activated by, word form processing.

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36.434 **Contrast Polarity in Letter Identification**

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Although previous studies on detection or reading have not consistently shown significant polarity effects, our studies of background effects on text readability have shown that, on a gray background, dark text is more readable than light text. Our readability tasks included searching for target words within a paragraph of text, word identification, word discrimination, and letter identification. For all tasks, positive contrast task responses were slower and less accurate than those for negative contrast tasks. Polarity effects are often explained as the result of separate channels for the two polarities. Effects in reading-related tasks might result from the increased experience people have reading dark letters on a light background. To differentiate between these explanations of the polarity effect, we surrounded gray letters with a small positive or negative pedestal. The pedestal polarity determines the channel polarity, opposite the apparent polarity of the letter. Stimulus-response confusion matrices and response latencies were collected from 14 observers for 4 repetitions of 12 letters presented randomly at 6 letter or pedestal contrasts (-0.4, -0.2, -0.1, 0.1, 0.2, 0.4). Performance was computed as information transmitted per second from the confusion matrices pooled over repetitions and the corresponding average latency. The letters without the pedestals replicated earlier effects, the information rate in bits per second was 3.86 bits/sec for the negative contrast and 3.76 bits/sec for the positive ($F = 6.29$, $p<.05$). The information rate was also larger for the negative contrast versus the positive contrast pedestal (3.82 bits/sec vs. 3.74 bits/sec; $F = 6.99$, $p<.05$). The pedestal results are in the direction of the pedestal contrast, rather than the perceived contrast of the letter, supporting the channel explanation over the experience explanation of the polarity effect.

36.435 **Visual spread reading: Noisy letters in their natural context**

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Keywords: Reading; Letters; Noise; Crowding.

We quantified text legibility as a function of various factors present in natural texts. We adapted the visual spread method (Poirier, Gosselin & Arguin, submitted) to a reading task. Stimuli were sentences conforming to MN Read standards (Legge, Ross & Luebker, 1989, O&VS) mixed with dynamic probabilistic noise – i.e. each pixel in the image was associated with a probability that its polarity was inverted on a given refresh cycle of the display screen. Even low levels of noise can alter letter shapes. Noise level varied continuously over the image as initially determined by Gaussian-filtered noise. Participants adjusted noise levels in the text using the mouse until the text appeared homogenously noisy. We assumed that participants increased (or decreased) noise at locations where stimulus features were easy (or difficult) to encode, thus that local noise setting would correlate with legibility.

Data on 5 participants and 10 texts revealed interesting effects; demonstrating the method's validity for assessing legibility in natural texts. For example, participants put more noise (1) over spaces than over letters, (2) over the first and last letter of words than over middle letters, and (3) over letters that are highly discriminable (e.g. for the 15 letters that appear at least 10x in the texts, $r = .45-.61$ with confusability data using traditional psychophysical techniques; see Fiset, Dupuis-Roy, Arguin & Gosselin, in preparation).

Critically, these preliminary analyses demonstrate the sensitivity of the method to the legibility of individual letters within its natural context. In-depth analyses will include various other factors, e.g. letter and word frequency, word length and type, letter position in the word, as well as possible interactions between these factors.

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36.436 **Reading Horizontal and Vertical English Text**

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Purpose: There are three formats for arranging English text for vertical reading—upright letters are arranged vertically (marquee), or horizontal text is rotated 90° to the right or left. Previous research has shown that reading speed is slower for all three vertical formats, with marquee slower than either rotated formats (Byrne, 2002). It has been proposed that the size of the visual span—the number of letters recognized with high accuracy without moving the eyes—is a visual factor limiting reading speed. We predicted that reduced visual-span size for vertical text is correlated with the slower vertical reading, and that differences in visual-span size are associated with the differences in reading speed across the three vertical formats.

Methods: Twenty-four normally sighted young adults were randomly assigned to groups tested with either lowercase or uppercase text. Visual span profiles, plots of letter-recognition accuracy as a function of letter position left or right (horizontal orientation) and above or below (vertical orientation) the midline, were measured with trigrams (strings of three random letters). Size of the visual span was defined as the area under this profile, converted to bits of information transmitted. Reading performance was measured using two presentation methods—RSVP (Rapid-Serial-Visual-Presentation) and flashcard (a block of text on four lines)—for horizontal, marquee, rotated right, and rotated left conditions.

Results: Sizes of the visual span and reading speeds showed a qualitatively similar dependence on text formats for lowercase and uppercase and both RSVP and flashcard reading. Correlations were computed between reading speed and visual-span size across the four test conditions. Averaging across subjects and reading tasks, the correlation accounted for 83% of the variance in reading speeds.

Conclusions: Our results are consistent with the view that horizontal/vertical differences in reading speed are due to changes in the size of the visual span.

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36.437 **User Interface Software for Low Vision Access to the Internet**

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There are about 60 million persons worldwide who have uncorrectable low vision. Development of technology that can help low vision users access the World Wide Web has far lagged behind that designed for totally blind users. We have developed a user interface software called LowBrowseTM to help those with low vision more effectively access Internet web pages. LowBrowseTM utilizes a transcoding design that renders the webpage structured document in two distinct windows: a top frame for reading, and a bottom global frame for navigating global layout of the webpage. The style sheet parameters including font color, font size etc. of the reading frame can be configured according to the users' preferences and best performance. Once the users choose their optimal and most comfortable style settings, they will be able to read all the following web content in that selected setting. A large cursor is used in the global frame to aid navigation in the global layout of the webpage. When the cursor hovers over text, that text is displayed in the reading frame, at a user prefered color, size, font and background configuration. The text is displayed as a single line in the reading frame, and up-arrow and down-arrow keys are used to switch between lines if the text string is more than one line. When the mouse hovers over images, they are rendered in a separate popup window that displays the image with zoomable scale. User preferences and settings are saved in the user's directory and persist across browser sessions. LowBrowse is currently implemented as a Mozilla Firefox Extension. In summary, LowBrowseTM can present content tailored in a consistent fashion according to the low vision user's preference for any Web page.

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Sunday, May 11, 2:30 - 6:30 pm
Poster Session, Orchid Ballroom

Eye Movements
Object Perception 1
Smooth Pursuit and Perception

Eye Movements

36.501 The effect of attention size and information density on saccadic adaptation during real-world image search

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Generally speaking, saccadic eye movements are both very quick, covering up to 500°/s, and very accurate, usually within an error of 1% of target eccentricity. Despite persistent pressure by growth, fatigue, and aging, saccades are believed to remain accurate throughout life by a form of motor learning termed saccadic adaptation. Robust saccadic adaptation to induced post-saccadic visual error has been demonstrated by trans-saccadically displacing targets. Somewhat recently, Wallman et al. (VSS, J. of Vis., 2001) demonstrated that when both a large and small sectioned circle were presented simultaneously and participants attended the smaller, saccadic adaptation was four times greater than when participants attended the larger. However, the observed effect in this study could possibly be accounted for by the concentration of post-saccadic visual information available to the participant while attending the smaller target. In the study, the size of the rings, 8.5° and 0.8° respectively, could allow more information for a visual error computation to be available earlier in the occipitotemporal pathway, as the small target can be contained by neurons as early as V1 (RF around 1.5°) as compared to post-V4 (RF around 4°) with the larger target. We tested this hypothesis by having participants search a real-world image for a pre-displayed cutout using a recently presented gaze-contingent paradigm to study saccadic adaptation (Garaas et al., J. Neusci. Meth., in press). In four separate conditions, the cutouts were either large (4° x 4°) or small (1° x 1°) and were chosen from either the first or fourth quartile of possible cutouts ranked by contrast and spatial frequency. Results from the task provide evidence that saccadic adaptation is primarily influenced by the concentration of visual information available at the attended location, as participants show a nearly two fold increase in the amount of adaptation while searching for the high-information targets.

36.502 Effects of age, target characteristics, and viewing distance on ocular counterroll in healthy humans

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The ocular counter-roll (OCR) reflex generates compensatory torsional eye movements during static head tilt. OCR gain is defined as the ratio of change in eye position to change in head position. Previous reports of OCR gain have varied considerably among normal subjects, perhaps due to the use of different targets and viewing distances. This study compared OCR gains during viewing of well-controlled targets (simple vs complex, near vs far viewing) in healthy subjects (n=60; age 10-62). Two visual stimuli were used: a simple target consisting of a central fixation cross against a uniform gray background, and a complex target consisting of the same fixation cross against a high-contrast grid pattern. Each stimulus was presented at near (0.33m) and far (1.0m) viewing distance. Eye movements were recorded using a video-based eye tracker. Change in torsional eye position was plotted as a function of head position step (0±40° in 5° steps), and a sigmoidal fit was performed as part of a non-linear regression. Mean OCR gain was calculated from the slope of the regression line. Factorial and repeated measures ANOVA were performed. Mean OCR gains were higher in younger subjects (<30 years), during viewing of far targets (p<0.001), and also during viewing of complex

targets (p<0.05). There was significant interaction between target distance and complexity,

with a larger reduction in gains for simple targets during near viewing (p<0.03). OCR gain is

highest when using complex targets, which provide additional visual spatial orientation cues. Decreased OCR gain during near viewing may minimize the vertical disparity induced by the specific geometry of eye rotations during torsional movements, thereby optimizing stereopsis during convergence. The normal database created by this study can now be used to evaluate patients with different disorders, including skew deviation and peripheral vestibulopathy.

36.503 Behavioral genetic evidence for plasticity in the oculomotor system

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By establishing the relative influence of genes versus environment, a classic twin study can point to visual functions that exhibit more or less plasticity due to experience. Such knowledge informs theories of development and helps to identify those visual functions most likely to respond to therapeutic intervention. Here, we use a twin study to demonstrate substantial plasticity in one important aspect of oculomotor function. Specifically, we find evidence that an individual's vergence position with inputs to the eyes dissociated, or phoria, is due mainly to environmental influences rather than genes.

We measured phoria at nearpoint (40cm) in 310 pairs of identical (n=258) and fraternal (n=52) twins using a Maddox Rod with a target for accommodation. Twins had highly similar phorias (r=0.60), which in isolation could result from sharing either genes or environment. However, despite sharing twice as many genes (100% vs. 50%), identical twins' phorias were no more similar (r=0.58) than fraternal twins' (r=0.67), suggesting that phoria results from environmental rather than genetic influences.

Phoria has traditionally been thought of as one's latent tendency toward manifest oculomotor deviation, or strabismus. Our lack of evidence for a genetic contribution to phoria must therefore be reconciled with previous evidence that strabismus is substantially genetic. We propose that phoria and strabismus may not be simply graded expressions of a common tendency. Instead, distinct mechanisms with different developmental origins may contribute to phoria and strabismus. Our study is the first we are aware of to demonstrate substantial oculomotor plasticity using the twin method.

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URL: www.sunyopt.edu/research/wilmer

36.504 Eye Movement Strategies in a Fixation Search Task: Humans versus Models

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Previously we found that humans can approach optimal performance (in time and accuracy) when searching for a known target in backgrounds of broadband (1/f) spatial noise (Najemnik & Geisler, 2005, Nature, 434 387-391). However, there are a number of fixation selection strategies that can achieve similar levels of performance. These efficient strategies include fixating the location with the highest posterior probability of being the target (MAP searcher), fixating the location that maximizes the probability of correctly localizing the target after the eye movement is made (Ideal searcher), and fixating the location where the expected entropy of the posterior probability distribution is minimized (the ELM and EEM searchers). To determine which model most accurately describes the human fixation strategy, we measured the pattern of eye movements in a search task where a known Gabor target appeared in one of four possible pre-cued locations within a circular background of 1/f noise. All target locations were 4 deg from the initial fixation point at the center of the display. The two outermost locations were fixed at the right and left of the display, 180 degrees apart, while the middle two locations were randomly chosen on each trial from 9 possible equally-spaced locations between the two outermost locations. Following the cues, the subject initiated the display, which appeared for 500ms; this duration was picked to allow just one eye movement. The task was to indicate which of the four cued locations contained the target. We find that human observers fixate in a pattern that is highly dependent on the pattern of pre-cued locations and that they often make saccades to locations between potential target locations. The results are qualitatively consistent with the Ideal and EEM searchers, less consistent with the ELM searcher and completely inconsistent with the predictions the MAP searcher.

36.505 **Visual saliency re-visited: Center-surround patterns emerge as optimal predictors for human fixation targets**

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Humans perceives the world by directing the center of gaze from one location to another via rapid eye movements, called saccades. In the period between saccades the direction of gaze is held fixed for a few hundred milliseconds (fixations). It is primarily during fixations that information enters the visual system. Remarkably, however, after only a few fixations we perceive a coherent, high-resolution scene despite the visual acuity of the eye quickly decreasing away from the center of gaze: This suggests an effective strategy for selecting saccade targets.

Top-down effects, such as the observer's task, thoughts, or intentions have an effect on saccadic selection. Equally well known is that bottom-up effects—local image structure—influence saccade targeting regardless of top-down effects. However, the question of what the most salient visual features are is still under debate. Here we model the relationship between spatial intensity patterns in natural images and the response of the saccadic system using tools from machine learning. This allows us to identify the most salient image patterns that guide the bottom-up component of the saccadic selection system, which we refer to as perceptive fields. We show that center-surround patterns emerge as the optimal solution to the problem of predicting saccade targets. Using a novel nonlinear system identification technique we reduce our learned classifier to a one-layer feed-forward network which is surprisingly simple compared to previously suggested models assuming more complex computations such as multi-scale processing, oriented filters and lateral inhibition. Nevertheless, our model is equally predictive and generalizes better to novel image sets. Furthermore, our findings are consistent with neurophysiological hardware in the superior colliculus. Bottom-up visual saliency may thus not be computed cortically as has been thought previously.

URL: http://www.cognition.tu-berlin.de

36.506 **Fixation Region Overlap Analysis (FROA) - A Data Driven Approach To Hypothesis Testing Using Eye Gaze Fixation Data**

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The study of eye movement patterns is a valuable tool for psychological research in several domains such as reading and scene analysis. Here we outline a new methodology for the analyses of fixation data that can be used to examine the representation and recognition of three-dimensional object shape. In principal, fixation patterns can be used to infer properties of local image features that support shape recognition. However, a number of methodological problems must be overcome. For example, it is unclear how predicted fixation patterns from different theoretical models can be statistically compared to observed data. In addition, where analyses are based on the definition of a priori areas of interest (AOIs) the spatial precision, and theoretical validity of the AOIs, can limit the validity of the analyses. To address these issues we outline a new approach, known as the fixation region overlap analysis, which uses observed fixation patterns to generate AOIs that can be subject to analyses for shape information content. These analyses statistically contrast the degree of spatial overlap between the observed AOIs, and those predicted by a random distribution and any number of theoretical models of shape analysis, including mathematical and those derived from lesion data. This methodology provides a quantitative and statistically valid technique for the analysis of fixation patterns in studies of shape recognition, and has applications in other research domains.

36.507 **Perisaccadic mislocalization in slow saccades**

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Despite frequent saccadic gaze shifts during visual exploration we perceive the outer world as stable. Under laboratory conditions, however, space constancy can be challenged: Briefly flashed stimuli are systematically mislocalized around the onset of saccadic eye movements. One well-established pattern of perisaccadic mislocalization is an anisotropic localization bias towards the saccade target which has been termed a compression of apparent positions (e.g., Ross et al. 1997, Lappe et al. 2000). The dynamics of perisaccadic mislocalization vary considerably between subjects. Recently, we observed that a large part of inter-individual variance in perisaccadic compression strength can be explained by corresponding variations in mean saccadic peak velocity (Ostendorf et al. 2007). The observed correlation may indicate a modulation of visual reafferent processing by extraretinal signals associated with the oculomotor command, leading to stronger perceptual compression with higher saccade velocities. Alternatively, differential retinal stimulation due to a variable displacement speed may result in different degrees of spatio-temporal uncertainty for peri-saccadically flashed stimuli. This could, at least partially, explain an association between individual mislocalization patterns and corresponding saccade velocities as well (Brenner et al. 2006).

Here, we aimed at dissociating the oculomotor command and the velocity of corresponding saccades in order to better discriminate between these two hypotheses. To this end, we examined perisaccadic mislocalization in one patient with an autosomal dominant spinocerebellar ataxia (SCA Type 2) who exhibited markedly slowed saccades. We compared the dynamics of perceptual mislocalization in this patient with a control group of ten healthy subjects. A clear correlation between perisaccadic mislocalization strength and mean saccadic peak velocity was observed in the control group. The patient however exhibited a disproportionally strong compression with respect to her mean saccadic peak velocity. The observed dissociation supports the notion that extraretinal signals contribute to the phenomenon of perisaccadic mislocalization.

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36.508 **Microsaccades drive illusory motion in "Enigma"**

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Visual images consisting of repetitive patterns can elicit striking illusory motion percepts. For almost 200 years, artists, psychologists and neuroscientists have debated whether this type of illusion originates in the eye or in the brain. For more than a decade, the controversy has centered on the powerful illusory motion perceived in the painting "The Enigma", created by op-artist Isia Leviant. However, no previous study has directly correlated the Enigma illusion to any specific physiological mechanism, and so the debate rages on. Here we show that microsaccades, a type of miniature eye movement produced during visual fixation, drive illusory motion in Enigma. We asked subjects to indicate when illusory motion sped up or slowed down during the observation of Enigma, while we simultaneously recorded their eye movements with high precision. Before "faster motion" periods, the probability and magnitude of microsaccades increased. Before "slower/no motion" periods, the probability and magnitude of microsaccades decreased. These results reveal a direct link between microsaccade production and the perception of illusory motion in Enigma, and rule out the hypothesis that the origin of the illusion is purely cortical. They also have important implications for other types of illusory motion effects arising from static images.

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URL: http://smc.neuralcorrelate.com/

36.509 **Disruption of Voluntary Saccade Commands by Abruptly Appearing Visual Stimuli**

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Saccades can be made both reflexively in response to a sudden appearance of a sensory stimulus as well as voluntarily to an object of interest in the visual field. However, there has been little study of how the interaction of voluntary and reflexive systems depends on the timing of their commands. We studied the ability of a suddenly appearing distractor to disrupt a voluntary saccade command, and how this ability depended on the spatial and temporal relations between the visual stimulus and the voluntary saccade plan. Two subjects' saccades were monitored at 500 Hz using an Eyelink II video eye tracker. They first fixated a central arrow, which pointed either left or right. 500-800 ms later the fixation stimulus disappeared, cuing the subject to make a saccade of 8° to a blank space in the direction the arrow pointed. A 2°x2° distractor appeared at a time 40-130 ms before the saccade. The distractor could appear at the saccade goal (0° separation), or else at the same eccentricity, separated in direction by 22.5°, 45°, 90°, or 180°. Subjects were instructed to ignore the distractor. As a control, in 1/6 of trials no distractor appeared. Trials with differing distractor/saccade goal separations were run intermixed. We found that for large distractor/saccade goal separations (90°, 180°) there was a large notch in the saccade timing histogram, such that virtually no saccades occurred from 80-100 ms after distractor appearance. When this separation was small (0°, 22.5°), more saccades were elicited 80-100 ms after distractor appearance (i.e. "express saccades) than in control trials when no distractor was present. These results strongly suggest that the transient component of a visual response has a much stronger impact on voluntary saccade generation than does the sustained visual response, thus elucidating the time course of the remote distractor effect.

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36.510 **Eye Movement Strategies: A Comparison between Individuals with Normal Vision and Simulated Scotomas**

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Purpose: Central visual field deficits (i.e., macular degeneration, MD) can impair individuals' visual performance. Individuals might use alternative eye movement (EM) strategies to compensate the deficiency, e.g. by making use of the unaffected periphery. Furthermore, visual tasks for those individuals would be effortful, that is, they would need to increase EM frequencies and durations to make accurate responses. Method: We presented computer-generated (MATLAB) images either with or without simulated scotomas to normally sighted individuals. Scotoma properties were varied to correspond to different stages of MD. We recorded EM (EyeLink II eye tracker) when observers were making target discrimination tasks. Data were collected for fixations, X and Y positions of EM, and behavioral responses such as accuracy and reaction time (RT) in a 3D texture discrimination task. Results: Fixation durations and variability were bigger for simulated MD. Number of fixations was also higher for MD. Mean X and Y positions were similar for control and MD, but they were more variable for MD. Behaviorally, RTs were longer and more variable for MD and more errors occurred. Conclusion: Central visual field loss impaired visual performance. Visual tasks could still be performed, but EM parameters and temporal and spatial EM patterns needed to be adjusted. This suggests that specific visual aids and training programs could be designed by incorporating residual visual functions (i.e., peripheral visual field) during dynamic scene perception.

36.511 **Effect of central scotoma on eye movement behavior**

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In low vision rehabilitation, patients with central vision loss are taught to use their peripheral vision to perform tasks once done by the fovea (e.g. reading). Patients are taught eccentric viewing techniques in conjunction with visual aids such as magnifiers. Scanning strategies may also be taught (e.g. look into the blind field for missing information), however it is not clear how eye movements may compensate for visual field loss.

Using methods described previously (Renninger, et. al. JOV 2007) we compute the information gained by subjects as they perform an adaptive shape discrimination task. The difference between the comparison shapes is adjusted to maintain discrimination performance at 75% correct and allow comparison between normally-sighted individuals (20/20) and patients with low vision (20/200 – 20/700). The efficiency of the eye movement strategy is taken as the ratio of information gained at a given fixation location, divided by the maximum gain possible. The computation takes into account the size and location of the scotoma, as measured by microperimetry with a scanning laser ophthalmoscope. Eye movement parameters such as fixation dwell time and saccade amplitude were also measured.

Results: Fixation dwell times varied substantially and were negatively correlated with saccade amplitudes, however no difference was observed in these eye movement parameters between normal and low vision subjects. Low vision patients with smaller scotoma (~5deg) made highly efficient eye movements, similar to normally-sighted individuals. As scotoma size increased (up to 20deg), efficiency declined rapidly and even fell below chance levels in the most advanced cases.

Conclusion: Extensive field loss may further impair functional vision by reducing the ability of subjects to select and prepare saccades to points of high information in the visual field. Rehabilitation that seeks to increase eye movement efficiency may help patients, especially those with moderate central field loss.

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36.512 **Mean Gaze Duration Validates Self-Reports of Image Importance**

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When individuals make color preference choices between images, are they focusing on areas of an image they find most likeable or areas they find most important? Self-reports provide data regarding whether an individual believes a certain area of an image is important or attractive but, according to past research, may not accurately reflect how their attention is allocated. Eye-tracking participants while performing such a task can provide physiological data corresponding to an individual's location of attention while viewing a scene. Such information can also be used to corroborate self-report data.

We performed two experiments combining paired-comparison data, self-reports and eye-tracking information to determine if participants' self-reports were valid and to assess whether individuals used the important or the more liked areas of an image to make their decision.

In experiment one, 53 participants completed a 2-AFC color preference test and exit survey. The stimuli for the test were four-panel images of faces or landscapes. Participants saw images with identical content but varied on color. They rated how likeable and how important they felt each quadrant of a particular image was to their decision. We selected image pairs that showed statistically significant liking-importance discrepancies (i.e. highly liked but not important or very important but disliked) for the next experiment.

In experiment two, a separate pool of twelve participants completed a 2-AFC color preference test using the selected pairs from the first experiment one while wearing eye-tracking apparatus. Contrary to many results indicating participants' gaze duration at a target is proportional to how well-liked that target is, we hypothesized that gaze duration would be longer at "important" images rather than "liked" images. Results supported that hypothesis and indicated that participants' self-reports of image importance were accurate, as average gaze duration was directly proportional to rated image importance.

36.513 **Inverting faces does not abolish cultural diversity in eye movements**

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Face processing is thought to be invariant across all humans. Since the seminal work of Yarbus (1965), studies of eye movements have consistently revealed systematic, analytical sequences of fixations over the eyes and the mouth during face processing. This triangular scanpath observed in Western Caucasian (WC) observers has long been assumed to represent a universal, biologically-determined information extraction pattern for faces. However, we recently reported a striking cultural contrast. Contrary to intuition, East Asian (EA) observers focused on the central region of faces to extract information holistically during upright face recognition (Jack et al., 2006), questioning the universality of eye movements for faces.

It is well established that vertical inversion of objects disrupts natural perceptual strategies and markedly impairs individual face recognition (e.g., Yin, 1969). The comparable lack of experience across cultures with inverted faces represents a unique opportunity to establish the extent to which perceptual cultural strategies are robust and might reveal fine-grained use of diagnostic information.

Here we monitored the eye movements of WC and EA observers while they learned and recognized WC and EA inverted faces. Both groups of observers showed a comparable impairment in recognizing inverted faces of both races. In contrast, eye movements revealed differential facial fixation scanpaths. WC showed a scatter inverted triangular scanpath with a bias towards the mouth, whereas EA uniformly extended the focus of their fixations from the center towards one eye. Interestingly, the bias towards the upper part of the face (i.e., mouth) in WC suggests that the extraction of visual information from inverted faces is driven by spatial tuning more than diagnostic information (i.e., eyes). Overall, cultural perceptual differences in eye movements resist the face inversion effect and, critically, reinforce the view that face processing can no longer be considered as arising from a universal series of perceptual events.

36.514 **Unusual mechanism of monocular oscillopsia**

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Among neuro-ophthalmologic manifestations of multiple sclerosis (MS), eye movement (EM) disorders are frequent. Internuclear ophthalmoplegia (INO), isolated ocular-motor palsy, gaze-evoked nystagmus and pendular nystagmus are the most frequently reported EM disorders. Pendular nystagmus is characterized by involuntary to-and-fro oscillation of eyes, usually horizontal and conjugate. Monocular nystagmus has only been reported in the abducting eye of INO. We present two cases of monocular oscillopsia (MO) due to an unusual monocular nystagmus of pendular aspect. The first patient is a 40 year-old woman who experienced partially regressive VI nerve paresis as the first manifestation of relapsing-remitting MS. She complained of right eye paroxysmal oscillopsia. Neuro-ophthalmologic examination revealed normal visual acuity, visual field, contrast and colour discrimination. EM examination showed right esotropia and monocular horizontal tremor of right eye, triggered by abduction. There was no paresia or slowing of left adducting eye. EM recording showed a 5 Hz, 3° amplitude tremor of right eye, induced by abduction. The second patient is a 42 year-old woman whose initial complaint was MO of adducting left eye. EM examination showed left INO, with slowing of adduction and jerk nystagmus of the abducting eye in right-sided gaze. There was also a monocular horizontal tremor of adducting left eye. She lately developed acute left-sided optic neuritis. Recent EM recording showed a persisting 6 Hz, 2° amplitude tremor of adducting left eye. MO is usually reported either as a sign of posterior or anterior INO, or as a peripheral paroxysmal disorder such as superior oblique myokimia. These mechanisms can not explain our two cases which are both triggered by a specific eye position and disclose a paresia in the same eye direction. Different mechanisms are discussed: paroxysmal manifestations due to peripheral hyperexcitability or evolution of a central monocular paresia.

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36.515 **Training eye movements: can training people where to look hinder the processing of fixated objects?**

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Findlay & Walker's (1999) model of eye movement control specifies a system where the need to fixate and the urge to make a saccade (represented by activation in the 'FIXATE' and 'MOVE' centres, respectively) are in competition, and are bound together by reciprocal inhibitory links. This has important ramifications for attempts to train eye movements, as any attempt to focus upon one aspect of eye movements may degrade behaviour that is dependent upon the other. In a series of experiments we tested the hypothesis that directing eye movement training towards the MOVE centre would hinder the ability to extract task relevant information when fixating. Participants carried out a difficult discrimination on a centrally presented letter at the start of each trial. This initial task was purposefully designed to compete with the additional requirement to search a simultaneously presented peripheral array for a target digit amongst non-digits. Two participant groups provided the crucial comparison data: one was given No Training (NT) throughout; the second were given eye Movement Training (MT), being informed that the peripheral target appeared in a predictable pattern from one trial to the next. As predicted the MT group showed evidence that their respective training detracted from their ability to initially process the central letter: this group needed to re-fixate the letter for longer durations in order to respond correctly. This research adds to the growing body of evidence about the interplay between top-down and bottom-up factors in visual search by extending the previously underspecified higher levels of Findlay & Walker's model. Moreover the results are highly relevant for applied areas of vision research, such as driving, as they demonstrate that the emphasis often placed upon maintaining vigilant scanning (e.g. Mills, 2005) may be misplaced.

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36.516 **Gain of cyclovergence as a function of stimulus location**

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Earlier work from this laboratory established that cylovergence is induced more effectively by vertical shear disparity than by horizontal shear disparity in a large textured surface. We predicted that vertical shear disparity confined to stimuli along the horizontal meridian would evoke more cyclovergence than stimuli confined to the periphery. That is, shear disparity in the periphery can arise from surface inclination, while disparity along the central meridian arises only from torsional misalignment of the eyes. Binocular dichoptic stimuli were rotated in counterphase through 5˚ peak-to-peak disparity at 0.1 Hz and presented in a mirror stereoscope. The stimuli were 70˚ long randomly spaced lines that (1) filled a 70˚ diameter circle, (2) were confined to a horizontal band 7˚ wide, (3) filled the 70˚ circle but with the central horizontal band blank. We used scleral search coils to measure cyclovergence of three subjects as they fixated at the center of planar stimuli. As predicted, the mean gain of cyclovergence was significantly higher (0.23) for the central band than for the display with the central band blank (0.12). However, the gain for the full 70˚ display was higher (0.36) than that for the central band. We conclude that stimuli along the central horizontal meridian provide a stronger stimulus for cyclovergence than do stimuli outside the central meridian. However, increasing the total area of the stimulus also increases the gain of cyclovergence.

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36.517 **Translators' Ocular Measures and Cognitive Loads during Translation**

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Revised Hierarchical Model (Kroll and Stewert, 1994) predicts that translating into one's passive language is cognitively more demanding than translating into the dominant language. Such ocular measures as pupil size, number of fixations, blink frequency, and fixation frequency have been shown to be powerful indicators of a task's difficulty. The study aims to use these measures to test the assumption behind the Model. Two eye-tracking experiments were carried out. Experiment One's results showed translating into their passive language was more cognitively demanding than translating into their dominant language, as differences between pupil sizes, numbers of fixations, blink frequencies and fixation frequencies for the two tasks within subjects were statistically significant, using multivariate repeated measures analysis. Experiment Two also showed the same results as predicted by the Model, like Experiment One. For Experiment One, principal component analysis reduced the dimensionality of five ocular measurements to three components to describe the variability of the dataset: 1) number of fixations vs. task time; 2) fixation frequency vs. blink frequency; and 3) pupil size. Based on this, it would be advisable for future researchers to focus on number of fixations, blink frequency and pupil size, should they wish to replicate similar studies. Longitudinal analysis on the pupil size data demonstrated that there was a 'familiarity effect' (Hyönä et al.,1995) during both tasks, as the pupil size decreased in the middle of the tasks. However, this analysis also revealed that for both tasks 'familiarity effect' disappeared toward the end of both tasks, as the pupil size increased significantly in the end. This could be interpreted as sudden alertness to completion of the tasks or urge to proofread the translations.

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36.518 **Mental Rotation of Real Word Shepard-Metzler Figures: An Eye Tracking Study**

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The current study used eye movements to study processing of 3 dimensional figures from the Mental Rotation Test (MRT,Vandenberg & Kuse, 1988). It was hypothesized that participants of low spatial ability, compared to high ability individuals, would show as rotation increased, greater increases in reaction time (Shepard & Metzler, 1972;Just & Carpenter, 1976), number of fixations (Carpenter & Just, 1985) and the number of times they switch eye gaze from one figure to another. Exploratory interest area analysis sought to determine if there were differences in features attended for low versus high ability subjects.

Subjects were identified as high (N=4) or low (N=6) spatial ability by scores on the MRT. Eye movements were recorded as ten match pairs and ten mismatch pairs of Shepard-Metzler figures were randomly presented to the participants on a platform with one figure rotated on one axis either 0, 45, 90 degrees or rotated 45 or 90 degrees about two axes. Participants viewed each pair for 10 seconds and were asked to inspect, rotate and respond by fixating the answer box at the base of the platform.

Based on a priori hypotheses, data were analyzed using contrast analysis. Number of fixations yielded a significant difference between low and high ability individuals at 90 degree rotation (t(8)=2.34, p=.05), with low ability subjects making more fixations than high ability. Number of fixations switches between figures yielded a marginally significant difference at 90 degree rotation (t(7.96) = 2.15, p = .06). Exploratory interest area analysis indicated that high ability subjects are more likely to focus on the spatially salient features of the object, specifically corners. We are currently adding more participants to augment the power of other analyses.

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Object Perception 1

36.519 **Dissociation of Egocentric and Object-Centric Processing in Mental Rotation of Hand: Effect of Viewpoints of the Visual Stimulus and the Viewers' Own Hands**

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We explored the possible dissociation of egocentric or object-centric processes in the mental rotation of hand, which may invoke a mental transformation of either the stimulus or viewer's own body parts. The stimulus consisted of back or palm view of human hands created by a 3D graphics software. Each picture of the hand was presented at an orientation rotated in medial or lateral direction from the upright orientation. Each participant completed (1) a left or right hand judgment task (LR task) when either a left or right hand picture was presented and (2) a same or different judgment task (SD task) when pictures of two hands were presented. During testing, participants seated in front of a computer screen with their hands positioned on their laps with either the back or the palm facing up. The results of the LR task showed that the performance was better (hands were recognized more quickly and accurately) for rotations in medial direction (in-rotation) than rotations in lateral direction (out-rotation) (we termed this "out-rotation" effect). When the viewpoints of the stimulus and the "viewpoints" (imagining participants looking down) of the participants' hands were congruent, the performance was better than that for the condition with incongruent viewpoints. All these effects were found only in the LR task but not in the SD task. These results suggest that the processing of mental rotation in the LR task is limited by the biomechanical constraints of the corresponding physical rotation. Participants use different spatial transformation mechanisms in the LR (egocentric) and the SD (object-centric) task. It appears that the type of material and the gesture of the observers' own body parts and paradigms of mental rotation all determine the reference frame adopted and the out-rotation effect might serve as indicator for the dissociation of egocentric and object-centric mental rotation.

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36.520 **Mental rotation: Cross-task training and generalization**

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It is well established that performance on standard mental rotation tasks improves with training (McClurg & Chaille, 1987), but thus far there is little consensus regarding the degree of transfer to other tasks involving mental rotation. We assessed the effect of mental rotation training, on participants' Mental Rotation Test scores (Vandenberg and Kuse Test, Redrawn by Peters et al., 1995). Thirty participants were randomly assigned to one of three groups: the two experimental groups received mental rotation training either on a single day or on two separate days; the control group received no training between MRT tests. Importantly, training involved a diverse set of tasks. Participants who received training achieved higher scores on the MRT after two sessions, an advantage that was still evident after a one-week retention period. Preliminary results from a follow-up study show that our mental rotation training paradigm also generalizes to complex sensory motor tasks. Taken together, our experiments show that mental rotation is a skill that can benefit from training on related but not identical visual-spatial activities (see also Feng et al, 2007). Further, our results suggest that to achieve generalized improvement, training should involve a variety of mental rotation tasks.

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36.521 **How long does it take for the visual environment to influence the perceptual upright?**

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The perceptual upright (PU) (the orientation in which objects appear 'upright') is influenced by visual and non-visual cues concerning the orientation of an observer. The orientation of the visual background accounts for about 25% of the influence. How long does it take for the perception of upright to form? We used the OCHART method (Dyde et al. 2004 Exp Brain Res. 173: 612) in which subjects identified a character (p/d) the identity of which depended on its orientation. Using a three-field tachistoscope (Ralph Gerbrands, field of view 6.3 degs) subjects viewed the character against a background. Display times were varied from 50-600ms and were immediately followed by a mask. We used the method of constant stimuli with a range of character and background orientations each presented at least six times. From this, we could identify the orientation where the character was most easily identified (PU). There was no effect of the background at the shortest exposure times, even though the subject could comfortably identify the character. There was an increase in the size of the effect with increasing exposure duration with a time constant of about 200ms. Subjects are able to identify the gist of a background with an exposure of only 26ms (Joubert et al. 2007 Vis Res. 47: 3286). However, using information from the visual background to influence character recognition seems to take substantially longer than this. It is possible that different types of orientation cues differ in the time they take to be effective.

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36.522 **Letter identity misplaced in space and time**

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High-level visual cortical areas that encode object identity have a coarse representation of visual space. Consequently, fine-grained representations of space from other cortical areas might have to be integrated in order to encode an object's identity and precise location. In the present study, we used an attentive tracking task to separate the processing of identity and location information.

Subjects viewed a circular array of eight ring placeholders displayed around a central fixation point. They covertly tracked a colored ring that rapidly stepped through the array. A random letter was briefly shown inside the ring at each location. In each trial the ring would change color at one random location. The task was to report the cued location as well as the letter displayed in that location.

Observers accurately reported the cued location, but often failed to report the correct letter. Subjects made systematic errors by choosing letters from adjacent locations, indicating that they successfully processed the identity of the letters without explicit knowledge of their location. These errors are notable because they involve misconjunctions across both space and time.

These results indicate a failure to integrate a letter's identity with its precise location, and suggest a spatiotemporal dissociation between the processing of identity and location.

36.523 **Eccentric features integrate slowly**

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We read more slowly in the periphery, even though speed of information processing is faster there (Carrasco et al., 2003, Nature Neuroscience). At an eccentricity of 15 degrees, we read more slowly by a factor of 3.5. We get slower as eccentricity increases, even when the stimuli are presented at optimal print size and spacing at each eccentricity. Why is peripheral reading slower? In this study, we minimize the need for eye movements by using Rapid Serial Visual Presentation (RSVP). We measure "reading" rates for stimuli of various complexities -- words (in context), 26 letters, two letters, and gratings (of two different orientations) -- presented at eccentricities of 0 and 15 degrees. A stream of six items is presented at a variable rate and the reader names the items at leisure. The QUEST staircase procedure homes in on the threshold presentation rate for 80% accuracy. We find that the eccentricity effect (the ratio of "reading" rates at 0 and 15 degrees) is 3.5 for words (in context), 3 for 26 letters, 1.5 for two letters, and 1 (no eccentricity effect) for gratings. The eccentricity effect decreases with decreasing complexity (fewer features required), and it disappears when reading becomes a one-feature task. No integration is needed when a single feature suffices to distinguish the two items. Slower feature integration impairs peripheral reading.

36.524 **Connectedness and Inside/Outside Relation Affect Dot Numerical Judgment: Implications for Perceptual Objects Defined by Topological Attributes**

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A wealth of evidence in behavioral and neurological studies supports that number sense exists not only in normal adults with well-developed symbolic numerical system, but also among non-verbal animals and pre-verbal infants. For instance, monkeys could extract number information from visual dot displays irrespective of their exact physical appearance such as item shape, size, circumference and location. However, one basic question remains open of what properties exactly determine a numerical identity.

The present study first investigated how connectedness (an attribute of topology) affected dot numerical representation. Participants judged the number of dots in random spatial positions with brief visual presentation such that judgment was based on instantaneous impression without overt or covert counting. Several pairs of dots were connected via a thin line. We found that connectedness resulted in numerical underestimation, that is, the more connected pairs, the less dots perceived. This effect remained when changes occurred to local features such as item shape (dot or triangle) and connecting pattern (line segments or irregular curves, dots terminating the lines or merely on the lines). However, when line segments were merely attached to dots without actually connecting them, the underestimation was no longer observed. Further we investigated another attribute of topology, the inside/outside relation using the same paradigm. We found that when dots were enclosed by an arbitrarily-shaped envelop, underestimation occurred comparing to those with no dots enclosed; and this impairment increased with more dots enclosed. However, once the inside/outside relationship was destroyed, for example, the envelop was split into two open curves, the underestimation effect demolished.

To account for these data, we propose that numerical perception of visual items is based on the number of perceptual objects which could be defined by topological attributes characterized by either connectedness or inside/outside relation (Chen, 2005).

36.525 **Unseen objects can contribute to visual size averaging**

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People can rapidly extract average size information from a set of objects (Ariely, 2001; Chong & Treisman, 2003). Here we explored whether this average is computed using a late representation of the display that has undergone iterative processing, or an initial representation. We asked participants to judge the average size of a set of six circles presented for 30 ms, along with two additional circles that were either smaller or larger than the average. These additional circles were surrounded by four dots that either disappeared simultaneously with the circles, or remained for an additional 320 ms. When the dots disappeared simultaneously, the additional circles were visible. When the dots remained longer, however, the additional circles were invisible due to object substitution masking (Enns & Di Lollo, 1997). If the averaging process uses a late representation of the display, the masked circles should not influence average size judgments. In contrast, we found that masked circles strongly influenced average size judgments, suggesting that the averaging process does not require conscious perception. Average size was also overestimated when the circles were invisible relative to when they were visible, but this difference was not observed in the control condition where the mask did not contain a circle. We speculate that the size of the mask, which always subtended a larger area than the biggest circle in a display, participated in the global average. That is, the mask size was counted into the average calculation when it made the inside circles invisible. In summary, we found that masked circles strongly influenced size averages even though they were never consciously perceived, and that the four-dot mask itself could also contribute to the size average, but only when it blocks the conscious access to the masked objects.

36.526 **Visual statistical learning: spatial configuration or abstract association?**

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Statistical learning has been proposed as a mechanism enabling decomposition of complex sensory scenes. This type of learning occurs in multiple sensory domains and appears to happen without the viewer's explicit awareness. In vision, statistical learning may underlie the formation of object representations (Fiser and Aslin, 2001; Baker, Olson and Behrmann, 2004). While previous studies have demonstrated that humans can learn these regularities, little is known about the time course of this learning and the extent to which this mechanism is robust to changes in spatial configuration and the presence of distracting information. This study addressed these questions by means of an online measure of statistical learning. Participants viewed a scene containing multiple stimuli, one of which was a target (that indicated either a left or a right button press), one an associate, and the remaining were irrelevant distracters. Each target had a frequent associate (present on 80% trials) and an infrequent associate (present on 20% of trials). A given associate was paired equally often with left and right targets and carried no information about the response. Distracters were randomly selected and in no way aided observers in determining which target was present. Results indicated that statistical learning was rapid, occurring within 8 presentations of the target-associate pair. Furthermore learning occurred even though the spatial configuration of the target and associate varied from trial to trial and there were irrelevant distracters present. The ability of learning to take place despite configuration changes suggests that visual statistical learning is not just enabling the learning of specific spatial relations between stimuli, but rather that participants are picking up on a more abstract paired association between the target and its associate.

36.527 **Characterizing the shape and texture of natural objects using Active Appearance Models**

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Previous studies have shown that the way people categorize natural objects is related to the similarity in their visual appearance. Neuroimaging studies, for example, have found that patterns of activation in visual processing regions predict categorization behavior in human observers. In this study, we seek to characterize the space of parameters that observers use to represent the similarity between objects of a single category. We used Active Appearance Models (Cootes, Edwards, & Taylor, 1998) to characterize the visual properties of a category of natural objects (mammals). Active Appearance Models (AAM) describe the exemplars of an image category in terms of shape (defined by a deformable matrix of corresponding image points) and shape-free texture (derived by mapping image texture onto the mean shape). We identified a set of principal components of mammal shapes which are related to human perception of mammals, such as body compactness (which distinguishes tall, long-legged mammals such as deer from small, short-legged animals such as mice), and bulk (which distinguishes heavier mammals such as bears from lighter ones such as dogs). The principal component of shape-free texture in mammals emphasized roughness (smooth skin versus fur) and coloration (darker color on the foreparts than on the hindparts or vice versa). We compare the categorization results from the AAM to categorization patterns found in humans for the same image set and relate the structure of the image space to the structure of human conceptual space.

Smooth Pursuit and Perception

36.528 **Object recognition during eye movements**

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Primates use eye movements to bring and keep objects of interest in the fovea, the region of highest visual acuity, presumably to facilitate object recognition. Therefore, we measured in two experiments how eye movements affect the performance for recognizing letters. The letters were presented within a noise patch, which was either stationary (fixation) or moved horizontally with 10.57 deg/sec (pursuit). It was defined by a one octave wide, band pass filtered noise, with a central frequency of 3 cycles per letter. In the first experiment we compared letter recognition performance during steady state pursuit and fixation over a range of presentation durations and contrast levels. In the second experiment, subjects had to make a vertical 7.5 deg saccade to the stimulus before either fixating or pursuing it. In this case, the letters were presented at different points in time after saccade onset. The results show that letter recognition is only slightly impaired during steady-state pursuit. To reach the same level of performance, either more presentation time or more contrast is required. The same was true for fixation and pursuit after an initial saccade. However, in the later case the recognition rate increased slowly with time relative to saccade onset and reached a plateau only at around 150 ms. In sum these results show that object recognition of moving objects is quite good during pursuit. After saccades, object recognition takes longer to reach a stable level of performance than expected from saccadic suppression, which lasts 50 to 100 ms.

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36.529 **The control of gaze in dynamic random noise displays**

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Numerous attempts have been made in the past to predict where observers fixate when viewing natural images (Itti et al 06, Tatler et al 05, Kienzle et al 06). Despite great efforts, it seems that the prediction rate for fixation vs. random patches is limited between a ROC-area value of 0.62-0.68. We used displays containing dynamic random noise to explore whether prediction performance could be higher with dynamic stimuli free of semantic meaning. We also added small local perturbations to the random noise images to see whether those could attract subjects' gaze. The noise stimuli were flickering bar codes with a spatial and temporal frequency spectrum of 1/f, mimicking the statistical properties of the real world. Small perturbation targets were generated by adding a small change to the movie, defined by luminance, color, contrast, flicker, or movement. The location of the perturbation was defined relative to the current gaze position at varying eccentricities. Several thousand saccades were recorded with an EyeLink II system from several subjects. In one series of experiments, subjects had to press a button to indicate that they had noticed the perturbation target. A classification analysis of fixated versus non-fixated movie patches showed that the prediction rate for our stimuli varied between 0.55-0.62 (ROC area), almost as high as the results obtained with static images. We did, however, find that the movie perturbations were quite effective in attracting gaze. Between 24% and 52% of the perturbations were followed by a saccade to the target stimulus. In many of these cases (up to 18%), the target stimulus went unnoticed. An analysis of the spatial distribution of fixations following target stimuli showed that center target stimuli were more effective than peripheral ones. These results indicate that it is in principle possible to steer gaze to certain image locations.

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36.530 **Selection of Superimposed Surfaces by Speed**

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Bottom-up attention is driven by stimulus features, however most studies have not distinguished whether it is occurring at the level of the object or the feature itself. This is because those studies employed spatially separate stimuli. To study object-based selection, we superimposed two surfaces (random dot kinetograms, RDKs) to control for location-based mechanisms. Another advantage of using this paradigm is that RDKs have a set of well defined parameters which allows us to vary different features (e.g. speed) systematically. We performed 3 experiments to investigate the effect of speed on surface selection. In experiment 1, subjects fixated a central dot and an aperture with a single surface of dots moving left or right appeared in the periphery. After a random period of time, the fixation spot disappeared which was the cue for the subjects to saccade to the aperture. The speed of the surface varied trial-by-trial, from 0.6-24 deg/sec. Saccading to the surface resulted in an automatic pursuit of that surface. Pursuit speed was proportional to surface speed. In experiment 2, a second surface was placed in the aperture, moving at a constant speed in the opposite direction. The other surface varied in speed, and pursuit was again measured. In contrast to theories suggesting that higher speeds are more salient, subjects had no preferential selection for a faster moving surface when presented with 2 superimposed surfaces moving in opposite directions. Experiment 3 varied one surface's speed while the other surface was static. At slow speeds, automatic pursuit was not detected. However, at fast speeds, the moving surface was pursued even in the presence of a static surface. Overall, these findings suggest that motion is salient when presented alone or when presented against a static surface but not when presented against opposing motions.

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36.531 **Hering's Law Tested with the Pursuit Theory of Motion Parallax**

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The visual system requires a pursuit signal to disambiguate the depth-sign of motion parallax (MP). The pursuit theory of MP suggests that stimulus motion in the same direction as pursuit is perceived in near depth. Absent the pursuit signal, depth from MP is ambiguous. This perceptual role for pursuit, separate from moving the eyes, may help us better understand the pursuit system. Hering's Law of Equal Innervation states that the drive signals to the two eyes are a linear combination of a vergence (disconjugate signals to the two eyes) and version (conjugate pursuit signals to the two eyes). One recent alternative is that the eyes receive individual drive signals. These experiments used random-dot MP stimuli on which observers performed depth-phase judgments. Binocular viewing was accomplished with ferro-electric shutter glasses. The MP stimulus was presented to a single eye while a fusible framework and fixation point was presented stereoscopically. Fixation point movement directly towards one eye results in asymmetric eye movements. Hering's Law suggests the moving eye is driven in the same direction by both vergence and version signals, but the stationary eye receives equal and opposite vergence and version signals. An MP stimulus presented to the stationary eye is unambiguous with the depth sign concordant with the direction of the pursuit signal given by Hering's Law. In control conditions, with the previously moving eye now occluded, the MP stimuli are ambiguous. Vergence does not appear to disambiguate MP. In addition to supporting Hering's Law and the pursuit theory of MP, these results indicate that a pursuit signal can be generated, and can disambiguate depth from MP, with the eye remaining stationary. This provides additional support for previous results suggesting pursuit can countermand full-field OKR and disambiguate depth from MP, even though the eye remains stationary.

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36.532 Selection of Superimposed Surfaces by Density

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Bottom-up attention is driven by stimulus features, which may be occurring at the level of the object or the feature itself. Most studies investigating stimulus-driven selection have used spatially separate stimuli and thus are confounded by spatial mechanisms. To investigate whether it is spatial or object-based, we superimposed two surfaces (random dot kinetograms, RDKs). We asked whether dot density, previously found to be involved in bottom-up attention, can also drive object-based selection in the absence of spatial mechanisms. Superimposing two surfaces of different densities places both densities at the same spatial location and thus, those densities are separated only by the surface on which they appear.

We performed 2 experiments to investigate the effect of density on surface selection. In experiment 1, subjects fixated a central dot and an aperture with a single surface of dots moving left or right appeared in the periphery. After a random period of time, the fixation spot disappeared which was the cue for the subjects to saccade to the aperture. The density of the surface varied trial-by-trial from 0.24-30.6 dots/deg2. Saccading to the surface resulted in an automatic pursuit of that surface. We found that pursuit speed varied with surface density. In experiment 2, one surface again varied in density while a second surface was placed in the aperture, moving at the same speed in the opposite direction and of a constant density. We varied the opposing surface's density across sessions (range: 0.24-1.9 dots/deg2). As the relative difference in density between the two surfaces decreased, the gain of pursuit to the higher density surface decreased. At equal densities, no pursuit occurred. These findings are consistent with competitive circuitry between the two surfaces. Overall, these results suggest that density is a salient object feature that can drive automatic selection, regardless of location-based mechanisms.

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36.533 Improvement of chromatic temporal resolution during smooth pursuit eye movement

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When image motion is produced on the retina either by an objects' movements or movements of an observer's eyes, temporal signal integration in subsequent processing could lead to image motion blur. Nevertheless, the perceived image appears to be relatively clear. One mechanism possibly responsible for this motion deblurring is neural integration of visual signals along the motion trajectory, as well as at the same retinal location. In agreement with this hypothesis, different colors presented at the same retinal location, but along separate motion trajectories, are veridically segregated more than expected from local chromatic flicker fusion (Watanabe & Nishida, 2007). Here we report that this improvement of temporal resolution, which had been demonstrated only for object movements, is further enhanced when observers view physically stationary patterns while making smooth pursuit eye movements. We presented on a dark background two arrays of evenly-spaced yellow bars, one above and the other below the fixation point. In the pursuit condition, the fixation point moved at 16 deg/s for 20 deg from the left end to the right end of the CRT screen. When the fixation point reached the screen center area, one of the arrays briefly changed into a red-green alternating grating. The observers had to indicate in which array the color change occurred. The retinal red-green alternation rate varied between 13.3 to 27.1 Hz depending on the inter-bar spacing. In the object-motion condition, the observers viewed moving bar arrays while fixating on a stationary point, and detected a similar color change. The result shows that the detection of a red-green signal, which requires temporal resolution of the two colors, is better in the pursuit condition than in the object-motion condition. This indicates that motion deblurring during pursuit not only suppresses subjective blur (Bedell & Rott, 1996), but also improves objective temporal resolution.

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36.534 Smooth pursuit eye movements and the prediction of visual motion

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Control of motor behavior crucially depends on the ability to predict motion of visual objects in space and time. In sports, athletes are usually advised to keep their eyes on the visual object of interest, i.e. the ball, in order to hit or catch it optimally. The resulting smooth pursuit eye movements enable better vision by stabilizing the target on the fovea. At the same time, they produce a retinal velocity error of target and background motion which has to be compensated. Here we report results from experiments that address the question whether smoothly tracking a visual object effectively helps to predict its motion trajectory in space. Human observers tracked or fixated a small visual target with the eyes. In the pursuit condition, the target moved linearly and at a constant velocity towards a stationary vertical line (goal); in the fixation condition, the goal moved towards the stationary target. Presentation duration (200, 600 ms), distance between target and goal (3, 6, 9°), and angular movement direction (90° ± 15°) were varied from trial to trial. Observers had to judge whether the target would hit or miss the goal. Both stimuli were extinguished before the event. Shorter distance of target to goal generally improved prediction performance. Motion prediction during pursuit was not improved by longer presentation duration of target and goal. During fixation, however, performance decreased to chance level for short presentation duration. These results suggest that pursuit eye movements can be advantageous for predicting the trajectory of a moving object in space when motion sampling time is short.

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36.535 Scaling of anticipatory smooth pursuit eye movements with target speed probability

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Anticipatory pursuit allows accurate eye movement initiation with little delay when the target has a predictable behavior, either in its direction, timing or speed. Anticipatory velocity is less extreme when many target speeds are randomly interleaved within a block, compared to anticipatory velocity in a block with a unique target speed (Heinen, S. J., Badler, J. B., & Ting, W. (2005). Timing and velocity randomization similarly affect anticipatory pursuit. Journal of Vision, 5(6), 493-503). We asked how a parametric manipulation of the probability of a given target speed within a block of trials modifies anticipatory eye velocity. We recorded pursuit eye movements of human subjects for targets moving in a fixed direction but with two different speeds in a gap paradigm. Probability of occurrence of a 15 deg/sec speed over a 5 deg/sec one was 0, 10, 25, 50, 75, 90 and 100% in different blocks. Our results showed that mean anticipatory pursuit velocity (evaluated 80 ms after target motion onset) is proportional to the probability of a given target speed within a block, ranging from about 3 to 6 deg/sec from the lowest to highest probability. This result suggests that anticipatory pursuit behavior is built upon a probability-weighted average of different expectations.

We further investigated how different expectations are combined to form a single anticipatory behavior from the point of view of statistical inference modelling. In particular, we compared different models of probability encoding (finite state Markov model and Bayesian integration of evidence) that could underlie the observed anticipatory velocity.

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36.536 Superior colliculus inactivation biases target selection for smooth pursuit, saccades, and manual responses

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Recent evidence implicates the superior colliculus (SC) in the selection of targets for saccades and pursuit, and also the control of covert visual attention. These findings raise the possibility that the SC supports target selection for any kind of response. We have now tested whether the SC supports target selection for manual responses as well as eye movements by reversibly inactivating the SC.

We evaluated target selection using a 2-alternative delayed match-to-sample task, with the target identified by a color cue presented at central fixation. On saccade trials, the target and distracter were presented in opposite hemifields at an eccentricity of 3.5°, slightly above or below the horizontal meridian. On pursuit trials, the stimuli initially appeared at similar locations but moved horizontally towards and across the center of the display. On manual response trials, the monkey viewed stimuli like those on saccade trials, but was required to maintain fixation and respond by button press. Blocks of saccade, pursuit, and manual response trials were interleaved before and after focal inactivation of SC by injection of muscimol (0.5 µl per injection, 5µg/µl).

Focal inactivation of the SC affected manual responses, though somewhat differently than eye movements. When the target was located in the region affected by the inactivation, the percentage of correct responses decreased for manual responses, as well as for saccades and pursuit. However, when the target was located out of the affected region, there was no change for manual responses, although performance improved for both pursuit and saccades.

These results show that SC inactivation causes a selection bias in favor of stimuli located outside of the affected region of retinotopic space, even when it results in an orienting movement towards the affected region (smooth pursuit) or a response that has nothing to do with orienting gaze (button press).

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36.537 **Peripheral motion enhances target selection during smooth pursuit**

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Performance on a detection task during smooth pursuit is improved by peripheral motion which is consistent with the motion of the task stimulus (Watamaniuk and Heinen, 2007). Here, we ask whether consistent peripheral motion can also facilitate saccade target selection during pursuit. The target stimulus comprised five, small (0.2 deg) bright spots arranged in a 'X' configuration with a 7.4 deg diagonal extent. At the beginning of each trial, the target appeared and the observer fixated the center spot. After a random period, the five-spot target began to move at a constant speed (10-30 deg/sec). At a randomly selected time between 100-500 msec, one of the 4 surrounding spots became larger. The observer's task was to saccade to the spot that enlarged. The five-spot target was presented either on a homogeneous, dark background, or in a field of 500 dots of the same diameter, but with slightly lower luminance, moving at the same velocity as the target. Background dots were randomly positioned within a large rectangular aperture but excluded from the target area. The presence of the dot background decreased the latency of saccades in the task, answering our initial question affirmatively. But why? Since shorter latency saccades were not due to improved image stabilization by the dot background, we hypothesized that instead the dot background (when present) controlled pursuit, releasing attention for the saccadic system from the pursuit spot. We asked in particular if attention was completely released by the dot background during pursuit by introducing a temporal gap with the pursuit dot disappearing before target selection. The gap decreased saccade latency whether the dot background was present or not. The results suggest that the dot background releases attention to perform target selection, but that some attention is still used to pursue the spot when it is present.

36.538 **Accuracy and precision of tracking eye movements as a function of age**

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The accuracy of pursuit and optokinetic nystagmus is known to decline with age. However, only a few studies have compared these two types of ocular following in the same observers and those that do confound stimulus size with type of eye movement (small for pursuit, large for nystagmus). Moreover, measures of precision have not been reported, despite the detrimental effect noisy eye movement may have on sensitivity to motion and visual detail. Eye movements were therefore recorded in younger (age 20-34) and older (age 60-82) observers who viewed grating patterns (0.6 cpd) moving at speeds of 4.8, 9.6, 19.2, and 38.4 deg/s. In the deliberate condition, they were asked to 'follow' the gratings and in the reflexive condition, they were asked to 'stare'. Gain was used to assess accuracy by dividing mean eye speed by target speed. Precision was assessed by partitioning motion variability into Drift (standard deviation across a set of slow-phase means) and Shake (median across a set of slow phase standard deviations – the distribution was skewed). This is analogous to partitioning the sums-of-squares in ANOVA. Drift reflects long-term variability across slow-phases. Shake reflects short-term variability within each slow-phase. We found that eye movements were less accurate in older observers by around 10-15%, while drift was similar across age groups. Shake increased with stimulus speed, slightly more so in older observers in the deliberate condition. However, no age-related differences in shake were found in the reflexive condition. A similar experiment using random dot patterns yielded little differences between age groups on any of the measures. This is possibly because features in the dot patterns were easier to track than the repetitive features in gratings. We will also report on how accuracy and precision depend on age for stimuli containing less predictable motion.

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36.539 **Sensitivity to retinal and extra-retinal motion signals as a function of age**

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During smooth pursuit, object motion is often judged by combining estimates of retinal motion with extra-retinal estimates of eye velocity. The latter are thought to be based on motor commands emanating from the eye movement system. Retinal motion sensitivity is known to decline in older observers but little is known about the precision of extra-retinal signals. We therefore measured retinal speed discrimination thresholds using a standard 2AFC technique and compared results to a pursuit condition in which the same stimulus was tracked by eye. The stimulus consisted of dim dots on a black background in a dark room. Using a sample of older (mean age = 67.9) and younger participants (mean age = 22.5), speed discrimination was assessed for standard speeds of 4.8, 9.6, 19.2 deg/s. In the 'fixation' condition, a static fixation point was displayed and participants were asked to judge the motion of the moving stimulus presented for on average 200ms. In the 'pursuit' condition, participants judged the same stimulus motion whilst tracking a pursuit target moving at the same speed as the dot pattern. Experiment 1 replicated previous studies by showing a significant age-related decline in discrimination performance in the fixation condition. Interestingly, we found no difference in the pursuit condition. However, the lack of effect could have resulted from participants using the pursuit target (prior to the dot pattern) as an additional source of information about motion not available in the fixation condition. Experiment 2 resolved this problem by equating duration across the two conditions and also controlling for possible use of retinal slip that could occur before pursuit was initiated. With these controls a similar pattern of results was observed, with the exception that both age groups performed worse in the pursuit condition. These results imply that extra-retinal signals show more resistance to age-related decline.

36.540 **Simultaneously adapting retinal motion and smooth pursuit eye movement in orthogonal directions**

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Adapting to retinal motion yields a motion aftereffect (MAE). An 'extra-retinal' MAE can be obtained when adapting to repetitive pursuit. When the adaptation simultaneously combines retinal motion and pursuit, the resulting direction of the MAE suggests the two types of aftereffect combine vectorially. An alternative is that the direction of the aftereffect is opposite to the motion perceived during adaptation. To differentiate between these two hypotheses, we measured perceived direction of motion during adaptation and during MAE. Stimuli consisted of moving random dot patterns presented centrally (about the pursuit target) or peripherally (10 ° eccentric to the pursuit target). All stimuli were presented in the dark on a black background. The pursuit target executed a sawtooth wave (period 1 s) consisting of constant upward motion ($P = 4$ °/s) and abrupt return. The retinal motion of the dot pattern was horizontal ($R = 4$ °/s). Adaptation consisted of R only, P only or R+P combined. Experiment 1 showed that central and peripheral adaptation produced similar MAE directions. Experiment 2 investigated central adaptation and found that perceived direction during adaptation could not predict the perceived direction during test. Similar results were found in Experiment 3 which investigated adaptation and test in the periphery. As a final test of the vectorial-sum hypothesis, Experiment 4 alternated brief sequences of R and P within a single adaptation. We found that MAE direction was equivalent to the sum of the component MAEs. Overall, these results suggest that MAE following simultaneous adaptation is the vectorial combination of adapted retinal and extra-retinal motion signals.

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36.541 **Influence of perspective and disparity on vergence smooth pursuit**

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We have investigated how perspective and disparity contribute to vergence smooth pursuit eye movements, when following a target's motion in depth (MID). It has previously been shown that vergence is produced in response to both disparity and sufficiently strong size cues, however, only with both cues defining the same MID direction [1]. Here, we varied the two cues so as to also counteract one another to elucidate the relative efficacies of the two cues in driving vergence smooth pursuit eye movements.

The smooth pursuit target was an annulus surrounding fixation (3°-5°), consisting of dynamic or static random dots. The target performed periodic triangular MID with constant velocity (0.4Hz) and was displayed for the duration of one period. The MID was specified by applying changing binocular disparities and changing the size of the target (texture and size changed congruently). We varied the direction of MID defined by changing size while MID defined by disparity remained constant.

Vergence movements followed the changing disparity quite accurately, with an onset latency of 150ms, when both cues defined the same MID direction. However, vergence decreased as a function of the direction of MID defined by changing size. Results were independent of motion amplitude (100, 150 and 200 mm from screen depth). Dynamic dots had a slight negative influence on performance, because both changing size and disparity cues were degraded.

Our results show that both monocular cues and binocular cues significantly contribute to vergence. Although disparity is the main contributor, about 7-35% of vergence could be attributed to perspective.

[1] Erkelens C.J., Regan D., Human ocular vergence movements induced by changing size and disparity, J.Physiol. (1986), 379, pp.145-169

36.542 **Anticipatory Pursuit Is Influenced by a Concurrent Duration Reproduction Task**

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The ability to predict upcoming events is important to compensate for relatively long sensory reaction delays. When stimuli are temporally regular, their prediction depends on an implicit representation of elapsed time. However, it is unclear whether the underlying timing mechanism is separable from a conscious, explicit perception of time, and whether it is shared by different motor effectors. To probe the temporal processing component of prediction, subjects performed an implicit timing task, where they used smooth pursuit eye movements to accurately track a fast-moving target after a constant-duration blank interval. The task was performed either in isolation, or concurrently with an explicit timing task, where a manual response was required at the instant of target motion onset. The onset of anticipatory pursuit eye movements was used to quantify the subject's implicit estimate of elapsed time.

Onset times were delayed significantly in blocks with the concurrent manual task relative to the pursuit task in isolation. During the concurrent task there was also a correlation between the oculomotor and manual response latencies, and both modalities showed an influence of responses from preceding trials. In the framework of the Scalar Expectancy Theory (SET) model, the results are consistent with a centralized attentional gating mechanism that allocates clock resources between explicitly- and implicitly-timed tasks. Model simulations show that slow fluctuations of the attentional gate could account for the observed influence of previous trial responses.

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36.543 **Fixations Gain Reward by Reducing Model Uncertainties**

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Why do we make eye fixations to specific places? The standard account of the locus of fixations has been that constellations of co-located features serve as the targets of gaze [1]. Although it has been suggested that fixation locations may be determined by a surprise measure that calculates whether the distribution of features at a location is unexpected [2], this account is still feature-based.

Our own hypothesis is that task-based reward governs the choice of locations [3]. Numerous studies have established that reward can be seen as the basis of eye fixations via correlations at the neural level, but we have described a completely novel hypothesis: Fixations can reduce uncertainty in the state of a cognitive behavior's control program. We have predicted that, given that the central evaluation is reward-based, eye fixations should be made to the location that promises the most reward for uncertainty reduction. This hypothesis had been tested in a virtual reality simulation with humanoid models and shown to be superior to standard methods.

We now report that our hypothesis has been tested using human subjects' walking data [4]. When subjects walk by approaching pedestrians, they fixate them with a probability that varies predictably depending on ancillary tasks that the subjects are engaged in, such as following a leader. Our reward based model predicts that these variations in probability will have a mean of 0.17 with a standard deviation of 0.03 which is very close to the observed mean of 0.19. The closeness of this fit suggests that the feature-based account of eye fixations may need extensive revision.

1. L. Itti and C. Koch, Nature Reviews Neuroscience, 2001
2. L. Itti and P. Baldi, IEEE CVPR, 2005
3. N. Sprague, D. Ballard and Al Robinson, ACM TAP, 2007
4. J. Jovancevic and M. Hayhoe, JOV, submitted

Acknowledgement: NIH R01 02983

Monday Sessions

Monday, May 12, 8:30 - 10:00 am
Talk Session, Vista Ballroom

Global and Biological Motion

Moderator: David Whitney

8:30 am

41.11 Brain activity evoked by motion direction changes and by global motion coherence shows different spatial distributions

Oliver Braddick[1] (oliver.braddick@psy.ox.ac.uk), John Wattam-Bell[2], Dee Birtles[1,2], Jennifer Loesch[2], Laura Loesch[2], Kathryn Frazier[2], Janette Atkinson[2]; [1]Dept of Experimental Psychology, University of Oxford, UK, [2]Visual Development Unit, Dept of Psychology, University College London

Visual evoked potentials (VEPs) can be generated by the transitions between coherent and incoherent optic flow patterns. These must arise from neural systems that detect global properties of visual motion. The reversal of motion direction of a coherent pattern could activate both global and local motion mechanisms. Here we ask whether VEPs for such motion reversal events have a different source to those for changes in motion coherence.

High-density steady-state VEPs were recorded with a 128-channel geodesic sensor net for dot patterns moving in either concentric circular paths or in uniform translation. Coherence VEPs were elicited by alternation at 2 Hz between patterns of 100% coherent motion and similar dots with random movement directions. Response at the first harmonic frequency was taken as an indicator of global coherence processing (Braddick et al, VSS 2006). Direction-reversal VEPs were elicited by reversal of motion direction in the same patterns at 2 Hz.

Amplitudes of the VEP signals were compared across each of five regions of the posterior scalp. As in previous work (Braddick et al VSS 2006) coherence VEPs were greatest close to the posterior midline of the scalp. Direction-reversal VEPs, in contrast, showed a more lateral focus, with a distribution significantly different on ANOVA from the coherence VEPs.

We conclude that the neural generators of the direction response, local or global, are at least in part different from those for the global coherence response. We will discuss how these results relate to the multiple areas shown to respond to local and global motion in neuroimaging studies, particularly V5/MT and V3A, and to the changes in the location of global coherence responses seen in development.

Acknowledgement: Supported by Research Grant G0601007 from the Medical Research Council

8:45 am

41.12 Biological motion is not identifiable by motion alone

Hongjing Lu[1,2] (hongjing@ucla.edu); [1]Department of Psychology, University of California, Los Angeles, [2]Psychology Department, University of Hong Kong, Hong Kong

Observers readily recognize actions in a dynamic (but not static) point-light display, suggesting that humans may identify biological motion using local motion signals. However, a point-light display provides configural information, albeit impoverished. I report two experiments using a novel stmulus with masks across apertures, demonstrating that when configural information is entirely eliminated, local motion information is insufficient to identify biological motion.

Participants were asked to identify walking direction of a human behind apertures. The stimulus consisted of 729 Gabor (drifting sine-wave gratings). Drifting velocity of Gabor was determined by a specified 2D motion of each element. Foreground elements lay on the trajectory of the walker; background elements off it. In Experiment 1, orientations of gratings were randomly assigned, eliminating configural information. When foreground Gabors drifted in the velocity consistent with 2D walker motion but background Gabors drifted randomly, participants were completely unable to identify walking direction (51% correct). Control conditions in which 2D motion of all background Gabors were the same (creating perception of a coherently moving background) yielded high accuracy (91%). Experiment 2 replicated the chance-performance condition of Experiment 1 but added configural information. Orientations of foreground Gabors were randomly assigned following a uniform distribution centered at the body structure orientation. Performance improved to 62%, 73%, 98% when the distribution range was ±80°, ±40°, ±10°, respectively. Biological motion is thus identifiable after adding even a small amount of noisy configural information.

Furthermore, randomizing 2D motion in foreground elements did not affect identification performance in both experiments. Similar results in Experiment 1 were also obtained using Plaids (two superimposed Gabors with orthogonal orientations), despite their reduced local motion ambiguity compared to Gabors. These findings suggest that local motion information serves to segment foreground against a noisy background, but additional configural information is necessary to identify biological motion.

9:00 am

41.13 fMRI reveals distinct processing of form and motion features in biological motion displays

Jan Jastorff[1] (jan.jastorff@med.kuleuven.be), Guy A. Orban[1]; [1]Laboratorium voor Neuro- en Psychofysiologie, K.U.Leuven, Medical School, Leuven, Belgium

Functional imaging experiments have implicated several visual cortical areas in the recognition of biological motion stimuli (review by Giese and Poggio 2003). In order to identify the contribution of these areas to the perception of point-light displays, we conducted two human fMRI experiments using each a 2x2 factorial design.

The point-light stimuli consisted of twelve white dots presented on a black background, displaying leftward and rightward walking human figures.

In the first experiment, one factor manipulated the global form of the stimuli by spatially scrambling the starting position of each dot. The second one modified the kinematics of the stimuli by changing the trajectory of each individual dot to simple translation. In the second experiment, the first factor degraded local opponent motion by presenting the points belonging to one side of the human body twice, moving in phase. The second factor kept the local opponent motion intact but degraded coordinated limb movement by spatially scrambling the starting position of the dots in y-direction.

Random effects analysis over 17 subjects showed that within cortex activated by biological motion, activity increasingly differentiated between the conditions starting from the Lateral Occipital Sulcus via the Middle Temporal Gyrus being most specific for point-light walker in the Fusiform Gyrus. Moreover, we found a clear dorsal / ventral segregation of form and motion processing. While more ventral areas showed a main effect of form and to a lesser extend of opponency, more dorsal areas exhibited an interaction between form and motion or a main effect of motion.

These results indicate a prominent role of the fusiform areas in processing of biological motion. Furthermore, they are in close correspondence with monkey electrophysiology, defining two classes of neurons (“snapshot” - and “motion” neurons) in the lower and upper bank of the STS respectively (see VSS abstract Vangeneugden et al, 2008).

Acknowledgement: supported by Neurocom, EF 05/014, IUAP 05/04

9:15 am

41.14 Neural bases of visual motion perception deficits in autism

Kami Koldewyn[1,3,4] (kkoldewyn@ucdavis.edu), David Whitney[2,3], Susan Rivera[2,3,4]; [1]Neuroscience Graduate Group, University of CA, Davis, [2]Department of Psychology, University of CA, Davis, [3]Center for Mind and Brain, University of CA, Davis, [4]M.I.N.D. Institute, University of CA, Davis

Quick, accurate biological motion perception is fundamental to our understanding of the visual social world. Recent evidence has suggested that people with autism may show a selective deficit in visual motion processing. If biological motion perception is impacted in this group, it could significantly contribute to their deficits in social cognition and reciprocity. We investigated coherent and biological motion processing deficits in those with autism, as compared to a matched control sample, employing both psychophysical and fMRI paradigms. Using the method of constant stimuli, we measured coherent motion, biological motion, and global form detection thresholds. Coherent motion was measured with random-dot displays where coherence was varied through a standard "random-walk" manipulation. Biological motion displays were point-light depictions of a person walking embedded in moving dot displays whose coherence was varied. Global form perception stimuli were static glass patterns whose coherence was varied based on the percentage of dots aligned along a global form. As a group, those with autism showed both higher coherent and biological motion thresholds while matching control group performance on the coherent form task. The autism group also showed reduced MT+, STS and parietal area activation during in-scanner versions of coherent and biological motion tasks while showing similar levels of activation in V1. Additionally, activation in MT+ and STS in control individuals steadily increased with increasing directional motion or biological motion coherence. No consistent relationship between psychophysical and neural responses was evident in data from the autism group. These results provide evidence for a selective impairment in psychophysical and neural processing of visual motion in individuals with autism.

Acknowledgement: This work was supported by a mentor-based pre-doctoral fellowship from Autism Speaks (SR)

09:30

41.15 Phantom flow parsing: Global visual compensation for observer movement-entrained retinal motion

Paul Warren[1] (warrenpa@cardiff.ac.uk), Simon Rushton[1]; [1]School of Psychology, Cardiff University

We have recently suggested that optic flow arising due to observer movement is parsed from the retinal image (e.g. Rushton & Warren, 2005, Current Biology, 15, R542-3). It is proposed that this flow parsing process is involved in segmenting the visual scene into moving and scene-stationary objects during observer movement. Here, we present a strong test of this hypothesis and demonstrate that flow parsing depends on global optic flow processing.

Observers (monocularly) fixated the centre of limited lifetime radial flow displays consistent with forwards movement through a cloud of dots. Dots were presented in the upper hemifield, the lower hemifield or both. Simultaneously, a horizontally moving probe was presented at different distances (2 or 4cm) above or below fixation. Observers were then asked to indicate perceived probe trajectory using an adjustable onscreen paddle. Flow parsing predicts that the radial flow will be parsed from the retinal image, and this process will affect perceived probe trajectory. Specifically, in this case, parsing should add an additional perceived downwards component when the probe is above fixation (and vice versa) and its magnitude should increase with distance from fixation. Furthermore, if flow parsing relies upon global visual processing then perceived trajectory should be consistent with these predictions regardless of whether motion is present in the same hemifield as the probe. The results confirm these predictions. By analogy to previous findings on 'phantom motion after-effects' (Snowden & Milne, 1997, Current Biology, 7, 717-722) in which a motion after effect was seen to transfer between adapted and non-adapted regions of the visual field, we say the latter result is due to phantom flow parsing.

These results contribute to a growing body of evidence for a purely visual mechanism, reliant upon optic flow processing, involved in the perception of scene-relative object movement during self movement.

09:45

41.16 Human-Assisted Motion Annotation for Real-World Videos

Ce Liu[1] (celiu@mit.edu), Edward Adelson[1,2], William Freeman[1]; [1]Computer Science and Artificial Intelligence Laboratory (CSAIL), MIT, [2]Department of Brain and Cognitive Sciences, MIT

The computations of the human visual system are presumably well matched to the statistics of natural scenes. What are those statistics? It would be appealing to analyze massive amounts of imagery with machine vision systems. However, it is often preferable to hand-label images for the variables of interest since humans are far more accurate than machines. Useful hand-labeled databases include the continuity of contours (Geisler et al., 2001) and the segmentation of images (Martin et al., 2001). We wish to analyze motion in natural image sequences. Hand labeling motion sequences provides a serious challenge. The sheer number of pixels is vast, and assigning a velocity to every pixel in every frame would drive away even the most patient labeler. Based on recent computer vision techniques, we have designed a computer system for efficient motion annotation. The image sequence is represented as a set of overlapping layers, each with smooth motion. The observer marks the boundary and provides a depth ordering of each object in a given frame. The computer system propagates the layer annotation to the other frames and estimates a set of flow fields. The user picks the best flow field that yields accurate matching between two adjacent frames and agrees with the smoothness and discontinuities of the image. When flow estimation fails, the user can label sparse correspondences between two frames, which the system automatically interpolates to a dense correspondence. We find that the mean absolute deviation of eight subjects' annotations of one sequence is around 0.1 pixels, and the human labeled motion of a sequence with veridical ground truth also has a mean error of around 0.1 pixels. We have labeled 20 video sequences with plans to label hundreds more. This will provide a useful motion database for researchers in both human and machine vision.

Monday, May 12, 8:30 - 10:00 am
Talk Session, Royal Palm Ballroom 4-5

Attention to Objects and Scenes

Moderator: Marlene Behrmann

8:30 am

41.21 Object-Based Attention: Beyond Gestalt Principles

Xingshan Li[1] (xingshan.li@vanderbilt.edu), Gordon D. Logan[1]; [1]Department of Psychology, Vanderbilt University

Though much evidence supports object based attention, how an object is defined is still uncertain (Logan, 1996). Most work on object based attention uses bottom-up factors to define objects. In a classical demonstration, Egly, Driver, Rafal (1994) used two parallel rectangles arrayed horizontally or vertically, to contrast space-based and object-based attention. In a critical comparison of the invalid cue conditions, they found that RT was faster when the target was in the cued rectangle than when the target was in the other rectangle, though the distance from the cue and the target was the same in these two conditions.

Using the same paradigm as that used in Egly et al. (1994), we found an object-based attention effect when the objects were defined top-down by Chinese words. We presented four Chinese characters spaced equally in the four corners of a square to control bottom-up organization. Each display contained two two-character words, arrayed horizontally or vertically. We cued one of the characters and presented a test probe in the cued location (cue valid) on 75% of the trials. On 25% of the trials, the probe appeared in an invalid location in the same word or in the other word. If skilled Chinese readers perceived these words as objects, RT on cue-invalid trials should be shorter when the target is in the cued word than when it is in the other word. The results confirmed this hypothesis. RT on cue-invalid trials was shorter when the target was in the cued word than when it was in the other word. Since we controlled for bottom-up organization, our results show that top-down factors alone can define objects and constrain the deployment of attention.

Acknowledgement: This research was supported by grant number R01-MH073879-01 from the National Institute of Health and by grant number FA9550-07-1-0192 from the Air Force Office of Scientific Research.

8:45 am

41.22 A Model of Top-Down Control of Attention during Visual Search in Real-World Scenes

Alex Hwang[1] (baquibul@gmail.com), Marc Pomplun[1]; [1]University of Massachusetts at Boston

Recently, there has been great interest among vision researchers in devising computational models that predict the distribution of saccadic endpoints in naturalistic scenes (e.g., Itti & Koch, Vis. Res. 2000, Bruce & Tsotsos, NIPS 2006). In these studies, subjects are instructed to view the scenes without any particular task in mind so that stimulus-driven (bottom-up) processes guide visual attention. However, whenever there is a task, additional goal-driven (top-down) processes play an important – and most often dominant - role. Pomplun (Vis. Res. 2006) showed that during visual search in real-world scenes, attention is systematically biased towards image features that resemble those of the search target. Therefore, in order to understand and predict attentional selection in real-world scenes, we need to have a computational model of top-down attentional control in addition to existing bottom-up models.

In the present study, we devised such a top-down model based on three basic principles: First, visual similarity between the search target and local image portions for several stimulus dimensions is defined using a histogram-matching technique. Second, the informativeness of these dimensions for a given search display is computed as an entropy-related function of the target-similarity "landscape". Third, as suggested by previous studies (Pomplun, 2006; Shen, Reingold & Pomplun, Percept. 2000), more informative dimensions are assumed to have a greater influence on attentional selection in visual search. The relative importance of each stimulus dimension and its dependence on informativeness is obtained from empirical eye-movement data. We tested the model by having it predict the distribution of saccadic endpoints in another experiment using real-world search displays. The predicted distributions revealed a strong similarity to the empirically observed ones, indicating that the model identifies the most important factors contributing to top-down attentional control in visual search.

This project was supported by Grant Number R15EY017988 from the National Eye Institute.

9:00 am

41.23 Natural Image RSVP task performance is predicted by measurements of bottom-up Bayesian Surprise exhibited by image sequences

Terrell Mundhenk[1] (mundhenk@usc.edu), Wolfgang Einhäuser[2], Laurent Itti[3]; [1]Department of Computer Science, University of Southern California, [2]Institute of Computational Science, Swiss Federal Institute of Technology (ETH), [3]Department of Computer Science, University of Southern California

The performance of observers on a Rapid Serial Vision Protocol (RSVP) task is causally linked with the amount of bottom-up Bayesian Surprise (buBS) exhibited by both target and distracter images in RSVP sequences. In this paradigm, observers watched a sequence of 20 images at 20Hz. One of the images in the sequence might contain a picture of an animal target at chance. Subjects had to respond as to whether or not they spotted the target. Observers' performance was compared with the amount of buBS images in the sequence exhibited. The buBS information metric defined by (Itti and Baldi 2005; Itti and Baldi 2006) gives a measure of the amount of information gain both within an image (between image locations) and between images. Using the coarse statistics of buBS we were able to alter the performance of observers on an RSVP task by changing the order of images within a sequence. Placing images of high surprise both before and after the target image impairs the ability of observers to recall the target(Einhäuser, Mundhenk et al. 2007). Here we show coarse statistics for buBS in both color and Gabor orientations is significantly different between RSVP sequences observers find easy (subjects tend to spot the target correctly) compared with ones that observers find difficult. In particular, course statistics for mean buBS are elevated in the flanking images before and after the target in difficult RSVP sequences. Further, buBS is significantly different in some features such as vertical lines as much as 250ms before the target image with a relaxed period 100ms before the target. This lends support to the two stage model of visual processing (Chun and Potter 1995). Additionally, we can use the buBS statistics to inform us of the amount of bottom-up attention capture intrinsic in images in RSVP sequences.

URL: http://ilab.usc.edu

9:15 am

41.24 A new masking technique for natural scenes reveals the saliency of an image

Claudia Wilimzig[1] (claudia@klab.caltech.edu), Rufin VanRullen[2], Christof Koch[1]; [1]California Institute of Technology, Div of Biology, Pasadena, CA, [2]CNRS Toulouse, France

Masking is a key experimental tool to precisely control the visibility of visual stimuli. We explore a new technique for masking images, in particular natural scenes: briefly flashing (e.g., 10 ms) a natural scene followed by a brief flash of a negative version of the same scene. The stimulus and its negative version are inversely related like a photo and its negative and can be obtained by subtracting the stimulus from the maximum palette entry in each respective color channel. This technique is related to experiments showing that for two differently colored lights flashed subsequently, people report a blended version of both stimuli as if the process underlying perception integrates over both stimuli (Efron, 1967). If the visual system perfectly averaged over stimulus and mask, subjects would report seeing a uniform gray patch. Contrariwise, in some areas of the picture subjects reported deviations from mere gray perception. We show (1.) that these areas are systematically related to predictions of computational approaches to saliency (Itti & Koch, 2001, e. g.) such that our masking technique masks everything but the most salient regions of the image; (2.) that this effect cannot be achieved by using standard masking techniques or no masking; (3.) that this masking effect is weakened but not abolished in a dichoptic version of the experiment.

These results have significant implications for the neuronal coding of saliency and for computational approaches to saliency. In particular, we show that a simple thresholded wavelet transform, computing local contrast intensities with positive and negative values corresponding to two different polarities (ON- and OFF-center cells), corresponds to people's percepts. Given the similarities between percepts and saliency maps, this may provide an alternative, and less costly, tool for computational approaches to saliency.

Acknowledgement: ONR, NGA, Alexander von Humboldt foundation

9:30 am

41.25 The scope of social attention deficits in autism: Prioritized orienting to people and animals in static natural scenes

Joshua J. New[1] (joshua.new@yale.edu), Robert T. Schultz[2], Julie Wolf[2], Jeff L. Niehaus[3], Ami Klin[2], Brian J. Scholl[1]; [1]Department of Psychology, Yale University, [2]Child Study Center, School of Medicine, Yale University, [3]Department of Psychology, UC Santa Barbara

A central feature of autism spectrum disorder (ASD) is an impairment in 'social attention' -- prioritized processing of socially-relevant information. For example, people with ASD do not show the same visual interest in (and biased processing of) the eyes and face. Beyond such specific cues, however, socially relevant stimuli are preferentially attended in a broader categorical sense: in particular, observers orient preferentially to people and animals (compared to inanimate objects) in complex natural scenes (New, Cosmides, & Tooby, 2007, PNAS). To determine the scope of social attention deficits in autism, we explored whether this bias was evident in people with ASD (both children and adults, with IQs ranging from 56 to 140). In each trial, observers both with and without ASD viewed alternating versions of a natural scene, and had to 'spot the difference' between them. This difference involved either an animate object (a person or animal) or an inanimate object (a plant or artifact) that either reversed its orientation or repeatedly disappeared and reappeared. Participants were not made aware of these categories, and change detection performance (in terms of both speed and accuracy) was measured as an index of automatic attentional prioritization. Control participants without ASD showed prioritized attention to people and animals, replicating previous work. This could not be explained by lower-level visual factors, since the effect disappeared when using blurred or inverted images. Our primary discovery was that individuals with ASD also showed the same prioritized social attention for animate categories. This prioritized social attention increased slightly with age, and was generally unrelated to their clinically-evaluated social abilities. These results suggest that social attention -- and its impairment in autism -- is not a unitary phenomenon: specific impairments in processing faces and eyes may occur despite the intact categorical prioritization of visual social information.

URL: http://www.yale.edu/perception/

09:45

41.26 Selectivity for faces as exogenous attentional cues

James H. Elder[1] (jelder@yorku.ca), Dahlia Y. Balaban[1], Aryan Kamyab[1], Laurie Wilcox[1], Yuqian Hou[1]; [1]Centre for Vision Research, York University

In the standard exogenous cueing paradigm, a peripheral visual pre-cue affects the time to detect a subsequent peripheral target. This exogenous attention effect is thought to be a reflexive process based on simple properties of the cueing stimulus. This is complicated somewhat by recent experiments in which human faces are used as pre-cues, and their effects depend upon facial expression. These results have been interpreted in terms of a reflexive process selective for threat-related signals. Here we examine whether exogenous cueing may be based on more general ecological principles, by comparing the efficacy of human face pre-cues with random-phase controls. The target was a bright 0.25 deg disk. The face cues were 2 deg natural images of faces with neutral expressions. The control cues had identical amplitude spectra but randomized phase. The intensity, hue and saturation of the face images and their controls were matched in both mean and variance. Subjects were asked to maintain fixation on a central cross. After 500 msec, a cue was flashed for 20 msec, 8 deg randomly to the left or right of fixation. Following a variable SOA, the target was displayed 6 deg randomly to the left or right of fixation until response. The location of the cue was not predictive of the location of the target. 45 observers each completed 960 randomly-interleaved trials. Faces were found to be significantly more effective as exogenous attentional cues than random-phase controls. Interestingly, this effect was lateralized in the invalid-cue condition. Specifically, the effect of an invalid face cue was significantly less pronounced when the cue was presented in the left hemifield and the target was presented in the right hemifield, than vice-versa. This finding can be interpreted in terms of a specialization for faces in the right hemisphere of the human brain.

Acknowledgement: Supported by NSERC and the PREA

Monday, May 12, 10:30 am - 12:15 pm
Talk Session, Vista Ballroom

Spatial Vision: Natural Scene Statistics

Moderator: Melanie Palomares

10:30 am

42.11 The parvo and magno-cellular systems encode natural image statistics parameters

H.Steven Scholte[1] (h.s.scholte@uva.nl), Sennay Ghebreab[2], Arnold Smeulders[2], Victor Lamme[1]; [1]Department of Psychology, University of Amsterdam, [2]Intelligent Systems Lab Amsterdam, University of Amsterdam

Natural images are highly structured in their spatial configuration. It has been shown that the distribution of contrasts of natural images is almost always adequately described by a Weibull type distribution (Geuseboek & Smeulders, 2003) in which 2 free parameters are fitted. These 2 parameters appear to structure the natural image space in a highly meaningful way. Here we examined to which degree the brain is sensitive to these parameters by covarying the ERP responses of subjects viewing 1599 natural images with these 2 parameters. The fitted parameters explained 50% of the variance of the early ERP signal, contrasting sharply with more traditional contrast measurements like Fourier, Michelson and RMS, which explained only 5-20% of the ERP variance. In addition, we found a correlation of 0.84% and 0.93% between the two parameters of the Weibull type distribution fit and a model of the parvo- and magnocellular system. Both observations suggest that the parvo- and magnocellular system evolved, amongst others, to estimate these parameters.

10:45 am

42.12 The temporal properties of contrast adaptation are matched to the statistics of illumination change in the natural world

Roland Baddeley[1] (roland.baddeley@bristol.ac.uk), David Attewell[1]; [1]Department of Experimental Psychology, Bristol University

Within the real world, surface reflectance varies over a very limited range. Illumination, however, can vary over many orders of magnitude. The luminance signal we receive from the environment is the product of these two variables, prompting the question; how does vision go about extracting the behaviourally important surface reflectance signal from the larger but less relevant illuminant? A possible solution could be to use a method of contrast adaptation whereby the incoming luminance signal is scaled based on the temporally averaged (log) input. Here we investigated; 1) how well this simple lightness constancy mechanism could work in the real world, 2) whether the optimal (log-linear) system for extracting reflectances has temporal parameters that match those observed behaviourally, 3) whether an exponential temporal weighting function (a Kalman filter) worked better than a power law impulse response, as has been suggested in the literature, and 4) whether the nature of a full Bayesian solution to this problem could shed light on how previous contrast exposure can change the temporal properties of contrast adaptation. To this end we measured, over 6 days, the illuminant incident on a person walking in a number of environments. Assuming three eye movements per second, and exposure to a distribution of reflectances measured within a forest environment, we were able to create luminance time series for which the actual series of reflectances that generated them were known. Using this data set we found that; 1) contrast adaptation greatly improves signal to noise ratio, 2) the best exponential time constant was 8 seconds and this matches the behavioural data, 3) an exponential weighting function is better than a power law; and 4) a full Bayesian solution functions better still, adaptively changing its time constant over a time scale of about 20 seconds.

11:00 am

42.13 Sensitivity to Spatial Distortion in Natural Scenes

Peter Bex[1] (peter.bex@schepens.harvard.edu); [1]Schepens Eye Research Institute, Harvard Medical School

Objective: The visual field generally appears veridical and undistorted in spite of variations in retinal projection and our poor sensitivity to spatial form in crowded peripheral vision. Here I measure sensitivity to spatial distortion to examine the accuracy of visual representation.

Methods: Spatial distortions were generated within one quadrant of large natural scenes, pink noise or phase-randomized natural scenes. The transition from undistorted to distorted regions was smoothed with a Gaussian window. The period of distortion was varied between 0.25-16 c/deg using band-pass filtered noise, newly generated each trial, to control the spatial displacement of remapped pixels. The magnitude of distortion was under the control of a staircase to generate distortion Modulation Transfer Functions (dMTFs). The observer was required to indicate which quadrant contained the distortion in a 4AFC task with feedback.

Results: Sensitivity to spatial distortion decreased with eccentricity (measured out to 8 deg) and required deformations as high as 2 deg. For natural scenes, dMTFs were band-pass with a peak for distortions over 1 c/deg. Sensitivity to distortions within pink noise or phase-randomized natural scenes was much higher and dMTFs for these stimuli were low-pass.

Conclusions: The fact that sensitivity is higher for random phase images suggests surprisingly that the presence of edges and contours in real scenes masks the presence of distortions. The 1 c/deg peak in dMTFs suggests that contour-finding processes prefer orientation changes within around 1 deg. Overall, humans are extremely insensitive to spatial distortions in natural scenes, suggesting that, like the perception of blur, the appearance of veridical visual space is entirely an illusion.

Acknowledgement: The Wellcome Trust

11:15 am

42.14 The attentional blink does not disrupt computation of the mean size

Sung Jun Joo[1] (sjjoo@yonsei.ac.kr), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Is statistical processing in vision immune to attentional constraints? To answer this question, we manipulated attentional resources engaged in statistical processing in visual arrays. An adapted attentional blink (AB) paradigm, in which a mean size judgment task was given as the second target (T2) and a digit was the first target (T1), was used to investigate observers' ability to compute mean sizes of visual arrays inserted in fast visual stimulus streams. This paradigm enabled us to test whether observers' performance on mean size judgments would depend on reporting T1 (dual task requiring the report of both T1 and T2 vs. single task requiring the report of T2 only) and on time lag between T1 and T2. Surprisingly, mean size computation was not susceptible to limited attentional resources: neither dual-task interference nor performance drop at short lags was evident. To make sure we engaged attentional resources sufficient for the AB in our paradigm, we used single size judgments instead of mean size judgments in the same paradigm and tested if single size judgments were susceptible to attentional constraints in our procedure. The results show single size judgments were influenced by both dual-task interference and time lag. Furthermore, even when we presented a random-dot mask following visual arrays for mean size judgments as substitution masking, no evidence of the AB was found. These findings indicate our paradigm is sufficient to manipulate attentional resources and in turn, statistical processing in visual arrays is indeed immune to attentional constraints.

Acknowledgement: This work was supported by the Korea Research Foundation Grant funded by the Korean Government (MOEHRD) (KRF-2007- 101039003-2007-8-0746)

11:30 am

42.15 Visual evoked potentials for dynamic Glass pattern perception in 4-5 month old infants

Melanie Palomares[1] (mcp@ski.org), Mark Pettet[1], Vladimir Vildavski[1], Chuan Hou[1], Anthony Norcia[1]; [1]The Smith-Kettlewell Institute, San Francisco, CA

Glass patterns are moirés created from a sparse random dot field paired with its rotated, expanded or translated copy. Because discrimination of these patterns is not based on local features, they have been used extensively to study global integration processes. Here, we investigated whether 4-5 month old infants (n=16) are sensitive to the global structure of "dynamic" Glass patterns by measuring Visual Evoked Potentials across the occipital pole. Dynamic Glass patterns are static Glass patterns that are sequentially-presented, and induce a strong illusion of motion. We presented circular Glass patterns that were globally updated at 1.0 Hz (That is, the organized pattern was presented for 500 ms then followed by random pattern for 500 ms). The dot pairs were 6.4 x 6.4 min white squares with a 25.6 min separation presented on a black background, and were locally updated at 20 Hz. Although we found strong sensitivity to the appearance of the local dots, we found no evidence for sensitivity to the global structure of the dynamic Glass patterns in the infants. When we connected the dot pairs of the Glass pattern with lines, we observed a significant difference between organized- versus randomized-field responses. We also recorded strong differential responses to organized versus randomized arrays of Gabor patches. Together our results suggest that the insensitivity to structure in conventional Glass patterns is at least partially due to inefficiencies in extracting the local orientation cues generated by the dot pairs. Once the local orientations are made unambiguous, infants can integrate these signals over the image.

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11:45 am

42.16 A visual sense of number

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Evidence exists for a non-verbal capacity to apprehend number, in humans (including infants), and in other primates. We investigated numerosity perception in adult humans, using the psychophysical techniques of adaptation. Adapting to large numbers of dots increased apparent numerosity (by a factor of 2-3), and adapting to small numbers increased it. The magnitude of adaptation depended primarily on the numerosity of the adapter, not on size, orientation or contrast of test or adapter, and occurred with very low adapter contrasts. Varying pixel density had no effect on adaptation, showing that it depended solely on numerosity, not related visual properties like texture density. We propose that just as we have a direct visual sense of the reddishness of half a dozen ripe cherries so we do of their sixishness. In other words there are distinct qualia for numerosity, as there are for colour, brightness and contrast, not reducible to spatial frequency or density of texture.

Acknowledgement: Supported by AUstralian ARC

12:00 pm

42.17 The visual system removes sensory noise from the representation of a texture

Michael Morgan[1] (m.morgan@city.ac.uk), Charles Chubb[2], Joshua Solomon[1]; [1]Optometry & Visual Science, City University London, [2]Cognitive Science, University of California Irivine

A texture consisting of elements all having the same orientation looks uniform despite the known presence of early sensory noise. To account for this paradox, we suggest that the visual system discounts the presence of its own noise, in the same way that it discounts normal amounts of optical blur in the retinal image. The mechanism for this discounting is a sensory threshold, which stops texture elements apparently departing from the texture mean unless they exceed a fixed threshold. We sought further evidence for this thresholding by measuring the just-noticeable difference (JND) in orientation variance between two textures as we varied the baseline (pedestal) variance present in both textures. We found the best discrimination when a small amount of variance was present in both textures, as would be predicted from a threshold.

Acknowledgement: BBSRC (UK)

URL: http://www.staff.city.ac.uk/~solomon/pubs/AdaptDiscrimination9.pdf

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Monday, May 12, 10:30 am - 12:15 pm
Talk Session, Royal Palm Ballroom 4-5

Visual Memory

Moderator: Shaul Hochstein

10:30 am

42.21 Memory Mechanisms for Familiarity Recognition and Identification

Shaul Hochstein[1] (shaul@vms.huji.ac.il), Volodya Yakovlev[1], Sandro Romani[2], Daniel Amit[3]; [1]Neurobiology Dept., Life Sciences Institute & Interdisciplinary Center for Neural Computation, Hebrew University, Jerusalem, Israel, [2]Dip. di Fisiologia Umana, Univ. di Roma La Sapienza, Roma, Italy, [3]deceased - Racah Institute of Physics, Hebrew University & Dip. di Fisica, Univ. di Roma La Sapienza, Roma, Italy

Encountering someone on the street, we can often say whether their face is familiar, though it may be difficult to identify the person: Familiarity memory may differ essentially from identification, which embeds and generates contextual information. We studied multiple stimulus memory in macaque monkeys using a modified delayed-match-to-sample task. In each trial, a sequence of 1-6 different images served as samples, followed by a match stimulus – a repetition of any of the samples (the cue). Sequence length and cue position were randomized. Repetition recognition entailed holding all sequence images in memory. For Experiment 1, we used 16 images. Miss errors, (failures to detect repetitions), increased with cue-match separation. False positives (FP; erroneous reports of a repetition), increased with trial duration. Overall, Hits reached 83% with 3.2% FP. For Experiment 2, we used 12,000 novel images; all stimuli were "Novel", except the final match and a number of images introduced as "catch" trials. Unexpectedly, performance was better than with well-trained stimuli, reaching 91% Hits, 2.6% FP. We suggest that monkeys use delay-activity working-memory for well-trained stimuli and a new strategy, based on modulated responses to repeated images, for Novel stimuli. The low FP rate suggests a between-trial memory reset mechanism. These results imply extremely effective one-shot learning of familiarity, resembling Standing's (1973) finding that people detect familiarity for 10,000 once-seen pictures (with 80% accuracy).

How is this immense memory established and maintained? We present a generic, simple neural network model, with coupled neural and synaptic dynamics, quantitatively simulating these behaviors, based on the same conservative Hebbian synaptic plasticity that generates delay-activity identification memory. Familiarity becomes the first step toward establishing identification. An inter-trial reset limits FP for previous-trial images. The model relates repetition and familiarity recognition with enhanced neural activity, as experimentally observed in most differentially responding prefrontal cortex neurons.

10:45 am

42.22 Remembering Thousands of Objects with High Fidelity

Talia Konkle[1] (tkonkle@mit.edu), Tim Brady[1], George Alvarez[1], Aude Oliva[1]; [1]Brain and Cognitive Sciences, MIT

Although people can remember a massive number of pictures (e.g.10,000 in Standing, 1973), the fidelity with which human memory can represent such a large number of items has not been tested. Most researchers in visual cognition have assumed that in such studies, only the gist of images were remembered and the details were forgotten. We conducted two large-scale memory experiments to determine the details remembered per item, by systematically varying the amount of detail required to succeed in subsequent memory tests. In the first study, 2500 conceptually distinct objects were presented for 3 second each. Afterwards, observers reported with remarkable accuracy which of two items they had seen when the foil was a categorically-novel item (92%), an item of the same basic level category (87%), or the same item in a different state or pose (87%). In the second study, 2560 items were presented and the number of exemplars presented from each category varied from 1 to 16. Observers reported which exemplar they had seen for categories with 1 previously viewed exemplar (87%) and maintained high accuracy even for categories with 16 previously viewed exemplars (80%). Thus, contrary to the commonly accepted view that long-term memory representations contain only the gist of what was seen, we demonstrate that long-term memory can store thousands of items with a large amount of detail per item. Further, item analyses reveal that memory for an object depends on the extent to which it is conceptually distinct from other items in the memory set, and not on the featural distinctiveness along shape or color dimensions. These findings suggest a "conceptual hook" is necessary for maintaining the large number of high-fidelity memory representations, and imply that the precision of visual content in long-term memory is determined by conceptual and not perceptual structure.

11:00 am

42.23 Neural evidence of statistical learning: Incidental detection and anticipation of regularities

Nicholas B. Turk-Browne[1] (nicholas.turk-browne@yale.edu), Marcia K. Johnson[1], Marvin M. Chun[1], Brian J. Scholl[1]; [1]Department of Psychology, Yale University

Our environment contains many regularities distributed in space and time that can be detected by way of statistical learning. This unsupervised learning occurs without intent or awareness, but little is known about its component processes, how it manifests over time, or how it relates to other types of learning. Here we use fMRI as a measure of statistical learning to explore these questions. Participants viewed short blocks of novel shapes appearing one at a time, while performing a motion-detection cover task. The underlying sequence of shapes constituted our primary manipulation. Structured blocks contained deterministic sub-sequences of shapes. Random blocks lacked this structure but were otherwise identical. Sensitivity to statistical structure was assessed by comparing fMRI responses to these two block types. This approach resulted in several discoveries about the nature of statistical learning. (1) Robust neural responses to statistical structure were observed during learning, despite weak subsequent explicit familiarity judgments -- indicating the utility of fMRI as a measure of statistical learning. (2) This neural evidence of learning emerged after surprisingly little exposure -- as made possible by our use of an online measure of learning. (3) The brain regions that were sensitive to statistical structure overlapped with those underlying other well-studied forms of learning and memory -- helping to characterize the nature of the component processes that support statistical learning. (4) Responses to statistical structure were also observed in visual cortical regions -- suggesting that these regions are sensitive to temporally contiguous relations in addition to static visual features. (5) Several regions involved in reflective processing exhibited enhanced responses to the beginnings of deterministic subsequences -- suggesting that anticipation per se need not be conscious, and may be a natural perceptual process. Collectively, these results emphasize both the power of statistical learning and its integration with other cognitive processes.

URL: http://www.yale.edu/perception/

11:15 am

42.24 The neural basis of implicit short-term memory: TMS investigations of visual priming

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Repeated presentation of the same or similar visual stimuli can improve the speed of detection or discrimination of those stimuli. This phenomenon, called visual priming, is due to an implicit short-term memory mechanism that can operate at the level of object features and by means of the activity of functionally specialised low-level visual areas. Despite a number of studies attempted to uncover the neural basis of visual priming, only recent TMS experiments could establish a causal role of specific extrastriate cortical areas in the generation of priming. A new TMS paradigm was implemented for interfering with the functional integrity of circumscribed portions of cortex during the inter-stimulus interval, so when the subject was basically idle. The rationale was that, if the targeted area was responsible for holding in memory the priming information from one trial to the next one, that information could be cancelled by TMS during the inter-stimulus interval and therefore priming would not take place. In this way it was possible to show that area V5/MT, known to be involved in motion perception, is also crucial for the generation of priming of motion direction (Campana et al., 2002, 2006). On the other end, left frontal eye field (lFEF), known to be involved in spatial cognition and saccade preparation, is also responsible for priming of spatial position (Campana et al., 2007). Finally, monkey studies showed that lesions of visual areas V4 and TEO, that have a major role in colour processing, impair colour priming (Walsh et al., 2000). Indeed, as postulated by the Perceptual Representation System hypothesis (PRS: Tulving & Schacter, 1990), these data suggest that the same visual areas involved in the representation of simple stimulus attributes such as colour, orientation, motion or spatial position, are also be responsible for the implicit short-term memory expressed by visual priming.

11:30 am

42.25 Increases in gamma-band activity do not predict spatial working memory retention in macaque monkeys

Geoffrey Woodman[1,2,3] (geoff.woodman@vanderbilt.edu), Min-Suk Kang[1,2,3], Rebecca St. Clair[1,2,3], Jeffrey Schall[1,2,3]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center, [3]Center for Integrative & Cognitive Neuroscience

It has been hypothesized that gamma-band oscillations (e.g, 25-80 Hz) of the electroencephalogram (EEG) support the active maintenance of representations in working memory. Consistent with this hypothesis, gamma-band activity has been reported during the retention interval of visual working memory tasks in humans. In the present study, we tested this hypothesis by recording EEG from surface electrodes on macaque monkeys during the memory retention of locations in the memory-guided saccade task. We found a decrease in gamma power evoked by the onset of the memory stimulus. However, the inconsistent increases in the gamma-band range relative to baseline were not associated with more accurate task performance when examined on a session-by-session basis. This is inconsistent with gamma activity being an effective mechanism of working memory maintenance. In addition, on a number of days we found a decrease in gamma-band power relative to the baseline during both the stimulus-evoked response and during the memory retention interval of this often-utilized working memory task. These findings show that gamma band activity unlikely to be related to spatial working memory retention macaque monkeys.

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11:45 am

42.26 Information limits visual short term memory

Dana Najjar[1] (dnajjar@mit.edu), Edward Vul[1], George Alvarez[1]; [1]Brain and cognitive sciences, MIT

Visual short-term memory (VSTM) is famously capacity-limited, but the nature of the capacity limit is under heavy dispute. One class of theories postulates that a fixed number of "objects" (usually 4) may be remembered. A second class suggests that capacity reflects a resource divided over multiple remembered entities. The second account, however, does not specify what this resource may be. Here we apply information theory to VSTM to derive a measure of this capacity-limiting resource: information as number of bits. We presented subjects with arrays of colors or orientations and asked them to remember one, two, or four items. Subjects then made settings to match the color or orientation of remembered items, and the average error of these settings was computed. From this measure we could define the probability of the true item value given one setting from the subject: $P(T|S)$. The uncertainty in this distribution is quantified by its Shannon entropy (in bits -- $H(T|S)$). We can compare this entropy, to a measure of entropy of our prior distribution $H(T)$: the probability of the true item value without seeing a subject's setting. The difference between these entropies $[H(T) – H(T|S)]$ is the mutual information between a subject's setting and the true value of a particular item – this corresponds to the amount of information we gain from one setting. We find that when subjects have to remember more items, they make greater errors, and the amount of information contained in any one setting decreases greatly. However, when we multiply this measure of information gained per item by the number of items remembered we find a constant number of bits (roughly 3). Thus, it appears that the formal definition of information is a good candidate for the resource that limits VSTM capacity.

12:00 pm

42.27 **Popping in and out of existence: The effect of gradual and abrupt occlusion on object localization**

J. Stephen Higgins[1,2] (higgins3@uiuc.edu), Daniel Simons[1,2], Ranxiao Wang[1,2]; [1]Department of Psychology, University of Illinois Urbana-Champaign, [2]Beckman Institute, University of Illinois Urbana-Champaign

The human visual system typically tracks the position of objects as they move. However, when disruption occurs (e.g., as objects are occluded and disoccluded, an eye movement occurs, or when objects spontaneously disappear and reappear), we must determine whether or not the objects have moved. In most real-world perception, stable aspects of the surrounding environment provide landmarks for this recalibration process. Previous studies showed that when two objects are briefly viewed and then removed from view, the object reappearing first serves as a landmark for the object reappearing later. This results in the misperception that the second object has moved when, in fact, only the first one (the landmark) actually did. We explored whether this "landmark bias" was due to the objects' abrupt onset/offset by removing and revealing the objects more naturally. If the landmark bias represents a general process in which people treat the first object to reappear as the stable object, then observers should continue to see the second object as having moved. Alternatively, if the landmark bias results from a disrupted initial representation after sudden onset/offset, then the landmark bias should be eliminated. To test this hypothesis, two objects appeared side by side after which a moving occluder entered from one of the four edges of the screen, temporarily covering the objects before exiting. The objects could be occluded simultaneously (top/bottom entrance) or sequentially (left/right entrance), and revealed simultaneously (top/bottom exit) or sequentially (left/right exit) to mimic the traditional landmark test procedure. When the objects disappeared and reappeared more naturally, observers showed no landmark bias to misperceive the second object as having moved. This pattern also held for invisible occluders which provide no location cues, demonstrating that vanishing objects are treated differently than objects that gradually disappear.

Monday, May 12, 8:30 am - 12:30 pm
Poster Session, Royal Palm Ballroom 1-3

Faces: Emotion
Perceptual Organization: 2D Shape
Scene Perception 2

Faces: Emotion

43.301 **TMS disrupts the perception and embodiment of facial expressions**

David Pitcher[1] (d.pitcher@ucl.ac.uk), Lucia Garrido[2], Vincent Walsh[3], Brad Duchaine[4]; [1]ICN and Department of Psychology, University College London

Theories of embodied cognition propose that facial expression recognition depends upon processing in modality-specific visual areas and also upon a simulation of the somatovisceral and motor responses associated with the perceived emotion. To test this proposal, we targeted transcranial magnetic stimulation (TMS) at the right occipital face area (rOFA) and right somatosensory cortex while participants discriminated facial expressions. TMS impaired discrimination of facial expressions at both sites but had no effect on a matched facial identity task. In a second experiment, double pulse TMS separated by 40ms was delivered at different times to rOFA and right somatosensory cortex during the expression discrimination task. Accuracy dropped when pulses were delivered at 60-100ms at rOFA and at 100-140ms and 130-170ms at right somatosensory cortex. These sequential impairments at rOFA and right somatosensory cortex provide strong support for embodied accounts of expression recognition and hierarchical models of face processing. The results also demonstrate that non-visual areas contribute to expression processing very soon after stimulus presentation.

43.302 **Emotion suppresses repetition suppression of faces**

Atsunobu Suzuki[1,2] (atsuzuki@uiuc.edu), Joshua Goh[1], Brad Sutton[1], Andy Hebrank[3], Lucas Jenkins[4], Blair Flicker[3], Denise Park[3]; [1]Beckman Institute, University of Illinois at Urbana-Champaign, [2]Program of Gerontological Research, University of Tokyo, [3]Center for Brain Health, University of Texas at Dallas, [4]Department of Psychology, University of California at Davis

Reduction of brain activation with repetition of faces, so-called repetition suppression, has been used to investigate face processing in the human visual cortex (Grill-Spector et al., 1999). In the present study, we investigated effects of emotion on repetition suppression of faces. Previous studies provided contradictory evidence on this issue, such that emotional faces produced less (Rotshtein et al., 2001) and more (Ishai et al., 2004) repetition suppression than neutral ones. We conducted an event-related functional magnetic resonance imaging (fMRI) experiment designed to resolve differences from the previous studies, and compared repetition suppression between emotional (angry and happy) and neutral faces in the fusiform gyrus and in the amygdala. When the same face was presented consecutively, we found that the peak amplitude of the fMRI signal in the middle and posterior parts of the fusiform gyrus was smaller for the second presentation than for the first, and this repetition-suppression effect was the largest for neutral faces and the smallest for happy ones. Results also suggested repetition suppression in the amygdala for neutral faces, which was positively correlated with repetition suppression in the fusiform gyrus. It thus appears that emotional faces ensured more sustained activation than neutral ones both in the fusiform gyrus and in the amygdala, providing support for the notion that emotional information undergoes extensive processing through interaction between the two regions.

43.303 **Identification of expressive faces in the attentional blink**

Julia Gomez-Cuerva[1] (j.gomez@bangor.ac.uk), Margaret C. Jackson[1], Jane E. Raymond[1]; [1]Bangor University

Conventional views of face perception hold that face identity and expression are processed by independent mechanisms and therefore predict that face identification should be unaffected by expression. However, some previous reports suggest that certain facial expressions of emotion (e.g., anger) may preferentially capture attention, thus aiding identification. To examine whether attention is allocated differently for different expressions and to determine whether this can aid person identification, we presented emotional faces in a sequential dual task (a skeletal attentional blink, AB, paradigm) comprised of two targets, each followed by a mask. T1 was an abstract pattern composed either of many squares or many circles; its mask was another abstract pattern. T2 was a face image of one of three different individuals; its mask was another similar neutral greyscale face. The first task was to report T1's texture (circles or squares) and the second task was to identify the T2 face. All stimuli were 85 ms in duration but the interval between the onset of T1 and T2 was varied so as to present T2 during and after the AB. On different trials, T2 had different emotional expressions (happy, angry, or fearful); expression was uninformative as to T2 identity and was carefully matched in intensity across emotions and identities. AB effects were evident regardless of the emotional expression of the T2 face, suggesting that none of the expressions tested "captured" attention. Although identification performance for short SOAs (in the AB) were unaffected by expression, faces with happy expressions were identified with significantly greater accuracy than faces expressing anger or fear for the long SOA conditions (after the AB). These findings suggest that expression can influence face identification when attention is available; however, when it is unavailable, expression information does not interact with face identification processes.

43.304 **Contrasting target visibility and visual awareness in unconscious emotional body perception**

Bernard Stienen[1] (B.M.C.Stienen@uvt.nl), Beatrice De Gelder[1,2]; [1]Laboratory of Cognitive and Affective Neuroscience, Tilburg University, Tilburg, The Netherlands, [2]Martinos Center for Biomedical Imaging, Massachusetts General Hospital and Harvard Medical School

Many approaches have been used to support the claim that visual discriminations are still possible in absence of visual awareness, notably concerning nonconscious processing of facial expressions. Interpretation of masking studies is often complicated by the fact that performance and target visibility tend to co vary. Metacontrast masking permits to create experimental conditions in which subjective visual awareness and the objectively measured visual discrimination ability are manipulated separately1. We used a metacontrast masking paradigm to investigate perception of bodily expressions without visual awareness. Pictures of bodies expressing anger and happy were used as targets. The masks consisted of compounds of body parts (trunk, six arms and six legs in various positions) and they were presented at 12 different SOA's varying from -50 to 133 milliseconds. Participants were instructed to categorize the expression of the target body and subsequently to indicate whether they had seen the body or not. The results show that affective stimulus perception without visual awareness is clearly observed for angry body stimuli and not for happy stimuli and that the effect is modulated by observer characteristics (when excluding so called overachievers2).

1. Lau, H.C. & Passingham, R.E. Relative blindsight in normal observers and the neural correlate of visual consciousness. Proc Natl Acad Sci U S A 103, 18763-18768 (2006).

2. Pessoa, L., Japee, S., Sturman, D. & Ungerleider, L.G. Target visibility and visual awareness modulate amygdala responses to fearful faces. Cereb Cortex 16, 366-375 (2006).

43.305 **Implicit and explicit processing of facial expression in childhood, adolescence and adulthood: An ERP study**

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The brain regions involved in emotion processing (e.g., the amygdala, prefrontal cortex) develop dramatically between childhood and adulthood, especially during adolescence. These changes are reflected behaviourally, with the ability to label or match facial expressions improving over time. Facial expressions can be subject to explicit conscious appraisal and evaluation, but they can also be processed implicitly. Implicit and explicit facial expression processing may be differentially affected by development. The aim of this study was to examine implicit and explicit processing of facial expressions in children (aged 6-7 years), adolescents (aged 11-15 years) and adults (aged 20-44 years). In addition to behavioural data, event-related potentials and facial electromyography were collected to index emotional processing. Happy, angry, fearful and neutral faces were presented and participants were asked to judge the sex of the face (implicit task) or the expression (explicit task). Differences in expression processing were evident at the face-sensitive N170 component measured over occipito-temporal regions. For adults, the N170 response was enhanced to negative (angry, fearful) compared to positive (happy) expressions, for both implicit and explicit tasks. The N170 amplitude for adolescents was reduced compared to that observed for the adults. In addition, implicit and explicit facial expression processing differentially affected the N170 component in the adolescents. Although, N170 amplitudes for the children were large, they did not differentiate between the expressions. The results suggest that there is a critical transition period between childhood and adolescence, which affects both implicit and explicit facial expression coding.

Acknowledgement: This research was supported by Macquarie University and the Australian Research Council

43.306 **Surprised but not Scared: Similarities and Differences in the Perceptual Structure of Facial Expressions of 7-Year-Olds and Adults**

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Children's ability to recognize facial expressions develops slowly through childhood. Pre-adolescent children are not as accurate as adults in recognizing intense facial expressions, especially when the expression is negative (e.g., fear and disgust, Durand et al., 2007). Studies using multidimensional scaling (MDS) indicate that adults' perception of facial expressions can be modeled by two underlying dimensions, namely, pleasure and arousal. In the current study, we used MDS to compare the perceptual structure of children and adults for facial expressions. When based only on intense expressions, the perceptual structure for facial expressions appears to already be adult-like in preschoolers (Russell & Bullock, 1985; 1986). Here, we collected similarity scores from a group of adults (n=16) using a rating paradigm and from another group of adults (n=16) and a group of 7-year-olds (n=16) using an "odd-one-out" paradigm for four different intensity levels of each of the facial expressions of six basic emotions. We calculated a three-dimensional solution using the INDSCAL procedure for each group (stress: 0.153 – 0.197), and applied hierarchical clustering analysis to the MDS solutions. Although tested with different paradigms, the two groups of adults had similar clustering. Similar to adults, children showed separated clusters for happiness and for anger, as well as a cluster including both sadness and disgust. Surprise and fear were clustered together in adults, but not in children. In adults, neutral was located close to happiness with all the lowest intensity expressions around it, while in children, neutral was close to surprise, and the lowest intensity expressions diverged from their main categories, but were not pulled toward neutral. The results suggest that 7-year-olds have a systematic perceptual structure of facial expressions that overlaps only partially with that of adults.

43.307 **Lost in Translation: Culturally Tuned Eye Movements Impair Decoding of Facial Expression Signals**

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Face processing has long been considered a unique and universal biological skill shared by all humans. Contrary to this widely accepted belief, we recently reported a striking cultural contrast in eye movements during face recognition (Jack et al., 2006). Transmitting and decoding facial expressions also plays a critical biological role for effective social interaction and communication. Yet, the question of whether facial expressions are universal is a matter of ongoing controversial debate. Despite numerous studies on facial expression, none have systematically investigated eye movements during expression categorization and the role of the culture of the observer.

Here we monitored the eye movements of Western Caucasian (WC) and East Asian (EA) observers while they categorized WC and EA faces displaying six basic emotions (happy, surprise, fear, anger, disgust and sad) plus neutral. WC observers were superior at categorizing expressions compared to EA observers, who showed a notable impairment in categorizing expressions typically suppressed in their culture - sad, disgust and anger. Interestingly, EA observers categorized these negative expressions more accurately with WC than EA faces, questioning the universality of emotion signal transmission. Fixation maps revealed striking culturally distinct scanpaths: WC observers showed a triangular pattern of fixations across expressions and race. Contrary to intuition, EA observers did not fixate the mouth region for any expression - even during accurate categorization of happy. These culturally tuned scanpaths clearly show that observers from different cultures fixate on different facial regions to decode expressions, engendering discrepancies in the communication space and inaccuracies when translating facial expression signals. The present data offers a novel explanation as to why misunderstandings frequently occur during intercultural communication, aside from the language barrier. Crucially, these observations demonstrate that facial expression decoding can no longer be considered as arising from a universal series of perceptual events.

43.308 The use of Spatio-temporal Information in decoding facial expression of emotions

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Facial expressions of emotions guide adaptive behaviors by communicating information that can be used to rapidly infer the thoughts and feelings of others. This information has partially been characterized using static images (e.g., mouth in low spatial frequencies for happiness, eyes in high spatial frequencies for fear; Smiths et al., 2005), but relatively little is known about the contribution of facial movement (but see Cunningham, Kleiner & Bülthoff, 2005). Thirty participants viewed 5,000 sparse versions of 80 static emotional faces, and thirty others viewed the 5,000 dynamic sparse counterparts corresponding to the six basic emotions from the STOIC database (Roy et al., 2007). Observers were required to categorize facial expressions as fearful, happy, sad, surprised, disgusted, or angered. More specifically, the sparse static stimuli sampled facial information at random locations at five one-octave SF bands (Gosselin & Schyns, 2001) and the sparse dynamic stimuli randomly sampled space and time (Vinette, Gosselin & Schyn, 2004). Online calibration of sampling density ensured 75% overall accuracy. We performed multiple linear regressions on sample locations (in space-time for dynamic stimuli) and accuracy to reveal the effective use of information for every emotion in the static and dynamic conditions. Our results with static stimuli essentially corroborate the findings of Smith et al., (2005) and our preliminary results with dynamic stimuli extend them by providing original data regarding the spatio-temporal characteristics of facial expression recognition—dynamic facial expressions appear to communicate unique spatio-temporal cues that may differentially contribute to recognition behavior.

43.309 Behavioral and fMRI studies of identity and expression perception in acquired prosopagnosia

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Acquired prosopagnosia, the inability to recognize familiar faces, is a rare neurological syndrome that is heterogeneous in both its behavioral deficits and anatomic lesions. One point of reported variability is the presence of impaired expression processing in addition to the impairments in identity processing. We studied the perception of identity and expression in four prosopagnosic patients and asked whether the behavioral findings correlated with data from functional magnetic resonance imaging (fMRI).

We investigated identity and expression processing with an oddity task containing separate identity and expression tests which were equated for level of difficulty in a group of 16 healthy controls. With fMRI, we used a functional localizer to identify damaged and intact face-selective brain regions. Last, we designed an fMRI adaptation study to obtain measures of identity and expression adaptation in the face-selective regions of each subject.

The oddity task showed impaired perceptual processing of identity in three patients, including two with anterior temporal lesions sparing the fusiform face area (FFA), occipital face area (OFA), and superior temporal sulcus (STS). This task also demonstrated clear dissociations in identity and expression impairments, with these three subjects showing normal discrimination of changes in expression, all of whom also had an intact right STS. Despite their difficulties recognizing the identity of faces, adaptation effects for identity were still observed in the OFA of all four patients, but not in the right FFA of the two patients with this area intact. Adaptation effects for expression were observed only in the right STS of the two patients with damage restricted to the anterior temporal lobes.

We conclude that expression can be relatively preserved in prosopagnosic patients with lesions sparing the STS, and that identity adaptation in the OFA does not index processes sufficient on their own to predict normal perceptual sensitivity to facial identity.

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43.310 Strategy for visual scanning of faces varies with the degree of Asperger Syndrome traits

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People with Asperger syndrome (AS) have difficulty identifying complex emotions (e.g., 'wary') that involve theory of mind but can identify basic emotions (e.g., 'happy') (Baron-Cohen et al., 2001 J.Child Psychol. Psychiat. 42: 241). They look less at the eye region of faces than controls do when discriminating basic emotions but not when viewing faces passively (Pelphrey et al., 2002 J. Autism Dev. Dis. 32:249). Does scan path strategy vary with AS severity? Is there a difference between how people with and without AS scan faces while identifying complex versus simple emotions? Eye movements were measured using an Eyelink 1000 while people with AS and controls viewed faces showing simple or complex emotions. Severity of AS was assessed using the Autism-Spectrum Quotient questionnaire (AQ: Baron-Cohen et al., 2001 J. Autism Dev. Dis. 31: 5). Participants viewed a fixation cross followed by a face which was surrounded, after 5s, by four words from which they selected the emotional expression. Scan paths were analysed in terms of the goal and latency of first saccade to the face, and the dwell times in different face regions during the face-viewing period. The frequency of people looking first at the nose, the dwell time in the nose region, and the dwell time on features in the lower part of the face in general, correlated with AQ. The frequency of looking first at the eyes, the dwell time in the eye regions, and dwell time on the upper part of the face were inversely correlated with AQ. There was no difference in scan paths when identifying simple vs. complex emotions. These data support the view that there is a continuum of AS tendencies extending into the so-called normal population that is reflected in scan path strategy.

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43.311 Recognizing static and dynamic facial expressions of pain : Gaze-tracking and Bubbles experiments

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Facial expression is considered to be the most reliable source of information when judging on the pain intensity experienced by another (Poole & Craig 1992). Nonetheless, observers in this situation show a systematic underestimation bias (Harrison, 1993; Kappesser & Williams, 2002). In the medical domain, this bias results in under-treatment, which leads to an insufficient pain relief for suffering patients. Despite the important impact of pain identification on patient well-being, the visual processes involved in the recognition of the facial expression of pain remain unknown. In this study, we used gaze-tracking and Bubbles (Gosselin & Schyns, 2001) to investigate the visual information used for the recognition of static and dynamic facial expressions of pain. Observers were required to categorize 80 dynamic or static facial expressions (the 6 basic emotions, pain and neutral) from the STOIC database (Roy et al., 2007). In the gaze-tracking experiment, twenty observers saw 6 times each of the 80 static and dynamic emotionnal faces. Gaze position was recorded while the stimuli were presented; heat maps were computed. The results for pain expressions will be discussed. In the Bubbles experiments, 5,000 sparse versions of these static and dynamic stimuli were created by sampling facial information at random spatial locations at five one-octave non-overlapping spatial frequency bands for the static stimuli, as well as in space-time for the dynamic stimuli (see Vinette, Gosselin & Schyns, 2004). Online calibration of sampling density ensured 75% overall accuracy. We performed mulitple linear regressions on sample space or space-time locations and on accuracy to reveal the information effectively used to recognize pain. Preliminary findings with static stimuli reveal that optimal information for the recognition of pain partly overlap with sadness and disgust ones. Preliminary results with dynamic stimuli indicate that motion contributes to the decoding of facial expressions of pain.

43.312 **Fearing Rembrandt's Male Portraits (Hess Revisited)**

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Eckhart Hess (1965) claimed that pupils dilate to pleasing images and constrict to displeasing images. This work has been most severely criticized on two grounds; first, the luminances and contrast of the images across conditions were not kept constant, and second, the pupil only constricts to light (Loewenfeld, 1966). To correct for these confounds we presented rightward or leftward facing male and female portraits by Rembrandt for 20 seconds each on a CRT in either their original (n=20) or mirror-reversed position to 30 observers while measuring their pupil size. After presenting each portrait, observers used a 1-9 Likert-scale to report how (dis)pleasing they found each image. We then took their difference in "pleasingness" ratings between the original and mirror-reversed images, and correlated it with the difference in average pupil diameter obtained between the original and mirror-reversed images. We found that differences in "pleasingness" ratings did not alter observer's difference in pupil size while viewing the female images. However, we found a strong correlation between differences in "pleasingness" ratings and observer's pupil size while viewing male portraits. Surprisingly, we found that as observers rated one of the image pairs (original viewing versus mirror-reversed) more displeasing their pupil size increased. This contradicts Hess' original findings (which predict a decrease in pupil size with more displeasing images). However, it agrees with Libby, Lacey & Lacey (1973) and suggests that perceived threat (connoted as "displeasing") correlates with an increase in pupil diameter as Darwin (1890) would have predicted.

References:

Darwin (1890). The Expression of the Emotions in Man and Animals, D. Appleton & Co., N.Y.).

Hess (1965). Attitude and pupil size. Scientific American, 212, 46-54.

Libby, Lacey & Lacey (1973). Pupillary and cardiac activity during visual attention. Psychophysiology, 10(3), 270-294.

Loewenfeld (1966). Comment on Hess' findings. Survey of Ophthalmology, 11, 291-294.

43.313 **Adaptation to Facial Expressions**

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Facial expressions form a limited and stereotyped set of stimulus categories that are readily recognizable and which may in part be encoded in distinct neural pathways. We used adaptation to examine the interactions between the perception of the six basic expressions (anger, fear, happiness, sadness, surprise and disgust). The Singular Inversions program FaceGen Modeller was used to create faces with varying degrees of expression relative to a neutral face with average characteristics. Observers used a seven-point scale to rate the perceived magnitude of these expressions before or after adapting to the neutral face or the extreme level from each of the six categories. In each case adaptation produced the strongest changes in the perceived intensity of the adapting expression, so that the aftereffects are selective for each category. Non-adapted expressions also tended to be reduced in perceived magnitude rather than enhanced (though weak enhancements were suggested in happy or sad faces after adapting to surprised faces, or vice versa), and the largest changes in the ratings occurred for moderate contrasts of the stimuli rather than in the neutral (zero-contrast) face. This general pattern of the adaptation effects is more consistent with partially separate representations of the different expressions rather than a strong opponent coupling between specific expressions.

43.314 **Emotion Perception in Neutral Expressions**

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Four experiments suggest a continuous representation of emotions in a norm-based face space (sometimes called mean-based face space), where faces are represented as variations from a mean or norm face. In particular, we show that the vertical distance between eyes, nose and mouth of an individual face is correlated with the perception of anger and sadness in face images displaying a neutral expression. When the vertical distance between eyes and mouth is made larger than that of the average face (i.e., the average distance within a population), the perception of sadness increases (experiment 1). A decrease of the same distance from that of the average face increases the perception of sadness (experiment 1). The perception of anger/sadness does not appear on the opposite side of the mean face (experiment 2). For example, a decrease of the eye-mouth distance on faces with larger distance than that of the mean face, are not perceived angrier. This effect is also clear from "face sketches" where the eyes have been reduced to dots, and the mouth, brows and nose to a single line (experiment 3). In experiment 3, the perception of sadness and anger were almost as strong as in the previous experiments where real faces were used. Furthermore, in experiments 1-3, the perception of anger/sadness increased proportionally to the feature distance, suggesting a continuous representation in a norm-based face space. A simple inversion of our stimuli disrupts this effect (experiment 4), suggesting that the characteristics being modeled by this face space correspond to second-order configural cues.

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43.315 **The effect of stimulus duration on the processing of facial expressions of emotion – an EEG study**

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From the work of Esteves & Öhman (1993), visual masking has been used to explore the processing of facial expressions at different levels of conscious awareness with growing evidence leading to the conclusion that emotion processing is automatic and can occur without conscious awareness. fMRI and patient studies of these phenomena have resulted in the putative subcortical pathway to the amygdala for threat related stimuli to be processed without conscious awareness. However, little is known about the temporal evolution of such processing.

We investigated this in an electroencephalographic study using a backward masking paradigm. Participants were presented with six different identities each displaying three facial expressions of emotion: fear, disgust and happiness and asked to categorize them by expression. Stimuli were displayed for 8, 24, 40 or 64ms and immediately replaced by a 200ms noise mask (with the same phase structure of a face, ie. an inverse square relation to frequency).

Considering two key face processing ERP components, the N170 and P3 complex, we found effects of both presentation time and expression. Specifically, for all expressions, we observed a parametric relationship between presentation time and the amplitude of the two components, with largest N170 amplitudes occurring to the most briefly presented stimuli and largest P3 amplitudes to the stimuli presented for the longest times. This double dissociation highlights key differences in the processing of facial expressions of emotion at different levels of awareness. Furthermore, differential processing of the three facial expressions was observed as a function of stimulus presentation time, with significant differences in all three expressions for the longest presentation times and only for fear for short presentation times.

These results will be discussed in the context of current theories on the processing of facial expressions of emotion.

Esteves F & Öhman A (1993) Scand. J. Psychol. 34:118.

43.316 **When Anger Spreads to One's Neighbors: Within-Hemifield Averaging of Facial Expressions**

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Perception of objects depends on neurons in the ventral visual stream that display high selectivity in responding to complex patterns. These neurons tend to have large receptive fields, which support position-invariant object recognition but also entail poor spatial resolution. Specifically, when multiple objects fall within the receptive field of a ventral visual neuron, unless selective attention is deployed to one specific object, the neuron's response tends to be the average of its responses to the individual objects. With complex stimuli such as facial expressions this neural averaging predicts that multiple expressions within a receptive field would be perceptually averaged. Perceptual averaging of facial expressions should occur across large spatial separations but only when faces are presented within the same visual hemifield, given that the receptive fields of face-tuned neurons have large receptive fields mostly confined within the contralateral visual hemifield. On each trial of our experiments, two faces (separated by ~ 7°) were briefly presented (100 ms) either within the same visual hemifield or across visual hemifields. Observers rated the valence of one face from the pair, which was indicated by a post-cue. Consistent with the prediction from neural averaging, when a face with an angry expression and a valence-neutral face with a surprise expression were presented within the same visual hemifield, observers perceived the valence-neutral face to be more negative and the angry face to be less negative compared to when the two faces were presented across visual hemifields. We thus demonstrated perceptual consequences of neural averaging with high-level visual features. When viewing time is limited and spatial selective attention is not engaged in advance, a strong feature gets softened and its influence spreads to weaker neighbors.

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43.317 **Evidence for adaptive design in human gaze preference**

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Many studies have investigated the physical cues that influence face preferences. By contrast, relatively few studies have investigated the effects of facial cues to the direction and valence of others' social interest (i.e. gaze direction and facial expressions) on face preferences. Here we found that participants demonstrated stronger preferences for direct gaze when judging the attractiveness of happy faces than that of disgusted faces, and that this effect of expression on the strength of attraction to direct gaze was particularly pronounced for judgements of opposite-sex faces (study 1). By contrast, no such opposite-sex bias in preferences for direct gaze was observed when participants judged the same faces for likeability (study 2). Collectively, these findings for a context-sensitive opposite-sex bias in preferences for perceiver-directed smiles, but not perceiver-directed disgust, suggest gaze preference functions, at least in part, to facilitate efficient allocation of mating effort, and evince adaptive design in the perceptual mechanisms that underpin face preferences.

Perceptual Organization: 2D Shape

43.318 **Shape classification based on natural shape statistics**

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We studied the classification of shapes into broad natural categories such as "animal" or "leaf", which with many shapes can proceed without overt basic-level recognition. Shape representation models often make implicit assumptions about what shape structures most often occur in natural shapes, but such assumptions are not generally closely tied to real-world measurements, and not tuned to naturally occurring classes. As a step towards "naturalizing" shape representation, we collected shape statistics from a large database of real shapes drawn from several natural categories, such as animals, and leaves, focusing on shape parameters relating to skeletal and axial structure as in the Bayesian skeleton estimation framework of Feldman & Singh (2006). These statistics allow for the creation of "ecologically-informed" shape models that generalize over the many specific individual structures observed in these classes. Building on the Bayesian skeleton model, we developed a mathematical approach to shape prototypification, which allows shapes to be probabilistically classified with respect to the prototype most likely to have generated it. To investigate human shape classification, we asked subjects to classify shapes that were constructed by taking a weighted average (suitably normalized) of animal and leaf contours, resulting in shapes that were parametric mixtures of the two classes. Subjects can indeed classify such shapes, and their classifications closely track the ground truth given by the mixing proportions. We model this classification process via a Bayesian classifier that assigns a posterior shape class as a function of the shape structure, using our database of class-specific natural shape parameters to inform the priors and likelihood functions. The resulting model gives a good account of the data, and sheds light on how novel shapes can be assigned to semantically meaningful real-world categories based on knowledge of structural regularities but without overt recognition.

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43.319 **Shape skeletons and shape similarity**

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Human judgments of shape similarity are notoriously difficult to capture with a simple similarity metric; traditional measures based on contour features often show dramatic failures. A critical problem underlying contour-based similarity measures is their failure to respect the global configuration of object parts. We propose a shape similarity measure based on an extension of previous work on Bayesian shape skeleton estimation (Feldman & Singh, VSS 2006; PNAS 2007). The maximum a posteriori shape (MAP) skeleton, defined as the skeletal structure most likely to have generated a given shape, provides a robust and intuitive estimate of a shape's part structure. Here we extend the probabilistic machinery of Bayesian shape analysis to motivate a shape similarity measure that is based on the probability that two shapes share a common generative origin. To validate this similarity measure we ran a series of experiments. Exp. 1 involves simple shapes that vary according to their number of perceived parts. Similarity judgments exhibit a gross discontinuity when part structure changes qualitatively, e.g. from one part to two, even when this apparent change arises from a small change in contour properties. This pattern of results cannot be explained by conventional contour-based measures, but naturally falls out of the skeleton-based similarity measure, which automatically assigns greater dissimilarity to shapes whose estimated shape skeletons are topologically distinct. Follow-up experiments using more complex shapes show comparable results: shapes with qualitatively similar skeletons show greater similarity, while differences in skeleton structure (i.e. changes in part structure) are associated with increased dissimilarity. Finally, we argue that the derivation of a similarity metric from an overt probabilistic shape model provides a well-motivated account of the previously inaccessible connection between shape representation and shape categorization.

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43.320 **Skeleton-based segmentation of shapes into parts**

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Organizing shape representations in terms of parts allows one to separate the representation of individual parts from the representation of their spatial relationships---thereby providing a robust representation of shape that is stable across changes in the articulated pose of an object. However, the general problem of how the visual system segments shapes into parts remains unsolved. An attractive possibility, going back to the work of Blum (1973), is to compute parts based on the axial branches in a skeleton-based description of the shape---in other words, to isomorphize axes and parts. This approach fails, however, because of the numerous spurious axes produced by the Medial Axis Transform and its modern descendants. Most notable of these problems are the forking of the axes at the ends of blunt parts, and the extreme sensitivity to contour noise. In previous work, we proposed a Bayesian approach to the estimation of a shape's skeleton that overcomes these problems (Feldman & Singh, PNAS 2006). Our approach treats shapes as arising from a mixture of generative factors and noise, and the maximum-a-posteriori (MAP) skeleton (the skeletal structure most likely to have generated a given shape) provides a perceptually reasonable estimate of the shape's skeleton. Here we show that the MAP skeleton also provides a perceptually natural account of part decomposition. Known geometric determinants of part decomposition and part salience---including negative minima of curvature, cut length, curvature, protrusion, necks and limbs---all naturally fall out of the Bayesian skeleton estimation. Specifically, the influence of these geometric variables on part segmentation/salience is reflected in the posterior probabilities associated with the corresponding MAP skeletons---despite the fact that our scheme does not explicitly compute contour curvature. This allows the part segmentation problem to be grounded in a single unifying process of Bayesian estimation of the shape skeleton.

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43.321 **Convexities Move, Concavities Follow**

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Many physical objects, particularly biological ones, have shapes that change due to natural movements, such as articulations. Such motion, while non-rigid, is generally constrained by underlying physical structure (e.g. a skeleton). One such constraint is the fact that contour regions that move independently of the rest of the object, such as fingers, are typically convex, while concave regions that form the boundary between convex parts (e.g. the space between fingers) do not move independently but only in conjunction with a larger---primarily convex---section of the object (e.g. the spaces between fingers moving along with the whole hand). The current study tested whether the visual system employs this regularity when assigning figure and ground in animated displays. Subjects who had to make a figural assignment to a dynamically deforming contour bounding two colored regions showed a bias for assigning figure so that the moving contour was convex rather than concave. This result held even when the dynamic cue was inconsistent with established static cues to figural assignment. This study extends earlier research showing a bias for biologically valid dynamic deformations (i.e. joint articulations; Barenholtz and Feldman, 2006) and provides evidence for a more general dynamic cue to figure-ground assignment that is based on the geometric properties of the motion of physical objects.

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URL: http://psy.fau.edu/~barenholtz/research/convexity

43.322 **Globally inconsistent figure/ground relations induced by negative parts**

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In conventional accounts of figure/ground organization, and in traditional Gestalt theory, figure/ground assignment is assumed to be globally consistent along the entire contour of a figure. If figure and ground reverse at one point on an object boundary, the entire boundary reverses, as in classical bistable figures such as the Rubin face/vase. Here we investigate a situation where local configural cues to figure/ground conflict with global cues: "negative parts." We constructed displays in which a circular shape included a "bay" or cut-out region. We tested figure/ground interpretation locally by using a moving probe (a region of the contour set in "trembling" motion). We asked subjects which color (the interior or exterior color) seemed to be moving; their response reflects figure/ground assignment, as the motion is perceived to be perceptually owned by the figural side of the boundary. We manipulated the shape and size of the bay, and the position of the probe (inside the bay or elsewhere along the contour). Subjects were significantly more likely to perceive the exterior as figural (that is, to invert the normal figure/ground assignment) when the probe was inside the bay than when it was outside, suggesting that the bay was indeed perceived as a "negative part." Moreover the shape (convexity) of the bay influenced figure/ground assignment when the probe was inside the bay, but not when it was outside; that is, the figure/ground inversion was local to the negative part itself, resulting in a globally inconsistent figure/ground interpretation. Two followup studies suggest that this phenomenon involved a local inversion of perceived depth, not mere contour ownership. The results suggest that figure/ground interpretation is a dynamic and complex process in which local and global cues combine and compete to produce an ultimate percept that may not be globally consistent.

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43.323 **Detection of globally processed radial frequency contours: Narrow-band shape channels integrate luminance and contrast cues**

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Radial frequency (RF) contours can be used to represent globally processed shapes such as triangles (RF3), squares (RF4) and pentagons (RF5). It has previously been shown that more than one shape channel is needed to account for the detection of a broad-range of closed-contour shapes, however it remains unclear how many shape channels are required. Our first study used subthreshold summation to estimate the minimum number of shape channels necessary to explain performance for patterns up to RF10. To achieve this, we tested whether combining two RF components onto a single path (one of which is presented at half-threshold amplitude) improved detection thresholds for a single RF component, compared to thresholds for detecting that component in isolation. Threshold improvement occurred when the two shape components were the same RF but not when the components differed in RF, suggesting the operation of multiple channels, each with at most the width of a single RF. Channel sensitivity to luminance- and contrast-defined shape cues was then evaluated. A set of two experiments showed that, (1) positive and negative polarity luminance-defined contours mask each other and, luminance- and contrast-defined contours mask each other; (2) luminance and contrast cues can be assembled into a single global shape. The overall results show that the narrow-band channels which process global contour shapes effectively combine luminance- and contrast-defined form information.

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43.324 **Adaptation to Radial Frequency Patterns in the Lateral Occipital Cortex**

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Background: We used functional magnetic resonance imaging adaptation (fMRIa) and radial frequency (RF) stimuli to investigate shape coding in the lateral occipital complex (LOC) – an important cortical area that mediates integration of local contour information. An RF pattern consists of a closed contour whose radius sinusoidally deviates from circularity as determined by frequency (i.e., the periodicity of bumps around the circle) and amplitude (i.e., bump size). As a Fourier basis set, the family of RF patterns defines a large space of unique closed-contour shapes. Methods: BOLD responses in LOC were collected for 7 participants on a 3T GE scanner according to standard fMRI techniques. LOC was localized by contrasting BOLD responses to scrambled and non-scrambled objects. Results: BOLD responses were lowest for blocks of purely circular stimuli than for all other blocks consisting of single RF contours with fixed shape and amplitude. Blocks in which contours varied in amplitude and/or shape exhibited varying degrees of adaptation release with respect to fixed-shape-and-amplitude blocks. Conclusions: Results are consistent with a population code in which closed-contour shapes are represented as deviations from a circularity prototype. In particular, we interpret weaker BOLD responses to pure circles as an instance of efficient predictive coding that reduces redundancy between neural outputs. We are further characterizing the topology of BOLD response in RF space and the corresponding shape selectivity of population subunits in LOC.

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43.325 **Interplay between pattern density and global form in Glass patterns**

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Glass patterns are random-dot patterns, where a number of dots is paired to dipoles according to a geometric rule (e.g. translation, rotation). Although their local structure is just dot pairs, a global form can be immediately perceived, making them useful stimuli for investigating form perception. A central question has been, whether Glass patterns are detected by global form detectors tuned to specific forms or by more local mechanisms. Pattern density can provide information about local and global processing strategies, as the number of random dots in the pattern affects especially the local structure of the pattern, perceptually deteriorating the salience of individual dipoles. In some previous studies, density has been found to affect the detectability of the pattern, whereas in others, no effect was reported. Here, we wanted to re-examine the issue. Furthermore, we varied the pattern extent in order to investigate both the effect of density and area summation.

Both rotational and translational patterns were used. Dot size was 4.3 and dipole length 8.6 or 25.8 arcmin. Stimulus density was varied from 0.27% to 27% coverage and radius of the circular area from 3 to 6 degrees. Possible edge artefacts were controlled by smoothing the border of the pattern with a Gaussian window. Thresholds for detecting Glass patterns were measured using a 2IFC task, where observers discriminated between a comparison stimulus consisting of coherently oriented signal dipoles (and random-dot noise) and a standard stimulus consisting of dipoles in random orientations. Proportion of signal dipoles was varied.

Results show that threshold vs. density curves are U-shaped, having their minima at middle densities. Area summation was found across the conditions, it being especially prominent in high-density patterns. Interplay between signal density and transformation type was found: maximum detectability is achieved at lower densities for translational patterns than for rotational.

43.326 Common elements of perceptual organization: illusory contours and dimensional consistency

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Evidence suggestive of holistic representation for faces often is obtained in tasks in a facial feature (e.g., a nose) is judged either in the absence or presence of a facial surround, with that surround being either consistent or inconsistent (at the level of identity) with the feature. These types of paradigms are similar to those used to reveal influences of global form on the perception of local features. The present project investigates the hypothesis that effects in facial perception and effects in object perception reflect the same characteristics of visual perception. There are two specific hypotheses that are addressed in this work: (a) Perceptual organization relies as much or more on similarity at the level of second-order characteristics than at the level of first-order physical similarity, and (b) perceptual organization reflects both perceptual and decisional factors. We tested these hypotheses using hierarchical forms in which one of the dimensions was created using illusory contours. Observers responded with judgments about each of the manipulated dimensions, allowing the data to be analyzed from the perspective of general recognition theory. In Experiment 1 the effect of consistency was examined with hierarchical illusory stimuli in the presence or absence of a to-be-ignored central element that itself could be either consistent or inconsistent with the global and local forms. In Experiment 2 the same effects were examined, but observers were instructed to identify the central as well as the global and local forms. Experiment 3 extended these comparisons to face- and object-like stimuli in which the global shape was an illusory contour. Results from all three experiments indicate that the perceptual organization of all types forms demonstrate common reliance on both perceptual and decisional components.

43.327 Perceptual filling-in on a natural blind spot influences pupillary light reflex

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Perceptual filling-in is induced when a light stimulus covers the retinal part (optic disk) corresponding to the blind spot. In this situation, the perceived surface seems to continue uniformly inside the blind spot and therefore the percept is larger than the area of actual stimulation confined outside the border. On the other hand, abrupt light stimulation causes reflexive contraction of the pupil, and the amount of reflex is known to change proportionately with light intensity. We aimed to see whether the pupillary light reflex in response to abrupt stimulus onset at the blind spot is based on the physical stimulation area or the perceived surface area as a result of filling-in. A white disk stimulus twice as large as the blind spot of the right eye was displayed for 80 ms either on the blind spot or on its two adjacent areas. The amount of pupil contraction was measured. As a result, almost the same amounts of reflex were observed in all the conditions despite the fact that actual retinal stimulation is smaller (50% in area) when the stimulus was on the blind spot. Moreover, no reflex was observed when only the inside of the blind spot was illuminated. These results reveal that the perceived figural area formed through the process of perceptual filling-in affects pupillary light reflex. In a control condition, a white annular stimulus of the same size as the blind spot was displayed at the position exactly surrounding it. In parallel with pupil-size measurement, participants were requested to judge whether the stimulus shape was a completely filled disk or an incomplete one. Even though the annulus was indistinguishable from the disk, the amount of light reflex to the annulus was less than the reflex to the disk, suggesting involvement of some high-sensitivity mechanisms for light reflex.

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43.328 Does the luminance condition for test figures change the illusion?

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The general illusion theory tells that at the equiluminant condition (EQ) the magnitude of the illusion would reduce. We confirmed (VSS2007), however, that Plasmid illusion (PL) and Gravity lens illusion (GL) kept their illusory effect at EQ. It might be promising if we could make a taxonomy of illusions based on whether the illusion follows or does not follow the EQ reduction theory with some accountable reasons. The EQ generally implies that the whole figure elements are equiluminant. Since the luminance of the test figures (TF) can be varied independently of the inducing figures (IF) and the background (BG) luminance, we investigated how much the illusory effects still held when the TF luminance was different from the IF and BG while they were red-green equiluminant. We found that the illusory effect of GL reduced to 60% of the EQ case, when TF were black or white. For PL the magnitude reduced similarly, though the amount of reduction was smaller. We might be able to assign every illusion to one of the typical patterns. A few classical illusions such as Ebbinghaus, Mueller-Lyer, and Orbison were investigated with the method. We found Ebbinhaus was similar to GL or PL. MuellerLyer was less clear whether the illusion held or varied. Orbison is the classical example that the illusory effects would disappear at EQ. It might give an insight for the illusion theory to realize the fact that IF of GL are filled circles and IF of PL are thick ring segments, while Mueller-Lyer and Orbison are composed of line segments. If the thickness of the lines is too thin, it will be actually difficult to observe the figures at EQ. The Mueller-Lyer was observed with varied line thickness. The appropriate conditions for Mueller-Lyer gave the similar results as PL.

43.329 Center of Mass Estimation in Three-Body Displays. The Influence of Median Length and Orientation.

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The purpose of this study was to investigate the influence of axis length on center of mass perception. Participants estimated the center of mass in three-body displays by moving a small judgment dot with a mouse. The displays consisted of three black-filled dots viewed against a white background. The dots were located at the vertices of virtual right triangles. We varied triangle position (direction the hypotenuse faced), orientation (vertical and horizontal) and axis length (ratio of smallest side to intermediate-length side from 1:1 to 1:5) . The center of mass or centroid in these displays is at the intersection of the medians, the lines that join a vertex to the midpoint of the opposite side. Axis length and median lengths are correlated. An increase in axis length produces a corresponding increase in the medians, which ought to make center estimation more difficult. The results confirmed our prediction. Mean error, measured as the difference between estimates and the true center, increased linearly with an increase in axis length. Our second dependent measure was response direction, the angular deviation of the estimate from the true center. Mean response direction always pointed downward but was shifted toward the orientation of the nearest downward median. Direction thus seems to be an accommodation between the influence of gravity and the orientation of the nearest median.

43.330 fMRI used to distinguish conjoint and independent representation of perceptual axes

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Perceptual stimuli can be defined as parametric variations along multiple axes. Alternate parameterizations can partition the stimuli differently; for example a set of rectangles can be described as varying in height and width or in aspect ratio and size. It may be of interest to determine if a given pair of stimulus axes recruits neural populations that represent the two dimensions independently or conjointly. With fMRI, conjoint and independent representation may be distinguished through the examination of neural dissimilarity data that measure the inter-stimulus distance in neural representation between all pairings of a set of stimuli. Specifically, the identification of a Euclidean neural distance metric (Minkowski=2) versus City-block (Minkowski=1) for pairings across both of the perceptual dimensions indicates conjoint and independent coding, respectively. Using a continuous carry-over design (GK Aguirre, 2007), the necessary neural dissimilarity measures may be obtained on both focal (within voxel adaptation) and distributed (across voxel pattern analysis) scales.

We will present simulations that suggest that adaptation and pattern metrics measured with fMRI reflect underlying conjoint and independent neural coding. We describe the construction of a "sub-additivity" covariate that may be used to estimate the Minkowski metric of neural representation, and the results of simulations that demonstrate the robustness of the approach to linear and non-linear distortions of the neural and hemodynamic responses. Optimizations of the stimulus space and the order of stimulus presentation within a continuous carry-over design are considered to maximize efficiency for estimation of the Minkowski neural metric. The results are further extended to consider non-metric cases (Minkowski <1, "feature contrast"; and Minkowski = infinity, "single feature"). The results of application of these techniques to the study of two-dimensional object shape and aspects of facial appearance will be presented.

URL: http://cfn.upenn.edu/aguirre/projects/carryover.shtml

43.331 **Exploring Shape using Goodness-of-Fit Measures**

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We studied the internal structure of rectangular frames by measuring the perceived goodness-of-fit of small probe shapes positioned within them. In Experiment 1, the rectangle's center was rated as the best-fitting position for a small, circular dot, with elevated fit ratings also along global axes of symmetry (both horizontal and vertical) and local axes of symmetry (on angle bisectors). Together, centeredness and symmetry accounted for more than 90% of the variance. Changing the probes to isosceles triangles or chevrons revealed strong orientational effects, especially when the probe's axis of symmetry aligned with the frame's axes of symmetry as mentioned above. Fit-ratings within rectangles at different orientations (0, 45 , 90 , and 135 degrees) showed that these orientational effects were driven by alignment with the rectangle's sides rather than with gravitational or retinal axes. Directional biases for better fit were also evident when the triangle pointed into the frame, upward, and/or rightward. The pattern of fit-ratings for a dot changed dramatically when a second contextual dot was also present, but high ratings were still observed when the whole configuration was symmetrical and when the two dots were close together and/or parallel to the frame's sides. When the two dots differed in size, thus breaking precise symmetry, observers gave higher ratings to positions that achieved balance in their visual weights. Alignment, proximity and symmetry were the most influential factors also when the contextual dot was replaced by a short line. When the line was extended, so that it divided the frame into two smaller rectangular parts, however, the pattern of fit ratings changed again, with the internal structure of the smaller inner rectangles dominating that of the larger outer rectangle. The implications of these results are discussed for aesthetic response as well as the perceived internal structure of shapes.

43.332 **Intrinsic Orientation and Learning Viewpoint in Shape Recognition**

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Two experiments examined the independent roles of the intrinsic reference direction (intrinsic orientation) of a shape and the learning viewpoint of the observer in recognizing the shape. Participants viewed a hexagon for one minute and then they made same-different judgments on two quadrilaterals derived from the hexagon or from the mirror version of the hexagon at the same view or at a novel view. The two quadrilaterals were derived by splitting the hexagon along an intrinsic axis, which connected two opposite vertices of the hexagon. In Experiment 1, the hexagon was presented with one intrinsic axis parallel to the learning viewpoint and another intrinsic axis parallel to the orientation of an external rectangle misaligned with the learning viewpoint. The results showed that participants were quicker in recognizing the two quadrilaterals split along the intrinsic axis parallel to the orientation of the rectangle than those split along the intrinsic axis parallel to the learning viewpoint and were quicker at the same view than at the novel view. The intrinsic axis effect and the view change effect were independent. In Experiment 2, the external rectangle was removed. The results showed that participants were quicker in recognizing the testing quadrilaterals split along the intrinsic axis parallel to the learning viewpoint than those split along the intrinsic axis not parallel to the learning viewpoint and were quicker at the same view than at the novel view. The intrinsic axis effect and the view change effect were independent. These results suggest that people establish an intrinsic reference direction to represent the geometric structure of a shape using an available cue of an external frame or their egocentric viewpoint and also represent their egocentric learning viewpoint with respect to the same intrinsic reference direction.

43.333 **Prior experience affects amodal completion in bonobos**

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Nagasaka, Lazareva, and Wasserman (2007) reported that prior visual experience with geometric 2-D shapes affects pigeons' perception of partly occluded shapes (amodal completion). Here, we investigated the effect of experience on amodal completion in bonobos by adapting the methods used in the study of Nagasaka et al. Specifically, we explored amodal completion in bonobos by analyzing the errors they committed in the process of learning a 3-alternative simultaneous discrimination task.

Bonobos 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., a blue circle occluded a red triangle); the complete and incomplete stimuli comprised the single shape that had been partially covered in the corresponding occluded stimulus (e.g., a whole triangle or a partial triangle, respectively). The correct response was to select the occluded stimulus; the dependent measure was the percentage of errors to the complete stimulus. Bonobos were trained until they reached criterion with one set of stimuli; novel sets of stimuli were repeatedly introduced.

At the beginning of training, the percentage of errors to the complete stimuli was similar to the incomplete stimuli and did not differ from chance (50%). After repeated training with different shapes, the percentage of errors to the complete stimulus increased above chance. Moreover, when the bonobos were re-exposed to the initial set of training stimuli, they committed 90% of their errors to the complete stimulus. Background perspective cues on half of the stimuli did not influence discriminative performance.

These results suggest that the bonobos came to view the complete stimulus as being more similar to the occluded stimulus than the incomplete stimulus. Extensive experience with two-dimensional images appears to facilitate amodal completion of partially occluded stimuli in bonobos, just as is the case in pigeons.

43.334 **Artists Drawing Angles: An Expertise Approach**

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If we can economically characterize good drawing, we can identify effective training techniques for the novice, and explore the underlying conceptual models of the expert.

The authors propose angle accuracy as a measure of excellence in perspective drawing. Using this metric, we establish a robust expert-novice difference: when drawing a complex still life in perspective, experienced artists are significantly more accurate than novices in angle representation. However, the experts are no better (or worse) than novices when estimating planar angles simply from observation. In other words, experts demonstrate a clear advantage in execution of angles while there is no difference between experts and novices for a measure tapping into their perception of those same angles.

This suggests that training and practice improves accuracy in drawing angles—a domain-specific skill. Drawing expertise does not demand or create more accurate angle judgment overall.

Novices were unusually accurate when participants drew a teapot, in many cases as accurate as the experts. This suggests that while most people can cope with the ordinary, the advantage of a drawing expert may rest in the ability to render even the extraordinary.

When participants made angle judgments from a still life, another important difference emerged. Experts were indistinguishable from novices when they estimated the angles that certain edges projected onto the picture plane (an egocentric measure). When they estimated the geographical slant (an allocentric measure) of edges in the still life, experts were more accurate than novices, a difference that approached significance. Drawing experts may use a three-dimensional internal model of the still life rather than simply 'flat-mapping' it onto the picture plane.

Scene Perception 2

43.335 **Comparison of Gist Models in Rapid Scene Categorization Tasks**

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The capacity of humans to perform a number of complex visual tasks such as scene categorization and object detection in as little as 100ms has been attributed their ability to rapidly extract the gist of a scene. Existing models of gist utilize various types of low-level features, color (Ulrich & Nourbakhsh 2001), Fourier component profiles (Oliva & Torralba 2001), textures (Renniger & Malik 2004), steerable wavelets (Torralba, et. al. 2003), and a combination of these (Siagian & Itti 2007). Some of the methods compute feature histograms from the whole image, while others encode rough spatial information by using a predefined grid system.

Here, we systematically compare gist models with categorization tasks of increasing difficulty. We investigate how far these low level features can describe complicated real-world scenes.

With three outdoor test sites – a building complex (26368 training images, 13965 testing images), a park full of trees (66291/26397 images), and a spacious open-field area (82747/34711 images) - which provide visually distinct challenges, we first ask the question of which scene belongs to which site. As a baseline for comparison fo other models we used the classification rate of our combination model (95% success). Then we divide each site into nine distinct segments, to test finer classification ability (baseline of 85% success). We finally divide the segments into smaller geographical regions, making it an even harder to do scene classification as the regions become more similar visually. This, in turn, forces the competing systems to look for detailed attributes to exploit. The hypothesis is that each particular system (or more importantly, the features they use) will be able to distinguish some segments but not others.

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43.336 **Scene understanding using attentional control of gist and texture information**

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How do humans deploy attention to rapidly recognize a scene from scenic information across multiple scales? How can neural models capture this biological competence to achieve state-of-the-art scene classification? The ARTSCENE neural system models how scenic evidence can be efficiently accumulated to classify natural scene images. ARTSCENE embodies a coarse-to-fine Texture Size Ranking Principle whereby spatial attention processes multiple scales of scenic information, ranging from global gist to local properties of textures. The model can incrementally learn and predict scene identity by gist information alone and can improve performance through selective attention to scenic textures of progressively smaller size. ARTSCENE discriminates 4 landscape scene categories (coast, forest, mountain and countryside) with up to 91.58% correct on a test set, outperforms alternative models in the literature which use biologically implausible computations, and outperforms component systems that use either gist or texture information alone. Model simulations also show that adjacent textures form higher-order features that are also informative for scene recognition. The model can also be generalized to include other scenic predictors such as coherent objects.

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43.337 **Spatiotemporal influence of colour on scene gist perception**

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Humans can perceive the content (gist) in a scene under pre-attention conditions. Previous work has shown that low spatial frequency information dominates this perception (Schyns & Oliva, 1994). In addition, colour pop-out shows that colour can be perceived pre-attentively, and coarse-scale colour is thought to contribute to scene gist, but only when colour is diagnostic (i.e. predictive) of a scene category (Oliva & Schyns, 2000). Here we investigate the spatiotemporal influence of colour on scene gist. Two types of image are used within our study: natural scenes where colour is diagnostic for scene category (e.g. mountains, coastlines), and man-made scenes where colour does not influence scene categorization (e.g. roads, buildings). Subjects performed a two-alternative forced choice task to identify the category of the presented scene for both natural and man-made scenes. Scenes were shown in three different chromatic conditions: normal chromatic, monochromatic, or inverted RG/BY chromatic channels. Chromatic condition and the duration of scene presentation was randomized within and between blocks. Our data show that for short presentation durations (<150 ms), accuracy for natural scenes categorization is high for normal chromatic, but low for monochromatic and inverted chromatic channel scenes. In addition, reaction times are fastest for the normal chromatic condition. For the man-made images, accuracy and reaction times are equal in all three chromatic conditions. For presentation durations over 150 ms, accuracy is high and reaction times are low for all three chromatic conditions, irrespective on the type of scene used. Our conclusion is that although colour plays a role in defining the course scale spatial layout used within the initial onset of rapid scene gist perception of diagnostic natural scenes, other features are used in scene gist perception within non-diagnostic scenes categories, and at longer presentation durations.

43.338 **The Roles of Central versus Peripheral Visual Information in Recognizing Scene Gist**

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Scene gist recognition is a critical early scene perception process. Viewers reach asymptotic gist recognition with masked stimulus durations of 100 ms, and most important information is gathered within 40-50 ms. The rapidity of gist recognition raises the question, where does the most important information for gist come from, central vision or the periphery?

Method: We briefly flashed scenes in either “window” or “scotoma” conditions. A “window” is a circular region showing the central portion of a scene, and blocking out all peripheral information. A “scotoma” is an inverse window--a circular region blocking out all central information of a scene, and showing only information outside the circle. In several experiments, we varied window and scotoma sizes and measured their effects on scene gist recognition to determine the importance of central versus peripheral visual information. Experiment 1 compared windows and scotomas with radii of 1°, 5°, 10.8° and 13.5° in a 27° x 27° image. Experiment 2 compared windows and scotomas with equal areas of 4, 10, 40, or 100% in circular images. Experiment 3 estimated the cross-over point for window and scotoma accuracy functions, to determine the critical radius producing equal gist recognition.

Results: Our data suggests that central information is more useful than peripheral information for recognizing scene gist. Fewer centrally located pixels are needed to achieve the same scene gist recognition accuracy as peripherally located pixels. However, scenes can be recognized at an asymptotic level without any information from the central 5° of vision (the fovea and parafovea), if > 50% of image pixels are shown in the periphery. Furthermore, we identified a critical radius, perfectly dividing scenes into a central region and peripheral surround, each producing equal accuracy. The ratio of pixels in the central versus peripheral regions was approximately 3:7, suggesting parallels with cortical magnification.

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43.339 **The Superordinate Natural/Man-made Distinction is Perceived Before Basic Level Distinctions in Scene Gist Recognition**

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Scene gist recognition is a critical early stage of scene perception. It is often operationalized in terms of categorizing scenes, such as label verification. Since Rosch, et al.’s (1976) seminal study, it has been assumed that basic level distinctions are made prior to superordinate distinctions, and a number of basic level scene categories have been identified (Tversky & Hemmenway, 1983). However, recent research has called into question the primacy of the basic level. Rogers and Patterson (2007) showed an object categorization advantage for the superordinate level over the basic level for speeded decisions, and Fei-Fei, et al. (2007) showed the “Indoor/Outdoor” scene distinction was perceived at shorter SOAs than basic level distinctions. Importantly, the Spatial Envelope model of scene gist recognition (Oliva & Torralba, 2001) assumes that the superordinate level “Natural/

Man-made” distinction occurs prior to basic level distinctions, such as “Mountain,” “Forest,” or “Street.” The current study tested this assumption of the Spatial Envelope model.

Methods: We used a subset of Oliva and Torralba’s scene images and their 2 superordinate (Natural, Man-made), and 8 basic level categories. Using a post-cued category verification task, level of categorization (Superordinate vs. Basic) was a between-subjects variable (N = 80). Images were briefly flashed (12 ms), and masked at 5 SOAs (12-72 ms) along with a no-mask control condition. SOA was a within-subjects variable.

Results & Discussion: Accuracy was greater in the Superordinate (Natural/Man-made) task than the basic level task (p = .002), and there was a strong main effect of SOA. Of primary interest, the superordinate (Natural/Man-made) advantage was greatest at the shortest SOAs, and decreased as processing time increased (p <.001), consistent with the Spatial Envelope model’s assumption that the Natural/Man-made distinction is made earlier than more fine-grained basic level distinctions. Thus, more abstract categorical distinctions may be accessed earlier in scene gist processing.

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43.340 **The Opportunistic Use of Reference Frames for Rotating Scene Stimuli**

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Object-based transformations are spatial transformations in which the reference frame of an object is mentally updated relative to the egocentric and environmental reference frames. Perspective transformations are those in which the viewer’s egocentric reference frame is mentally updated relative to object and environmental reference frames. The two have been differentiated based on behavioral, neuroimaging, and neuropsychological data (Zacks & Michelon, 2005). For scene stimuli, picture plane rotation appears to invoke object-based rotation to upright, even when the task appears to require taking a novel egocentric perspective within the scene (Shelton & Zacks, 2007). In a series of experiments, we explored how different references frames might be used to define “upright” for a scene stimulus. We created different combinations of congruent and incongruent reference frames by varying the orientation of the local (computer) and egocentric (participant) reference frame relative to the gravitational reference frame. We interrogated the data to see which orientation was fastest for making left/right judgments about objects in the scene (e.g., “If you came in the door, would the lamp be to your left or right?”). We used the relationship between the fastest orientation and the orientations corresponding to the three reference frames to infer the subjective upright. In Experiment 1, the congruence of any two reference frames was sufficient to define upright. In Experiments 2 and 3, the three reference frames were always in competition, and the egocentric orientation was consistently fastest. Together, the results suggest that rotated scene stimuli invoke some degree of object-based rotation to upright even when taking a perspective in the scene, and upright can be defined in multiple reference frames. This upright can be defined opportunistically when multiple frames coincide; in the absence of coincident frames, the egocentric reference frame appears to dominate.

43.341 **Multiple fixations do not enhance spatial memory for scene layout**

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Memory for a view of a scene tends to include surrounding layout that was never presented (i.e. boundary extension; BE). In previous research, providing prior knowledge that memory for the view’s expanse would be tested, did not eliminate BE, but did attenuate it (Intraub & Bodamer, 1993). Why? Prior test knowledge might have caused an increase in fixations to regions near the picture’s boundaries, thus enhancing representation of peripheral layout. To test this, we presented 12 close-up photographs for 4 s each (allowing multiple fixations) or 250 ms each (preventing multiple fixations). SOA was held constant at 5 s by interspersing a mask between pictures. Stimulus duration was crossed with test instruction. All observers (N = 144) were instructed to remember objects and backgrounds for a “memory test”; what differed was whether the specific test instruction preceded (test-informed groups) or followed (test-naïve groups) the sequence. At test, the same 12 pictures were presented again and rated on a 5-pt scale (“much-closer [-2]”, “slightly-closer [-1]”, “same [0]”, “slightly-wider [1]” or “much-wider [2]”). As expected, in the 4-s condition BE occurred in both instruction conditions but was greater in the test-naïve group (M = -.39) than the test-informed group (M = -.22). However, this was also the case when duration was only 250 ms (test naïve: M = -.37; test-informed: M = -.28). An ANOVA revealed a main effect of instruction F (1,140) = 5.5, p<.03, no effect of duration, F<1 and no interaction, F<1. Surprisingly multiple fixations did not affect memory for the layout’s expanse. Given only a single fixation, the representation of layout also expanded beyond its physical limits, and was similarly moderated by prior knowledge of the test. Thus, BE attenuation appears to draw on a global process, rather than an increase in high acuity sampling.

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43.342 **Spatial biases in scanning and remembering scenes**

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There are various examples of rightward biases in mental representation (e.g., Pollatsek et al., 1981; Halpern & Kelly, 1993). We examined whether any such bias occurs in memory for constructions of spatial layout (boundary extension; BE). Stimuli were photographs of scenes with a salient object near the right view-boundary and one near the left view-boundary. Eye movements were recorded (EyeLink II) and stimuli were presented in normal and mirror-reversed orientations. In Experiment 1, trials included a 500 ms picture (observers maintained fixation), followed by a 2500 ms mask. The picture reappeared with view-boundaries repositioned and observers adjusted them to reconstruct the original view. BE occurred on both sides, but the error was 5% greater on the right [t(23) = 3.9, p <.05]. Might this reflect an asymmetrical distribution of attention? To test this, in Experiment 2, observers were allowed 10 s of free viewing per picture and the direction of the initial saccade was determined. There was a leftward bias [t(22) = 3.6, p <.05]; 62% of first saccades were to the left. Might this attentional bias influence object memory? In Experiment 3, a sequence of 40 pictures was presented. Observers maintained fixation on each 500 ms picture; a 2500 ms mask was presented in the ISI. A 60-item yes–no object recognition test followed (20 left-side objects, 20 right-side objects, and 20 new objects). Recognition was better for objects shown on the left sides of scenes than for objects shown on the right [left-side vs. right-side A’ values: 0.72 vs. 0.67; t(23) = 2.4, p <.05]. These results demonstrate a leftward bias of attention that improves memory for detail on the left side of a briefly presented scene, while at the same time providing less constraint on boundary extension for the right side of space.

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43.343 **Scene perception and memory revealed by eye movements and ROC analysis: Does a cultural difference truly exist?**

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A number of studies on scene perception and memory have suggested cultural differences in how people look at scenes and what they remember from the scene: Americans attend more to foreground objects whereas Asians attend more to the context (Chua, Boland & Nisbett, 2005; Masuda & Nisbett, 2001). We investigated the influence of culture by recording eye movements during scene perception, and we also examined memory performance. American and Chinese participants looked at pictures consisting of a focal object in a background context and gave ratings on the degree to which they liked each picture. This encoding phase was followed by a memory test in which the relationship between the focal objects and the contexts was fully crossed (old and new objects were tested in old and new contexts); eye movements were also recorded in the test phase. Participants indicated whether they had seen each focal object in the study phase, using a six-point confidence scale (“sure old” to “sure new”). Receiver operating characteristic (ROC) based analyses showed that memory accuracy was reduced when objects were tested in new rather than old contexts; participants were also less willing to say “old” to objects tested in new contexts. However, neither the decrease in accuracy nor the response bias shift differed with culture. The eye movement patterns, including fixation durations and numbers of fixations, were also similar across cultural groups. Both groups made longer fixations, and more of them, on the focal objects than on the contexts; this pattern was observed in both the encoding and test phases. The similarity of eye-movement patterns and recognition memory behavior suggests that both Americans and Chinese use the same strategies in this task (see also Rayner, Li, Williams, Cave, & Well, 2007), in contrast with prior reports.

43.344 The perceived trajectory of objects crossing the perceptual horizon in a 3-D scene

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We reported previously (VSS, 2007) that the perceived layout of objects and the relation between the judged size and judged distance of objects in a 3-D scene depends on the position of the objects relative to the perceptual horizon. We found that the perceptual horizon was determined by a weighted combination of the implied vanishing point and the termination of the visible surface texture. The present study examined the effect of the location of the perceptual horizon on the perception of an object's motion trajectory. Observers viewed scenes in which an elliptical object moved against a linear perspective background. The location of the perceptual horizon was varied by changing the height of the implied vanishing point and the height of the texture boundary. The object moved with a constant projected speed to a constant height along one of three linear motion paths: diagonal from lower left to upper right, diagonal from lower right to upper left or vertical from bottom to top. Observers were asked to judge whether the object had changed its motion path in 3D or traveled along a straight path. We found that the level of the implied vanishing point had a significant effect on the perception of a change in the motion path whereas the height of the visible surface texture did not have a significant main effect on observers' judgments. However, the height of the texture boundary interacted with the level of the implied vanishing point in determining observers' perception of the motion trajectories. These results suggest that the perceived trajectories of objects in a scene depend on the location of the perceptual horizon which is affected both by the implied vanishing point and by the height at which the ground surface terminates.

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43.345 A Multinomial Processing Tree Model of Change Blindness and Change Detection

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In most change blindness studies, the failure to report changes is attributed to either a representational failure (the pre-change scene is not represented in memory) or to a comparison failure (pre- and post-change scenes are not compared). Here, I propose a multinomial processing-tree (MPT) model, which determines the relative contributions of representational and comparison failures to change blindness, as well as the level of detail of the scene representation. MPT models are statistical models used to measure latent cognitive processes from observable raw data. Cognitive processes are represented as model's parameters, their respective weights can be assessed, and the fit of the model to the empirical data can be evaluated via goodness-of-fit tests (Batchelder & Riefer, 1999). The MPT model I propose assumes that visual information is either represented in memory or non-represented, and, if represented, that visual representation can be compared to the currently-displayed view or not. Here, I ran one change blindness experiment to test the model's predictions. Observers (N=144) were shown a map of a virtual village and had to perform a 7-stage route in the map. Changes occurred on task-relevant or task-irrelevant objects. Observers were instructed to complete the route as quickly as possible, and to report perceived changes. Results show that differences in change detection performances are due to the quality of representation in memory, which depends on object's relevance for the task, and not to a comparison process (the model's weighting of the memory representation parameter varies from 19% to 82%, whereas the weighting of the memory comparison parameters remains stable in the range from 28% to 38%). Moreover, the model showed that only a task-relevant representation theory could fit the data. Implications for several theories of scene representation (Hollinworth, 2004; Irwin & Zelinski, 2002; Rensink, 2000; Triesch et al, 2003) are discussed.

Monday, May 12, 8:30 am - 12:30 pm Poster Session, Royal Palm Ballroom 6-8

3D Space Perception
Attention: Crossmodal and Cognitive Effects
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3D Space Perception

43.401 Differences in feature vs object binding across depth: Evidence from grapheme-color synesthesia

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Grapheme-color synesthesia is a human phenomenon in which a letter or number (grapheme) evokes the visual perception of color. The color is most often described as existing in the mind's eye (non-projector synesthetes) and less commonly as existing in the same spatial location as the printed text (projector synesthetes). Data have been collected from 12 grapheme-color synesthetes and matched non-synesthetic controls from a novel psychophysical experiment we developed looking at the effect of depth as it relates to synesthetic color priming. Our findings replicate previous studies showing synesthetes, and not non-synesthetes, are faster to name the color of a target patch that is congruent to the synesthetic color evoked by an achromatic letter that precedes the target patch. Critically, projector synesthetes show an interaction between spatial depth (as produced by stereoscopic goggles) and reaction time that resembles a pattern for non-synesthetes viewing colored letters followed by color patches. The combined data from these two experiments suggest that the mechanism underlying form-induced color is similar to that which induces wavelength color in non-synesthetes. It further supports previous claims that synesthesia exists at one end of a spectrum of physiological and perceptual experience ranging from non-synesthetic to complete awareness of synesthetically induced percepts. We are following up this imaging data with structural MRI to look for correlations between behavioral performance, perceptual descriptions, and neuroanatomical differences.

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43.402 Visual performance fields are retinotopic

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Goals: Performance in tasks mediated by basic visual dimensions, such as contrast and spatial resolution, is not homogenous across the visual field. Specifically, performance is better at isoeccentric locations along the horizontal meridian than along the vertical meridian (Horizontal-Vertical Anisotropy, HVA), and along the lower than the upper vertical meridian (Vertical Meridian Asymmetry, VMA). Given the lower density of ganglion cells and faster decline of cone density with increasing eccentricity along the vertical than the horizontal meridian, and the greater cone and ganglion cell densities in the lower versus the upper visual field, it has been assumed that performance fields are retinotopically defined. However, ecological hypothesis stress the importance of the allocentric location of visual information. Here we investigated whether performance fields for tasks mediated by contrast sensitivity are retinotopic (eye-centered) or allocentric (display-centered) in origin.

Methods: Observers viewed briefly presented radial arrays of eight suprathreshold Gabors at four cardinal and four 45o intercardinal locations. They determined whether a target tilted relative to the homogeneously oriented distractor Gabors was present. To dissociate retinotopic coordinates from allocentric coordinates, observers performed the task both with their heads upright and tilted -45o (left). In addition, the orientation of the distractor Gabors was varied over experimental sessions, such that each participant viewed vertical (0o) distractor Gabors with tilted targets (±60o) and -45o tilted distractor Gabors with tilted targets (-105o, +15o) in both the upright and tilted head positions.

Results: Observers showed both the HVA and VMA in the upright head condition, replicating previous findings (Carrasco et. al., 2001). Critically, there was a -45o shift in both the HVA and VMA when observers' heads were tilted -45o, with performance fields corresponding to a horizontal and vertical meridian defined by retinotopic coordinates.

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43.403 Importance of proprioceptive and vestibular information for visual space anisotropy

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In previous research we showed that in darkness, physically shorter distances towards the zenith are seen as equal to physically longer distances towards the horizon. It remained unclear, whether this difference in distance estimates, is a consequence of a shift in the position of the body, of the head, or of the eyes. In order to answer that question, three experiments were performed. In each experiment participants had the task to equalize distances of three rectangular lightning stimuli, on three different viewing directions. In the first experiment, those three directions were horizontal, tilted 30 degrees relative to the horizon, and tilted 60 degrees relative to the horizon. In the other two experiments, viewing directions were horizontal, tilted 45 degrees relative to the horizon and vertical. Participants in all three experiments performed estimates while sitting on the floor, in a dark room. In the first experiment there were 14 participants with their head and body fixed (using chin-rest), in the second there were 15 participants with their body and eyes fixed (using chair and special glasses with 1mm wide horizontal aperture), and in the third there were 16 participants with their eyes and head fixed (using special glasses and an automobile seat). Results first showed that for near distances, such as 1m, visual space is isotropic, and that anisotropy appears for distances over 3m. Data also showed that the head and body tilt elongates the visual space towards vertical direction (physically shorter distances towards the zenith are seen as equal to physically longer distances towards the horizon), but angular turns of the eye compress visual space towards vertical direction. According to that, we can conclude that the visual system, for distance estimates, uses additional information, proprioceptive (information from neck and eye muscles) and vestibular, but with different weights.

43.404 Exploring the Time Course of Egocentric Distance Perception with Visual Masking of a Real-World Environment

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Previous research has established that humans can walk without vision to previewed targets without large systematic error, and that they can do so with equal accuracy under brief (150 ms) and extended (>5 sec) viewing conditions. The present study determined the duration of viewing required to support accurate blindwalking performance, and began investigating the availability of distance and depth cues at the earliest stages of viewing. Participants binocularly viewed targets through a liquid crystal shutter that provided precisely-controlled glimpses of a real, naturally-lit indoor room. Glimpse durations were 50, 100, or 200 ms, after which there was either a visual mask or no mask. In Experiment 1, participants walked to a cone placed on the floor, 3-5 m distant. Performance was relatively good and equivalent at all three exposure durations (-10% error) but declined modestly in the 50 ms viewing condition when the masking stimulus was imposed. The results indicate that the cues required to support good blindwalking performance are available at or near the shortest manipulated time frame. In Experiment 2, the cues of relative size and angular declination were removed by suspending ball targets at eye level and by holding the angular target size constant. Performance was generally poorer (-20% error) than Experiment 1, and walked distance was not affected by target distance in the 50 ms viewing condition when the masking stimulus was imposed. However, performance improved systematically with increased exposure duration, suggesting that, unlike in Experiment 1, the cues provided by this context were not yet fully available at the shortest manipulated time frame. The study not only indicates a lower limit on the duration of viewing needed to support good blindwalking performance, but also suggests that different sources of information about distance and depth may take longer to extract.

43.405 Exploring the effects of self-representation on spatial perception in immersive virtual environments

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To what extent does providing people with a low-latency, fully tracked, geometrically detailed and faithfully-sized avatar representation of themselves within a head-mounted display (HMD)-based immersive virtual environment (IVE) affect the accuracy with which they estimate egocentric distances within that environment?

Previous studies have found that under most common conditions, people tend to understimate egocentric distances in IVEs, yet the reasons this underestimation occurs remain poorly understood. One theory is that, due to the many inherent uncertainties in being immersed in a novel virtual environment, people hesitate, at least initially, to assume that they can act on the visual stimulus provided by the HMD in the same way as they would act on the equivalent visual stimulus obtained in the real world. This suggests that we might be able to facilitate accurate spatial perception in IVEs by reducing these uncertainties.

In particular, although previous studies have shown that peoples' default ability to accurately judge egocentric distances in the real world is not impaired when they are prevented from looking down and viewing their bodies, it remains unknown what effects might result from providing people with a plausibly realistic self-embodiment in an IVE.

We have developed low-overhead methods for locally re-sizing a predefined avatar model to conform to an individual's body measurements. Using a 12-camera Vicon MX40+ tracking system, we can dynamically update the position of the avatar according to the movements of the person in real-time. In this poster we will present the results of a between-subjects experiment in which people are immersed in a novel IVE either with or without an avatar self-representation and are asked to indicate distance judgments via blind-walking to randomly-placed targets. To facilitate the between-subjects comparison, each participant's distance estimation accuracy in the virtual environment is measured relative to his/her baseline accuracy in the real world.

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43.406 The role if immersion in three-dimensional spatial processing

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The majority of experimental studies on three-dimensional (3D) visual-spatial processing have been conducted using traditional 2D displays. We were interested in the contribution of immersion to 3D image transformations and compared subjects' performance on spatial transformation tasks within traditional 2D, 3DNI (stereo glasses), and 3D-immersive (3DI –head mounted display with position tracking) environments. Fourteen participants completed a Perspective-Taking Ability (PTA) test where they imagined transforming their own perspective to a figure's perspective in a computerized scene and pointed to one of the several objects in the environment from the figure's perspective. In addition, 11participants completed Shepard and Metzler Mental Rotation Task (MRT), in which they mentally rotated 3D objects along the picture (X), vertical (Y), or depth (Z) axes. While the patterns of subjects' responses were not significantly different in 2D and 3DNI environments, we found a unique pattern of responses in the 3DI environment, suggesting that immersion trigger significantly greater use of egocentric object coding and visuo-motor strategies than the two other non-immersive environments. Specifically, for PTA, subjects made significantly more egocentric errors (e.g., errors related to body-coordinate system, such as confusion between right-left and back-front responses) than in the two other environments suggesting that 3DI triggered more egocentric coding. Furthermore, for MRT, while no differences were found between X-axis and Z-axis rotation in 2D and 3DNI environments, in 3DI, Z-axis rotations took significantly longer than X-axis rotations suggesting the greater use of visuo-motor strategies. Overall, our findings point out that 3DI environments are different from 3DNI and 2D, and that immersion is necessary to provide adequate information for building the spatial reference frame needed for motor planning and egocentric encoding.

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43.407 Angle of declination manipulations and their effects on distance judgments in virtual environments

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The angle of declination from the horizon to a location on the ground plane is considered to be an effective absolute distance cue when scaled by eye height. We manipulated this visual cue in two different ways to determine if the two different manipulations had similar effects on distance judgments in a HMD-based virtual environment. We measured distance judgments using a direct blind walking task to targets on the floor at 3 to 6 m. In the first manipulation, the image displayed in the HMD was shrunk by 30%. This has the effect of reducing the visual angle between the implicit horizon defined by perspective cues in the image and locations of interest on the floor. In the second manipulation, the virtual environment was tilted up 5.7 degrees, reducing the angle between gravity-indicated level and locations of interest on the floor. The amount of tilt was chosen to approximately match the angular change due to making the image smaller. For correctly displayed images, distance judgments in HMD-based virtual environment are substantially compressed. Shrinking the image led to distance judgments that were 98% of the intended distance, in contrast to 80% in the control condition, (F(1,21)=5.94, $p<0.05$). For the tilted condition, subjects' distance judgments were 84% of the actual distance and did not differ significantly from the control condition (F(1,21)=0.03, p=0.86). This work points to the importance of considering the frame of reference for the angle of declination distance cue. More generally, it suggests that some manipulations of perspective information for depth may have greater effects than others. The results also have implications for how displayed images might be modified to make spatial judgments in HMD-based virtual environments more accurate.

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43.408 Estimation of Distance on Flat and Uphill Terrains Using Visual Matching and Blind Walking Task

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We tested whether participants in a natural environment judged distances up a hill to be different from that on a flat ground and whether the same distance would be estimated differently by perception or action tasks. The experiment was conducted in an outdoor environment with both flat and uphill (8 degrees) terrains. In Experiment 1, participants first viewed a target distance (6, 8, 10, 12, or 14 m) on a flat ground or on a hill and then produced that distance through blind walking task (BWT), again either on the flat ground or uphill, with a total of four stimulus-response (view-walk) combinations (flat-flat, flat-hill, hill-flat and hill-hill). The results indicated that participants significantly overshot distance when they first viewed a distance on the flat ground and then walked uphill. This overshoot was not seen in the other three conditions. In Experiment 2, following a visual preview of target distances, in addition to responding by walking, participants also matched two self-to-target distances by verbally instructing an experimenter to position a target at a distance representing the previewed distance. While the overshoot in BWT was seen again in uphill walk following the preview on flat surface, the overestimation was not seen in distance matching task. The overestimation in uphill condition was also not found in Experiment 3, in which participants were given a distance value then were asked to produce that distance by adjusting their self-to-target distance in either flat ground or uphill condition. The results of these three experiments suggest that the overshoot might not be due to errors in the perception of target distance on a hill; instead it might be the result of errors in perceptual motor transformation during a less familiar mode of motor action (walking uphill) when the terrains are different during stimulus and response.

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43.409 Comparison of rope-pulling and blindwalking as measures of perceived egocentric distance

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Pulling a length of rope between the hands could potentially be used to indicate the perceived distance of objects. Like blindwalking, this response requires integration of body motion between limbs, but unlike blindwalking, it does not require locomotor ability or updating changes in one's location into a representation of the environment. These differences make rope-pulling an attractive alternative for measuring distance perception (e.g., in brain-injured patients, or when holding vestibular cues constant is of interest). Here, we assessed whether rope-pulling is indeed responsive to perceived distance by observing whether it shows a similar pattern of errors as blindwalking when egocentric distance cues are removed.

Participants (n=13) previewed targets in 3 viewing conditions: (1) Full Cue: binocular viewing of ground-level targets in a well-lit room. (2) Floor Occlusion: monocular viewing of ground-level targets under low lighting conditions. A box occluded the nearby ground-plane. (3) Reduced Cue: monocular viewing of glowing eye-level targets in an otherwise dark room. Targets were placed at 2.5, 3.5, 4.9, or 6.9 m. After viewing the target, participants donned a blindfold and indicated target distance by: (1) blindwalking to the previously viewed target location or (2) pulling a rope hand over hand to match the perceived target distance.

Responses using the two behaviors were highly correlated. More importantly, a nearly unchanging relationship existed between the two behaviors as distance cues varied. One-way ANOVA on the slopes and intercepts of the best-fitting lines relating walking to rope-pulling showed no significant differences between viewing conditions (slopes: F[2,36] = 0.08, p = 0.9; intercepts: F[2,36] = 0.19, p = 0.8). Thus, we found no indication that rope-pulling and blindwalking are controlled by distinct representations. Given previous evidence that blindwalking is controlled by perception (Philbeck & Loomis, 1997), we conclude that rope-pulling is, as well.

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43.410 Visually directed walking to targets viewed with severely degraded vision is surprisingly accurate

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In low vision navigation, an essential ability is the accurate judgment of object locations in the environment (Ludt & Goodrich, 2002). We investigated absolute distance perception in normal vision and simulated low vision conditions to ascertain the perceptual capabilities of individuals with profound low vision. Participants were normally sighted and tested monocularly in two conditions. In the first block of trials, participants wore goggles with stick-on blur foils, resulting in a tested acuity between 20/900 and 20/2000. In the second block of trials, participants wore goggles with clear flat lenses. Participants remained naïve to the test room until after the low-acuity condition was performed. The test room was 19′ x 22′ and brightly lit. Targets were two sizes of bright orange traffic cones, located on the ground-plane at egocentric distances of 2, 2.5, 3, and 3.5 meters. In some trials, no target was present. On each trial, subjects were asked if they could see the target. If they responded affirmatively, they walked blindfolded to the apparent target location while an experimenter moved the cone out of the way. Even though in the low vision condition the orange cones appeared as barely detectable orange blobs, group-averaged data exhibited near accuracy in walked distances. Walked distances in the normal acuity condition were also accurate, consistent with many other studies, with the between-subject variability somewhat less than for the reduced acuity condition. The room in which the experiment was conducted had a molding around the floor that was visible even while wearing the acuity-reducing goggles. Future work will examine if this provided a visual context allowing use of perspective information to estimate distance, even with severely degraded vision. The effects of varying the target distances, target types, and lighting conditions will also be considered.

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43.411 Demand characteristics, not effort: The role of backpacks in judging distance

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Does wearing a backpack increase perceived distance, or does it simply encourage subjects to increase numerical estimates? We first administered a questionnaire to students describing an experiment in which subjects were required to wear a backpack while making distance judgments. Nine of 14 subjects stated the “correct” (signed) hypothesis; the other five made an unsigned prediction. This indicates that the backpack hypothesis is transparent. We next manipulated the transparency of the manipulation. Subjects (N = 68) made distance judgments in a virtual hallway viewed through a head-mounted display. In the explicit burden condition subjects were told they would be wearing a heavy backpack while making distance judgments. In the implicit condition, the same heavy backpack was worn, but it was described as being part of the equipment necessary to operate the virtual reality (indeed the video box for the HMD was inside the backpack). A no-backpack control condition was also run. Because subjects made judgments in two different virtual environments, we expected that people in the control and implicit conditions would believe that the experiment concerned possible differences between the two environments. However, we expected people in the explicit backpack condition to believe that they were to judge distances as farther than they were. Based on an earlier replication of the backpack experiment outdoors with a male experimenter, we only expected to find evidence of demand compliance among women subjects. This prediction was borne out: Only female subjects in the explicit heavy-backpack condition showed an increase in distance estimates. Wearing a heavy backpack that was described as part of the VR equipment had no effect. We conclude that effects of backpacks on judgments of distance are probably due exclusively to demand characteristics and not to any actual change in perception when burdened.

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43.412 Changing spaces: Body size influences the perception of aperture width

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Previous research has shown that changing the body can influence the perception of distances in near space (Witt, Proffitt, & Epstein, 2005). In this set of experiments, we found that changes in body size altered the perception of the width of an aperture. In Experiment 1, participants were randomly assigned to either hold a large exercise ball or not. All participants’ perception of the width of the apertures was assessed using a visual matching measure. Those participants who held the exercise ball estimated the width of the aperture to be smaller than those who were not holding the ball. In Experiment 2, we asked participants to perform the same task, but this time their body size was altered by wearing a different object, a 45-inch rod that extended across the participants’ bodies. In contrast to the previous findings, participants who wore the rod overestimated the size of the aperture compared to participants who did not wear the rod. In Experiment 3, we assessed whether the perception of body size was accurate when holding the exercise ball and the rod. A group of participants estimated the width of their bodies (when holding the ball, when holding the rod, and when holding nothing) by visually estimating their width with a matching task and by drawing a representation of their width on a white board. Findings showed that participants overestimated their width when holding the ball and underestimated their width when holding the rod. The results suggest that the perception of body size plays a role in the estimation of the width of apertures and that the direction of change is dependent on participant’s perception of their width when holding different sized objects.

43.413 Studying the relationship between emotion and height perception in naturalistic settings

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This study analyzed the relationship between emotion and the perception of heights, in naturalistic settings, where participants would experience more fear and anxiety than could be evoked in the laboratory. Previous research has shown that people overestimate height more from the top than the bottom, especially when they are afraid of heights (Stefanucci & Proffitt, 2007). Participants in this study were 19 college students enrolled in an outdoor adventure course (experiment group) and 20 college students not enrolled in the class (control group). At various points in the semester, participants in the experiment group flew across a lake on a zip line and rappelled off of a four- story parking garage while secured by a harness. The procedure for the experiment and control group was matched except that participants in the experiment group actually jumped from the heights. Participants in both groups completed surveys before exposure to the height about their current emotions and their fear and anxiety about heights. On site, during exposure to the height, participants in both conditions completed a height matching task where they positioned an experimenter to be the same ground distance from them as they were from the height they were viewing. Participants in both conditions viewed a height from the top and the bottom. Participants also completed the Subjective Units of Distress Scale to assess their on-site excitement and fear. After the participants were exposed to the height, they again completed surveys about their memory for emotions during exposure, and their current emotions about heights. We found large differences in the fear experienced at the height in the experiment versus control groups and perceptual estimates were slightly higher in the experiment group. This study, when combined with earlier laboratory research, bolsters our understanding of the relationship between emotion and the perception of heights.

43.414 What sculpted depictions of 3-D objects reveal about visual and haptic mental representations

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When we sculpt an object, what aspects of the object’s geometrical information are depicted and to what extent? Furthermore, what can the statistical geometric properties of these depictions tell us about our mental representations of 3-D shape? Vision and haptics are largely responsible for our perception of 3-D shape. Past work has shown that our visual and haptic systems do not work congruently. Historically, art literature has suggested that what we perceive is often inharmonious with the real world. Previously, we examined the production of line drawings as a means to measure only visual perceptual ability. The present study examines visual and haptic perceptual differences using globally convex natural shaped 3-D objects. Sculpting objects relies on a direct mapping of three-dimensional information without the need for two-dimensional projection as in drawing. Participants were asked to sculpt objects based only on visual or haptic information. Two hands and normal vision were allowed for the actual sculpting. A stimulus set of 25 target objects was specified with a parametric range of statistical properties and manufactured with a 3-D printer. Each object’s shape differed in spatial frequency and amplitude. The human-sculpted objects were scanned in 3-D and statistically compared to the original stimuli. An interaction was obtained between modality and ability with respect to object frequency. An object with a higher spatial frequency was harder to sculpt when limited to haptic input as compared to only visual input. The opposite was found for an object with a low spatial frequency. An associated visual-haptic comparison experiment, with the same stimulus set found complimentary results. The finding that perceptual abilities of our visual and haptic systems differ, suggests that each system creates a different non-universal mental representation of 3-D shape.

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43.415 Metric Shape Perception Requires A 45° Continuous Perspective Change

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Introduction: Bingham and Lind (in press) have recently shown that Euclidean structure is perceived accurately with large perspective changes, namely a continuous 45° rotation. Their results were obtained by testing the perception of elliptical cylinders. Questions remain. First, it is unclear whether any 45° of perspective change or only a change to a 45° view of the major axis of the ellipse is important. A second question is whether performance would improve in proportion as more perspective change is provided. We investigated both questions. Methods: A 3D cylindrical object was shown with stereo and structure-from-motion and then, a 2D ellipse appeared on the computer screen. By pressing computer keys observers adjusted the shape of the ellipse so as to match the shape of the top of the object. In Experiment 1, we compared full and half rotation conditions. In the full condition, the object was rotated by 45° to one side from a canonical view looking straight down the major axis so that a 45° view of the axis was shown. In the half condition, the object was rotated by 22.5° to either side from a canonical view so that the perspective was changed by a total of 45° but the axis was not viewed from 45°. In Experiment 2, we used different rotation amounts, 11.25°, 22.5°, 30°, 37.5° or 45°. Results: The results of Experiment 1 showed that there was no difference between the two rotation conditions. In Experiment 2, we found that the only significant difference occurred between the three smaller perspective changes (11.25°, 22.5°, and 30°) and the two larger perspective changes (37.5° and 45°). Conclusion: Performance does not improve in proportion as more perspective change is provided and any 45° of continuous perspective change is both sufficient and necessary to perceive metric shape accurately.

43.416 **Playing Air Guitar Eliminates Effect of Ability on Perceived Distance**

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Perceived distance is influenced by the perceiver's ability to perform the intended action. For example, targets that are just beyond arm's reach look closer when the perceiver intends to reach to the targets with a tool (Witt, Proffitt, & Epstein, 2005). Experiments such as these demonstrate that perception is influenced by motor processes. An obvious question is to ask about the underlying motor process that can penetrate perceptual processes. We propose a motor simulation: participants simulate the intended action, and the outcome of the simulation (e.g. if the target is within reach) influences perception. We test this idea of motor simulation using an interference paradigm. Musicians estimated the distance and reached to targets with a tool, so the targets were within reach and therefore should look closer. However, some of the musicians listen to music played by their own instrument while performing the task. The idea is that these musicians cannot help but play along in their minds, so they did not simulate reaching with the tool. Without the outcome of the simulation to inform perception about the person's reaching capabilities, perceived distance should not be influenced by use of the tool. Consistent with this prediction, we found that musicians who listened to music played in their own instrument perceived the targets to be farther away than musicians who listened to music played by another instrument. These results suggest that motor simulation is one of the underlying processes that relates a person's ability to the perception of distance.

Attention: Crossmodal and Cognitive Effects

43.417 **Social and emotional biases increase with monetary incentives through attentional inhibition**

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The present study investigated how attentional selection and monetary incentives influence social and emotional judgment on unfamiliar faces and scenes. Attentional selection was modulated with a Go/No-Go task. A transparent color cue was superimposed on the face or scene stimuli. The participants responded when the Go cue appeared and inhibited their responses when the No-Go cue appeared. In the following evaluation task, the participants evaluated the trustworthiness of faces and the beauty of scenes. In Experiment 1, when monetary incentives were absent, no evaluation bias was observed on the Go trials. Only on the No-Go trials, the participants evaluated the uncued face more trustworthy than the cued one. When monetary incentives were given, however, evaluation bias was observed on both the Go and No-Go trials. On the Go trials, the uncued faces were evaluated less trustworthy and the uncued scenes were evaluated less beautiful. In addition, the participants evaluated the uncued face more trustworthy on the No-Go trials. The results of Experiment 1 implied that social-emotional traits of stimuli were devalued when the stimuli were inhibited by attention and this devaluation effect could be strengthened with monetary incentives. Experiment 2 was conducted to determine whether the devaluation effect in Experiment 1 was due to strengthened attentional selection. In Experiment 2, attention was directly modulated by endogenous arrow cues. When a valid arrow cue was present, the participants showed evaluation bias on both the Go and No-Go trials with face stimuli, which was similar to the results of trials with monetary incentives in Experiment 1. Taken together, these results suggest that evaluation of stimuli can be biased by attention and that monetary incentives can strengthen attentional effects on social and emotional judgment.

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43.418 **The influence of odor on perception of emotional stimuli**

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Emotion can play a major role on how we allocate our attention to relevant stimuli. Pereira et al. (2006) have shown longer reaction times, in a target detection task, when participants were exposed previously to unpleasant images; on the other hand, faster reactions times occurred when pleasant images were presented, suggesting an activation of appetitive motivational systems. The present study was aimed to investigate how odor affects performance in a 2-AFC paradigm proposed by Erthal et al. (2005). A central picture, taken from the International Affective Picture System (Lang, 1999), was presented briefly (200ms) flanked by two peripheral bars. The bars were located 10o to the right and left of the center of the screen with five possible orientations (0o, 6o, 11o, 22o and 45o). Participants (n=6) were asked to respond (key presses) whether or not the bars had the same orientation. The experiment consisted of three blocks; in each block a single type of picture (neutral, pleasant or unpleasant) was presented. There were two experimental sessions, control and appetitive odor (lemon oil). Experimental sessions were carried out in a counterbalanced way. Replicating Pereira et al. (2006), participants showed longer reactions times to trials in the unpleasant block in both sessions. However, participants were overall faster to respond during the appetitive odor session. This suggests that attentional resources are modulated both by positive pictures and appetitive odor resulting in an increased performance for this condition.

43.419 **How's My Hat? Effect of Emotional Expression**

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In the current study, participants had to decide whether a hat was centered on a head. The expression of the face was irrelevant to the task. There are numerous studies (e.g., Eastwood, Smilek, & Merikle, 2003; Fenske, & Eastwood, 2003; Valdes, Rutledge, Miles, & Olah, 2006) that have found that people are less able to ignore sad faces than happy faces. It was hypothesized that participants would take longer to judge the location of the hat when the face was sad. There were five expressions: happy, sad, embarrassed, neutral and angry. The faces were composites of an actual male and female face. The embarrassed expression was excluded from any analyses because the face was asymmetrical. The overall accuracy was high, 96 percent. The average response latency for correct responses was submitted to a 3 x 4 (location by expression) ANOVA. Only the main effect for expressions was significant, $F(3, 36) = 13.94$, $p <.05$. Post hoc analyses indicated that judgments about a sad face were significantly slower (730 ms) than the other conditions. A replication is planned with gendered faces. Some emotions are more likely to be associated with particular genders. For example people are more likely to view women as sad and men as angry (e.g., Condry & Condry, 1976; see Hyde, 2007 for review of gender as a stimuli). It is hypothesized that making judgments about women's sad faces will be slower than men's sad faces because of the automatic activation of this gender stereotype.

43.420 **Do the hands shift the eyes?**

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Bimodal visual-tactile receptive fields have been found attached to body parts, such as the hand. Later studies have shown that visual attention has been modulated by the nearby presence of a hand. Based on the evidence for oculomotor control of visual spatial attention, we asked whether the attentional modulation produced near the hand is integrated into the oculomotor system/saliency map. Subjects were tasked with fixating a spot on the screen. That spot disappeared as another appeared and subjects shifted their gaze to the new spot. In one experiment, on half of the trials, the subject's hand was placed near the midpoint of the saccade trajectory, palm facing towards it. On the other half of the trials, the subject's hand was placed on the lap. In a second experiment, on half of the trials the subject's hand was placed near the midpoint of the saccade trajectory, palm facing towards it. On the other half of the trials, the hand was again placed near the midpoint of the saccade, however the palm faced away from it. We analyzed the metrics of the saccades to see if hand proximity and palm/back of hand facing affected saccade trajectories. If attentional modulation produced by the hand is independent of oculomotor control of visual spatial attention, then hand proximity and facing should have no effect on saccade trajectories. However, we find effects of hand position on saccade trajectories, suggesting that the bimodal visual-tactile receptive fields are part of an integrated visual spatial attention mechanism controlled by the oculomotor system.

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43.421 **Endogenous selective attention to opposite-moving spectral components influences aftereffects in vision and audition**

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Goals: Endogenous selective attention to one of two competing visual motion signals of the same spectral composition skews the ensuing motion aftereffect (MAE) in favor of the attended signal (e.g., Lankheet & Verstraten, 1995; von Grunau et al., 1998). We studied this effect with competing signals of different spectral composition in both the visual and auditory modalities.

Methods: Adaptation stimuli comprised two competing motion signals of different spectral features moving in opposite directions. The visual adaptation stimuli consisted of sinusoidal gratings at 0.5 and 2 cycles/degree; the test stimulus was at an intermediate frequency. Non-overlapping auditory adaptation stimuli contained four low-frequency 'C' (131-1,046Hz) and four high-frequency 'F#' (1,475-11,840Hz) notes. The test stimulus contained five intermediate-frequency 'D' notes (294-2,349Hz); the range of the test notes overlapped the two adaptation ranges equally in the log (frequency) scale. Within a block of trials, subjects attended to the motion signal carried by low (or high) frequencies during adaptation. The direction of attended frequency was randomized across trials. Subjects reported the direction and duration of the ensuing MAE. We measured static and dynamic durations for visual MAE; nulling strength and duration for auditory MAE.

Results: Attention to spectral features played a significant role in modulating the ensuing MAE. A significant attentional modulation of auditory MAE was observed with both measures. The visual MAE direction was consistent with the frequency contingency of MAE (Shioiri & Matsumiya, 2006): low/high spatial-frequency adaptation signals dominated the dynamic/static MAE. However, there was a significant attentional modulation of MAE duration.

Conclusions: Our findings that selective attention to one of two spectral components that move in opposite directions during adaptation influences the subsequent MAE complement earlier findings of same-frequency adaptation in the visual modality, and extend these findings to the role of attention in the auditory modality.

43.422 **A Comparison of Spatial Attention and Representation in Vision and Audition**

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Neurologically normal observers demonstrate a small but significant leftward shift in the perceived midpoint of visual stimuli such as lines, a phenomenon called pseudoneglect (Jewell & McCourt, 2000). This leftward bias is attributed to a surplus of spatial attention deployed into left hemispace by the right hemisphere, which is dominant with respect to the control and allocation of spatial attention. It is presently unknown to what extent a similar asymmetry might exist for spatial stimuli presented via the auditory modality. If asymmetries arise at a site where space is represented amodally, then leftward bias should be independent of modality. On the other hand, if spatial attention is modality-specific, bisection error for visual and auditory objects might be dissociable. Moreover, visual attention is deployed across the visual field (200o), whereas auditory spatial attention can be deployed panoramically (360o). Healthy dextral subjects (N=21) performed an auditory interval bisection task. In the auditory bisection task the spatial interval to be bisected was defined by a sequence of two complex tones (200 and 400 Hz squarewaves; 300 ms duration) separated by 22o of angle. Subjects judged whether the location of a third, sequentially presented, complex tone (300 Hz) was leftward or rightward of the center of the spatial interval defined by the first two tones. Subjects performed the auditory bisection task when facing toward and away from the speaker array, allowing an index of attentional asymmetry in both front and back space. Subjects also performed a standard tachistoscopic visual line bisection task (McCourt & Olafson, 1997; McCourt & Jewell, 1999). A significant leftward bias was found in the visual bisection task, whereas significant rightward biases were found in the auditory bisection task, in both front- and back-space conditions. The results suggest that spatial attention is modality specific.

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43.423 **Neural Dissociation between Visual Awareness and Spatial Attention**

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To what extent does what we consciously see depend on where we attend to? Psychologists have long stressed the tight relationship between visual awareness and spatial attention at the behavioral level. However, the amount of overlap between their neural correlates remains a matter of debate. We recorded magnetoencephalographic (MEG) signals while human subjects attended toward or away from faint stimuli which were reported as consciously seen only half of the time. Visually identical stimuli could thus be attended or not, and consciously seen or not. Although attended stimuli were consciously seen slightly more often than unattended ones, the factorial analysis of stimulus-induced oscillatory brain activity revealed distinct and independent neural correlates of visual awareness and spatial attention at different frequencies in the gamma range (30-150 Hz). Whether attended or not, consciously seen stimuli induced increased mid-frequency gamma-band activity over the contralateral visual cortex, while spatial attention modulated high-frequency gamma-band activity in response to both consciously seen and unseen stimuli. A parametric analysis of the data at the single-trial level confirmed that the awareness-related mid-frequency activity drove the seen-unseen decision, but also revealed a small influence of the attention-related high-frequency activity on the decision. These results suggest that subjective visual experience is shaped by the cumulative contribution of two processes operating independently at the neural level, one reflecting visual awareness per se and the other reflecting spatial attention.

43.424 **Misdirecting people's attention: What can misdirection tell us about attention and awareness?**

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Magicians use misdirection to prevent their audiences from detecting their secrets. We designed a magic trick that could be used to investigate the way in which attention can be manipulated to prevent people from perceiving a visually salient event. By digitally manipulating this trick we demonstrate that participants' verbal reports reflect what they have seen rather than inferences about how they thought the trick was done. Moreover, eye movement records revealed that for a subset of participants, the detection of the event was not related to where they were looking at the time of the event. These results demonstrate a striking real world example of how overt and covert attention can be spatially dissociated. However, detection of the event resulted in rapid shifts of eye movements towards the detected event, thus indicating a strong temporal link between overt and covert attention. However, rather surprisingly, these results suggest that covert attention can be allocated at least 2 or 3 saccade targets ahead of where people are fixating.

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URL: http://www.dur.ac.uk/gustav.kuhn/

43.425 **It's about time: why right spatial neglect is mild**

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Neglect of right visual space arising from left hemisphere lesions is typically milder than the converse circumstance (left neglect from right hemisphere lesions). Recent theories of left neglect suggest that non-spatial deficits play a crucial role in the disorder. One potential explanation for the more mild nature of right spatial neglect would suggest that these patients may not demonstrate the same impairments in non-spatial functions that are evident in left spatial neglect. We examined this hypothesis in one patient (HW) with a posterior cerebral artery stroke affecting temporal and occipital cortex and the posterior thalamus.

Patient HW demonstrated mild right spatial neglect on line bisection and figure copying tasks. We then tested his perception of time on two tasks. The patient first had to estimate the duration (to the nearest second) of visual events presented for intervals of 5, 15, 30, or 60 seconds. Left spatial neglect patients demonstrate a characteristic performance on this task such that they massively underestimate all durations. The second task provided an auditory analogue to the visual time estimation task with the patient asked to estimate the duration of newspaper stories read aloud for durations equal to those used in the visual task. HW demonstrated normal estimates of visual events. For the auditory task he consistently overestimated durations and demonstrated a far greater degree of variance. We suggest that right spatial neglect is mild due to the absence of non-spatial deficits including the temporal perception of visual events.

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43.426 **The effects of stimulus-salience in object-substitution masking**

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Object-substitution masking (OSM) occurs when all items in a visual-search display are flashed briefly, with the masking stimulus surrounding the target remaining on view alone. Two experiments investigated how stimulus-salience affects OSM. The salience of target and nontarget items in a search display was manipulated through color. In Experiment 1, on a random one third of the trials the target was uniquely colored, making it highly salient; on one third of trials one nontarget was uniquely colored; on the remaining trials, no items were uniquely colored. We predicted that when the target was salient, target localization and identification would be facilitated, and OSM would be reduced. In contrast, we predicted that when a salient distractor was present target localization and identification would be hampered, and OSM would be exacerbated. This general pattern was observed in Experiment 1. In Experiment 2 we asked whether these salience effects were stimulus-bound or were contingent on top-down strategies. Experiment 2 was identical to Experiment 1, except that only one nontarget was uniquely colored. Color was thus task-irrelevant. Results showed that distractor salience influenced performance only when the mask and target terminated concurrently (i.e., trailing-mask-duration of 0 ms.). Critically, performance was not influenced by salience when a trailing-mask was presented. These results show that stimulus-salience influences OSM only when salience is task relevant. This is consistent with the idea that only task-relevant information contributes to the creation of a perceptual hypothesis.

43.427 **Asymmetry in object substitution masking occurs relative to the direction of spatial attention shift**

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A lateral mask persisting beyond the duration of a target can reduce its visibility (object substitution masking: OSM). Y. Jiang and M. M. Chun (2001) reported that a mask on the peripheral side of the target caused stronger OSM than on the central side. Assuming that spatial attention was focused on the target, the peripheral and the central masks were always located in the same and the opposite direction of an attentional path with reference to the target in their study. We hypothesized that the asymmetry of OSM relies on the asymmetry of mask configuration relative to the attentional shift. To test this, we conducted four experiments among which the presence or absence of the relative center-periphery relationship and the presence or absence of the asymmetric mask configuration were manipulated independently and orthogonally. In Experiment 1, we successfully replicated the asymmetric OSM discovered by Jiang and Chun. In Experiment 2, we compared two mask positions symmetrically placed with respect to the line connecting the fixation and the target but found no asymmetry. In the next two experiments, to manipulate the attentional trajectory to the target, we introduced a new paradigm in which participants were asked to identify two letters, the decoy and the target, sequentially presented in different positions. In Experiment 3, asymmetric OSM was not observed even in the presence of the center-peripheral relation if the mask arrangement was symmetric with respect to the attentional path. In Experiment 4, however, the asymmetric OSM was evident even without the center-periphery relationship if the mask configuration was asymmetric relative to the attentional shift. Taken together, all of these results suggest that the asymmetric OSM occurs relative to the direction of attention shift. We propose that this kind of asymmetry might be explained by attentional momentum associated with orienting toward the target.

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43.428 **Visual attention guided video compression**

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Human visual characteristics show promising future for applications to video coding. Here, we propose, implement, and test a universal visual attention based video coding platform (VAVC). This platform includes two main parts: the visual attention module and the video coding module. The visual attention module is used to generate saliency maps (or other maps which can represent human visual characteristics) according to the human visual system (HVS) while the video coding module is used to compress the raw video sequence according to the results of the first module. Using this platform, a saliency-based video coding algorithm is implemented. The bottom-up methods proposed in Itti et al. (1998) are adopted to get the saliency map. Then we transform the saliency map into the quantization map used in the latest video coding standard H.264 to guide the residual quantization. For the salient regions, we decrease the quantization step to reduce the artifacts, and for the non-salient regions, we increase the quantization step to increase the compression ratio. In our experiment, 18 natural video sequences are adopted for encoding with different methods while 6 subjects to evaluate these encoded results. Subjects were asked to subjectively rate on a 1-5 scale the perceptual quality of 3 variants of the clips: standard H.264, our VAVC (yielding on average 17.37% smaller file sizes), and rate controlled H.264 to match the smaller size of the VAVC encoded clips. The experiment results show that, for 64.9% samples, the subjective quality of VAVC-encoded clips is equal or better than traditional H.264-encoded clips. For 87.04% samples, the subjective quality of the proposed VAVC method is equal or better than the rate-controlled H.264 method for equal file size. Our results suggest that exploiting human visual characteristics can lead to better video compression without degrading perceptual quality.

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43.429 **Attentional Synchrony in Static and Dynamic Scenes**

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When multiple viewers attend to the same static naturalistic scene there is a high degree of agreement in terms of the regions viewers attend to but no synchronization of when they attend there. By comparison, real-world scenes are rich with temporally-defined visual events such as motion which have the potential to involuntarily capture attention. Initial studies of attention during dynamic scenes have reported a high degree of spatiotemporal agreement, henceforth referred to as Attentional Synchrony. However, these dynamic scenes are composed with viewer attention in mind e.g. film and TV footage depicting a single subject tracked by a moving camera. Therefore, it is not currently known if attentional synchrony is caused by the presence of motion, scene content, or compositional factors.

In this study the degree of attentional synchrony was measured while participants memorized static and dynamic versions of the same real-world scenes. All scenes were filmed by a static camera without any deliberate composition. As predicted, the degree of attentional synchrony was greater in dynamic compared with static versions of the same scene. On average, the gaze position of 6 participants was clustered within 15% of the screen area during dynamic scenes and 20% for static scenes. Both static and dynamic scenes began with a 1200ms period of high synchrony (<8%) as all participants attended to the screen center. Following this central-tendency the greatest moments of attentional synchrony appear to be caused by the presence of a single moving person (one person synchrony = 10%; more than one person = 17%). People are prioritized by attention in static scenes but do not create synchrony. These results indicate that there is greater attentional synchrony in dynamic compared with static naturalistic scenes when content and composition are controlled.

URL: http://www.psy.ed.ac.uk/people/tsmith2/index_html

43.430 **Visual Search in Children with ADHD: The Influence of Feedback on Selective Attention**

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There is an ongoing debate whether there is a primary deficit in visual selective attention in childhood attention deficit-/hyperactivity disorder (ADHD). We explored this question using a visual search paradigm, in which participants searched for a target that either 'popped out' of the display (a parallel search) or was difficult to find (a serial search). If visual selective attention is impaired in children with ADHD they should perform similarly to normally developing children in parallel search tasks, but should show poorer performance in serial search tasks. As motivation is an important influence on selective attention, particularly in children with ADHD, we also tested the hypothesis that children with ADHD can improve their performance in serial search tasks for a reward. We first developed and validated visual search tasks suitable for children with normally developing control participants. Children had to search for a pig wearing a blue hat and a green tie. We manipulated search type (feature or conjunction search tasks), set size, and feedback (correct/incorrect or reward). The results showed parallel search for feature search tasks and serial search for conjunction search tasks. We then compared children with ADHD with non-clinical controls using these new visual search tasks. Our results showed that children with ADHD and those in the control group were influenced similarly regarding RT and accuracy, by search type and set size, but differently by feedback. That is, children with ADHD and the control children did not differ in the reward feedback condition; however, in the correct/incorrect feedback condition children with ADHD were slower. Overall, these results suggest that children with ADHD show no specific deficits in selective attention but show poorer performance when external motivators are lacking. Therefore, our results support the hypothesis that self-regulation of effort may be the core deficit of children with ADHD.

43.431 **The effect of practice on top-down guidance in visual search for two types of complex target: Evidence from eye-movements**

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There are performance costs in search for two targets compared with two independent single-target searches. This dual-target cost remains after practice and with complex stimuli (Menneer et al., in press). Eye-movements during dual-target search for simple colour-shape conjunctions revealed a breakdown in colour selectivity that allowed the examination of irrelevant distractors (Cave et al., 2007).

We examined the dual-target cost with complex stimuli and across training. Participants completed 16 blocks (5376 trials) within 40 days on search of baggage x-ray images. Twenty participants conducted single-target search, either for metal-threat items (guns and knives) or for improvised explosive devices (IEDs). Another group conducted dual-target search for both target types simultaneously. Eye-movements were recorded to determine the frequency of fixation to objects of each colour (orange, green, blue/black, mixed).

Compared with single-target search, there were more fixations in dual-target search overall, as well as more time and more fixations taken to fixate the target. These differences held throughout training. In all searches, the majority of fixations were made to objects of the same colour as the predominant target colour(s): blue/black for metal-threats and mixed or orange for IEDs. In block 1, the proportion of fixations made to objects of non-target colour (green) was higher in dual-target search than in combined single-target search, but there was no difference in later blocks.

In conclusion, more objects are fixated in dual-target search than in single-target search even after practice. There is an initial guidance breakdown in dual-target search as observed by Cave et al.. However, with training, the effectiveness of target representations appears to improve, reducing the examination of non-target-coloured objects, and equating to that in single-target search. The persistent dual-target cost therefore seems to arise from the number of fixations required rather than through guidance breakdown.

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43.432 **Finding top-down guidance in singleton search: an exploration of critical conditions**

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Although it is clear that our expectations about the future are critical in determining our behavior, the degree to which they can exert influence over the allocation of attention is in dispute. This debate has been especially intense with regard to the issue of whether expectation about upcoming target features can influence attentional allocation to salient singletons. Recently, Theeuwes & Van der Burg (in press) used the irrelevant singleton paradigm and trial-by-trial cueing to examine the effectiveness of attentional set on the filtering of distractors. They found reaction time benefits to verbal cues that indicated the upcoming target feature (e.g., a diamond or circle), but only when there was an irrelevant distractor present. Our previous work (Leonard & Egeth, in press) has found that there can be benefits of attentional guidance in singleton search displays that lack salient distractors. In this series of studies, we sought to resolve these discrepant findings and also better understand what conditions result in the use of top-down guidance. We used stimuli typical of the irrelevant-singleton paradigm, such that the target was a unique shape in a field of homogenous items, and on some trials a distractor was presented that differed in color from the other items. On each trial, participants received either an informative verbal cue ("diamond" or "circle") that indicated the shape of the upcoming singleton target or a non-informative verbal cue ("either"). Benefits of informative cues were found overall and, more importantly, this was true in the no-distractor condition, replicating our earlier finding. Several additional experiments explicitly ruled out differences between our study and that of Theeuwes & Van der Burg, such as blocking of distractor presence and absence, as possible accounts for the discrepancy in results. We find that under appropriate conditions, top-down guidance speeds performance, with or without a salient distractor.

43.433 **Collinear Alignment Modulates Competitive Interactions in Human Extrastriate Cortex**

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When multiple stimuli appear simultaneously in the visual field, they are not processed independently, but rather interact in a mutually suppressive way suggesting that they compete for neural representation. The biased competition model of selective attention suggests that both top-down and bottom-up processes can help resolve this competition by reducing suppressive interactions between competing stimuli. Both top-down attention and bottom-up visual salience (via pop-out visual stimuli) have been found to reduce competition in extrastriate cortex. Here we investigated whether the mechanisms that subserve the grouping of collinear elements can reduce competitive interactions between competing stimuli in a bottom-up fashion. FMRI activity in visual cortex was investigated while subjects performed a target detection task at fixation. While subjects performed this central task, sixteen oriented colored gabors were displayed within the upper right visual quadrant (entire stimulus 4°x4°). The stimuli were either presented simultaneously (SIM) or sequentially (SEQ: each quarter of the stimulus (4 gabors) presented alone). In addition, stimuli either formed a line segment (4 gabors aligned) or did not. Greater activity was observed in extrastriate cortex for the SEQ condition compared to the SIM condition, regardless of stimulus alignment. This supports the biased competition model that predicts greater competition, and thus reduced activation, when the stimuli are presented simultaneously. Greater activity was also observed during the SIM condition in V3/V4 when the stimuli could be grouped together to form a line segment compared to when the stimuli did not form a perceptual group, suggesting that grouping by collinearity over-came competition. These results, combined with previous findings employing illusory contour figures, suggest that perceptual grouping can influence neural competition in a bottom-up fashion outside the focus of attention, likely representing a general principle of scene segmentation whereby processing is biased in favor of potential foreground elements.

43.434 **The various attention deficits in adult-ADHD and their relation to driving behavior**

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Despite the lack of adult-specific criteria in the DSM-IV-TR, reports in the literature over the past 20 years have provided strong evidence for the persistence of attention-deficit/hyperactivity disorder (ADHD) into adolescence. It is estimated that about 4% of adults suffer from ADHD. ADHD has many deleterious long-term consequences including increased risk for automobile accidents. The goal of this study is to examine the performance of adults with and without ADHD on a variety of attentional tasks (tapping into different attentional functions) and to explore possible relations between attention performance and driving behavior. The performance of adults with ADHD on four different visual attentional task (Continuous Performance Test, visual search, Posner' tasks with exogenous cues and strooplike) was compared to aged matched controls. In addition, 'driving behaviors' were assessed for all participants using a self-reported questionnaire (DBQ). Group comparisons between participants with and without ADHD in the above four attention tasks revealed significant differences in each one of the tasks. Furthermore, using z–scores (based on the statistics of the control group), we found different levels of performance in individuals with ADHD in each of the four attention tasks. That is, different participants with ADHD revealed different patterns of attentional difficulties. Interestingly, we found significant correlations between the performance in the attention tasks and certain driving slips (such as "intend to switch on the windscreen wipers but in turn switch on the lights") and violations ("take a chance and cross on lights that have turned red"). These correlations may suggest a substantial link between specific aspects of attention (and attention difficulties) and driving behaviors. We discuss potential theoretical and practical implications of these results.

43.435 **More than the sum of the parts: Further evidence for an interaction principle of attention**

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Attention improves processing of targets and can be engaged with or without the intention to attend to a specific stimulus. Recent work has shown that predictive central arrow cues, that have frequently been used to estimate effects of volitional orienting, trigger an interaction of reflexive and volitional orienting. The obtained effects are larger than the sum of reflexive and volitional orienting. Based on these findings an interaction principle has been postulated, stating that when cues that elicit reliable reflexive orienting are made spatially predictive, the resulting attention effects will be greater than the sum of the effects produced by reflexive and volitional orienting. Two experiments were designed to further test this principle. Experiment 1 assessed how reliable central arrow cues have to be in order to produce the interaction. The degree of predictability was varied systematically and the effects of central arrow cues (volitional and reflexive orienting) were compared to the effects of central number cues (volitional orienting). The results showed that central numbers had to be highly predictive for cueing effects to occur, confirming that orienting to these cues was volitional in nature. For central arrows cueing effects emerged at all predictability levels, increased gradually with increasing predictability, and importantly, exceeded those of central numbers, also when corrected for their reflexive component. Experiment 2 tested whether enhanced attention effects of central arrow cues are also evident in comparison to yet another central cue that measures volitional orienting: colour. The results showed that cueing effects triggered by predictive arrows, also when corrected for their reflexive component, exceeded those of predictive colour cues. In summary, both experiments verified the enhanced attention effects predicted by the interaction principle.

43.436 **(More) Evidence that nonpredictive arrows elicit reflexive orienting: An ERP study**

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Several recent behavioral studies have demonstrated that central nonpredictive arrows trigger reflexive shifts of spatial attention (e.g., Tipples, 2002; Ristic et al, 2002; Gibson & Bryant, 2005) as indexed by response time (RT) facilitation for targets occurring at cued locations. Despite the robustness of this behavioral effect, it is still unclear whether the reported RT effect reflects attentional modulation of early cortical visual processing typically associated with reflexive orienting to visual events measured with event-related potentials (ERP, e.g., Mangun & Hillyard, 1987; 1990; Hopfinger & Mangun, 1998). This amplification, or sensory gain, is often observed as an increased amplitude of the first large positive deflection in the sensory-evoked ERP, known as the P1. Here, we investigated whether reflexive orienting in response to a nonpredictive arrow resulted in an enhancement of the P1 component. Observers detected a peripheral target that occurred after the presentation of a central nonpredictive arrow cue. Replicating previous behavioral results, RT facilitation was observed for cued relative to uncued target locations. Importantly, at electrode sites contralateral to the target location, the mean amplitude of the P1 was also larger for cued targets relative to uncued targets. This result indicates that central uninformative arrow direction causes increased sensory processing in extrastriate visual areas. As such, these data add to the growing body of evidence indicating that the behavioral facilitation observed in response to central nonpredictive arrow cues reflects reflexive shifts of covert spatial attention.

43.437 **A surprisingly stimulus-specific effect of self-awareness on perception of mirrored and un-mirrored self-faces**

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Attention modulates perception of selected visual features, but can nonsensory mental factors such as states of self-awareness systematically influence visual perception? To reveal a visual effect of self-awareness, we considered the unique experiential associations of the perception of mirrored and un-mirrored self-faces with different states of self-awareness. When you look at yourself in a mirror examining your left-right reversed face, you are typically alone and your self-awareness is likely to be directed to immediate percepts including body sensations, potentially strengthening a neural association between the visual processing of a mirrored self-face and a state of internally-directed self-awareness. In contrast, when you look at your un-mirrored face in a photograph, you are likely to be with other people (to whom you show the photograph), and your self-awareness is more likely to be socially directed (thinking about how others think of you), potentially strengthening a neural association between the visual processing of an un-mirrored self-face and a state of socially-directed self-awareness. If visual processing gets selectively associated with concurrent states of self-awareness in this way, internally-directed self-awareness should selectively facilitate recognition of mirrored self-faces, whereas socially-directed self-awareness should selectively facilitate recognition of un-mirrored self-faces. To induce an internally-directed state of self-awareness, we instructed participants to focus on their breathing as a bodily sensation; to induce a socially-directed state of self-awareness, we instructed participants to think about their strengths and weaknesses, as people are typically concerned about how others perceive them in social situations. As predicted, internally-directed self-awareness enhanced recognition of mirrored self-faces (faster response time and stronger self perception), whereas socially-directed self-awareness enhanced recognition of un-mirrored self-faces. As mirrored and un-mirrored faces are highly similar, our results demonstrate that non-sensory mental states such as self-awareness can have a surprisingly stimulus-selective impact on visual perception.

43.438 **Effect of Perceptual Load on Response Control**

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The goal was to explore the relation between attentional control and response control. To do this, we manipulated the difficulty of a perceptual task and examined the impact on response control. A letter search task was used with letters potentially appearing in any of eight equally eccentric locations distributed in a circular array around fixation. Perceptual load was manipulated via set size (2, 4, or 8 letters). The colour of each letter was randomized (blue or red). The colour of the target letter (X) determined the response. For half of the subjects, a red target required a congruent response (target on left = left-hand keypress; target on right = right-hand keypress), whereas a blue target required an incongruent response (target on left = right-hand keypress; target on right = left-hand keypress). As expected, increases in set size slowed response times. Furthermore, incongruent responses produced slower responses than congruent responses. Critically, there was no interaction of perceptual load and response control suggesting that the perceptual difficulty of the task had no impact on response control.

43.439 **Holding up the Eyes, not the Hands: the effect of remote distractors on reaction times**

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The Remote Distractor Effect (RDE) is a robust phenomenon in which a saccade to a lateralized target is delayed by the simultaneous appearance of a distractor in the opposite hemifield (Walker at al., 1997). The premotor theory of attention proposes that covert shifts of attention reflect the activity of neural circuits used during saccade preparation, with the only difference being that the saccade is not executed (Rizzolatti et al., 1987). This theory predicts that the RDE should not be specific to saccadic responses but should generalise to any response that requires a shift of spatial attention. The aim of this study was to investigate whether the RDE applies to other effectors rather than the eyes. In the first experiment participants responded to a stimulus, at a predictable location, moving their eyes, or pointing to the target whilst maintaining central fixation. The target was presented alone or with a simultaneous distractor in the opposite visual hemifield. A reliable RDE was observed for eye movements, but not for pointing responses. The same pattern was observed in a more naturalistic version of the task, in which eye movements were not restricted. Contrary to the predictions of the premotor theory, these results suggest that shifts of spatial attention do not share all of the properties of saccadic eye movements.

43.440 **The Perceptual Fate of Onsets: Abruptly Appearing Objects Are Perceived Better**

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It is well established that abruptly appearing objects capture attention in a stimulus-driven manner under at least some circumstances (Yantis & Jonides, 1990; Christ & Abrams, 2006), leading to a prioritization of visual search. However, there has been much less attention on the possible consequences of this prioritization on the perception of the abruptly appearing objects themselves. To this end, the current study used a perceptually demanding gap discrimination task to assess whether new, abruptly appearing objects receive benefits in perceptual processing over old objects. Participants performed a gap discrimination task in which an array of placeholders was presented briefly prior to the presentation of a single landolt square. The square had a small gap in either the top or bottom, and participants were asked to respond to the location of the gap (top vs. bottom of the box) across a number of gap sizes. Importantly, the target could appear randomly in any one of eight locations in an imaginary ring around fixation, only four of which were preceded by a placeholder. It was shown that participants were significantly more accurate at judging gap orientation when the target was an onset (i.e.; was not preceded by a placeholder) across all gap sizes. Control experiments ruled out forward masking and target location uncertainty as possible explanations for these results. It was concluded that abruptly appearing objects receive a benefit in perceptual processing as a result of their status as new objects.

43.441 **The Effect of Target Detection on Visual Long-Term Memory for Background Scenes**

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Within dynamic events, the degree to which perceptual information is attended and later remembered varies over time. One cue that may lead people to attend to and encode perceptual information is the occurrence of a behaviorally relevant event, such as the appearance of a target in a stream of non-targets. However, target detection often interferes with concurrent, secondary task performance and therefore could reduce encoding of other information. In this study, we examined the dual-task interaction between detecting targets in a stream of non-targets and explicit memory for serially presented background scenes. For these experiments, participants monitored a black square in the center of a display for an occasional change in color (target event), while they encoded a long series of natural scenes into memory. Each scene was presented for 100msec with a 400msec interstimulus interval. Following the detection task, participants completed a recognition test that required them to distinguish between the old scene, a novel scene, and mirror-reversed versions of both scenes. Results showed that detecting a target event (i.e., color change to the central square) enhanced, rather than impaired, memory of the background scene that coincided with the target: Participants more accurately distinguished the old scenes from the new scenes, and the old scene from its mirror-reversed counterpart when it was previously presented with the target. However, accuracy was reduced for the scene that immediately followed the target. Follow-up experiments suggested that these effects diminished with longer presentation rates, and that the reduction in accuracy for scenes that followed the target was attributable to competition from the scenes that were presented with the target. Therefore, rather than resulting in interference, target detection facilitated secondary task performance. These data are consistent with the operation of a reward-based mechanism that globally reinforces perceptual information that coincides with behaviorally relevant events.

Acknowledgement: This study was supported in part by NSF 0733764 and NIH 071788

Monday, May 12, 8:30 am - 12:30 pm Poster Session, Orchid Ballroom

Binocular Rivalry and Integration 2
Receptive Fields and Maps

Binocular Rivalry and Integration 2

43.501 **Slow changes in neural state mediate percept switches in intermittent binocular rivalry**

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Background. When conflicting images are shown continuously to the two eyes, observers perceive either image in turn; perception fluctuates. When conflicting images are periodically turned off and back on, observers tend to perceive the same image on many consecutive presentations; perception stabilizes. This stabilization seems to reveal a priming trace of past dominance that acts during the current presentation, biasing perceptual competition in favor of the previously dominant pattern. This trace accumulates over presentations, so that a pattern that has dominated several times is more likely to regain dominance than a pattern that has dominated only once. Given this plausible account of percept repetition, why does percept switch at all during intermittent rivalry?

Methods. We presented rival stimuli intermittently and determined the frequency at which perception switched. In additional experiments we varied the blank duration that separates presentations; a parameter known to affect switch probability.

Results and Conclusion. Switches, although infrequent, were highly periodic, ruling out random fluctuations as their cause. Oscillation periods were on the order of minutes (hundreds of presentations), indicating that switches involve a signal that accumulates over minutes. Strikingly, the relation between blank duration and switching probability varied systematically with position within a slow oscillation cycle. These findings can be accommodated by a revised version of an existing model of perceptual stabilization1. Based on these results, knowledge of an observer's percept history can be used to predict future perception. Furthermore, the systematic evolution of the relation between blank duration and switch probability allows control over future perception by online adjustment of the blank duration.

NIH-EY13358

1. Noest AJ, van Ee R, Nijs MM, van Wezel RJ (2007). Journal of Vision 7(8): 10, 1-14.

43.502 A novel technique for generating perceptual waves during binocular rivalry and binocular fusion

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PURPOSE: During binocular rivalry, transitions in perceptual state can be triggered by abrupt contrast increments within a small region of the currently suppressed pattern. Transitions occur locally and spread throughout the pattern, creating a perceptual wave of dominance1. We developed a novel version of this procedure whereby opposing traveling waves are periodically created, producing time-locked changes in dominance.

METHOD: Observers dichoptically view two vertically elongated rival stimuli and track perceptual fluctuations within a small region of this configuration (monitoring area). During the viewing period, contrast increments (triggers) are alternately, repetitively presented within the upper and lower region of the two rival stimuli, respectively. Ideally, triggers presented to the upper (lower) region of a suppressed pattern should induce a downward (upward) perceptual wave that is evidenced by a delayed perceptual switch at the monitoring area.

RESULTS: We derived probability switch functions for the monitored area to infer the existence of traveling waves. Experiment 1 confirmed that switches in dominance were systematically modulated by the trigger period. Experiment 2 demonstrated that the delay between trigger presentation and perceptual switches was systematically related to the trigger's distance from the monitoring area. In Experiment 3, we presented vertically elongated figures to the two eyes where only the middle portion induced rivalry; monocular triggers were presented within regions of concordant binocular stimulation. Triggers within non-rivaling regions still modulated periodicity of perceptual switches within the region of rivalry, particularly when the trigger was close to the rival area.

CONCLUSION: This novel technique produces reliable perceptual waves whose properties can be inferred from data produced simply by tracking rivalry. This technique reveals that mechanisms underlying perceptual waves during rivalry also operate within regions of binocular fusion.

1. Wilson et al. (2001). Dynamics of traveling waves in visual perception. Nature, 412, 907-910.

Acknowledgement: EY13358/EY016752

43.503 Factors in the measurement of interocular inhibition fields

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Halos around lines, patches of coherent dominance, and traveling waves have been observed during binocular rivalry, which all imply some spatial spread in the interocular inhibition field of competing regions of space. The current series of experiments show that the range across which a target bar is rendered invisible during rivalry depends greatly on the luminance pattern defining the bar. Rectangular target bars, which were of uniform luminance, random noise, or filled with gratings oriented either parallel or perpendicular to the orientation of the target bar, were presented to one eye. Presented to the other eye were two rectangular suppressor bars equidistant from the center of the target bar. For horizontal target bars, the range of suppression was approximately 1 deg for target bars of uniform luminance or filled with a grating of parallel orientation, but only 0.5 deg for target bars filled with random noise or a grating of perpendicular orientation. For vertical target bars, the total time of suppression decreased by 20% or more, but the pattern of results with regards to the luminance profile of the target bar was very similar. Nevertheless, the inclusion of a small gap between the suppressor bars and the central portion of the target bar greatly reduced the frequency with which the target bar was rendered invisible. Also, the spread of suppression is likely not due to traveling waves in dominance, as no change in the time until suppression was observed as a function of the separation of the suppressor bars. Consistent with all of the results is that interocular inhibition fields extend 1-2 deg, but that the likelihood of interocular suppression occurring is mitigated by the nature of the luminance pattern perpendicular in orientation to the suppressors. The implications for models of interocular suppression will be explored.

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43.504 Binocular integration and normalization in primary visual cortex: an fMRI study

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The brain combines visual information from the two eyes and forms a coherent percept, even when inputs to the eyes are different. Psychophysical studies show binocular summation for compatible stimuli and rivalry or suppression for incompatible inputs. However, it is not clear how inputs from the two eyes combine in visual cortex.

We measured fMRI responses to single gratings (2 cpd, restricted to an annulus 1.5-2.8 deg eccentricity) presented monocularly, or pairs of gratings presented monocularly or dichoptically with several combinations of contrasts. Gratings had either the same orientation or orthogonal orientations (plaid). Subjects performed a continuous 2-back task on a sequence of digits at fixation to minimize top-down modulation of responses to gratings.

Dichoptic presentation of compatible gratings (same orientation) evoked greater activity than monocular presentation of a single grating only when contrast was low (<10%). A model that assumes linear summation of activity from each eye failed to explain binocular responses at 10% contrast or higher. However, a model with binocular contrast normalization, such that activity from each eye reduced the gain for the other eye, fitted the results very well. Dichoptic presentation of orthogonal gratings evoked greater activity than monocular presentation of a single grating for all contrasts. However, activity evoked by dichoptic plaids was equal to that evoked by monocular plaids. Introducing an onset asynchrony (stimulating one eye 500ms before the other which under attentive vision results in flash-suppression) had no impact on the results; the responses to dichoptic and monocular plaids were again equal.

We conclude that when attention is diverted, binocular interaction in V1 can be explained by a contrast normalization model in which the interaction between orthogonal orientations does not depend on the eye of origin, nor on the onset times, and cross-orientation suppression is weaker than interocular suppression for the same orientation.

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43.505 A causal role for right parietal cortex in binocular rivalry demonstrated with TMS

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Binocular rivalry occurs when dissimilar images are presented to the two eyes: the images compete for perceptual dominance, with each image visible in turn for a few seconds while the other is suppressed from awareness. Previous neuroimaging research has shown that right parietal and frontal cortical regions are involved in the perceptual transitions of rivalry. However, the correlational nature and coarse temporal resolution of neuroimaging preclude the attribution of a causal role to this activity, which may simply reflect attentional orienting to the perceptual transition. Here we used repetitive Transcranial Magnetic Stimulation (rTMS) to investigate the role of parietal cortex in rivalry. Volunteers (n = 6) participated in three testing sessions, each conducted on a different day: In one they received no stimulation; in the other two they received 30 minutes of 1 Hz TMS stimulation at 90% motor-threshold, to either right superior parietal cortex or to the homologous point in left parietal cortex. Following stimulation (or immediately in the no-TMS condition) they viewed a rivalry display (orthogonally-oriented Gabor patches, one presented to each eye) and reported their percepts continuously for ten minutes, by holding a different key down for each dominant stimulus. We found that stimulation of right parietal cortex shortened dominance durations in binocular rivalry, compared to no TMS and left parietal TMS. These results demonstrate a causal role for right parietal cortex in rivalry. Furthermore, they suggest that right parietal cortex maintains perceptual states during rivalry rather than initiating perceptual transitions.

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43.506 Enhanced depth perception following high-frequency repetitive transcranial magnetic stimulation of human area V2/V3

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Repetitive transcranial magnetic stimulation (rTMS) at 20 Hz over motor cortex can lower the threshold for motor evoked potentials (Pascual-Leone, 1994). Although rTMS at low frequency (1 Hz) can raise thresholds for evoking visual phosphenes (Fumal, 2003), rTMS has not been used extensively in the study of the visual cortex. We sought to examine the possibility that rTMS could be used to manipulate neuronal activity in specific visual areas, just as microstimulation, cooling, and pharmacological manipulation are used in animal studies.

Recent studies in both humans and monkeys have suggested that visual area V3/V3A contributes to the perception of depth based on binocular disparity; however change in function due to intervention in this area has not been demonstrated. We examined the impact of high frequency rTMS on human depth perception by using fMRI of retinotopically-organized areas to locate the target cortical region. A random dot stereogram, gradually increasing in disparity, was presented until the subject perceived it as being nearer or farther than the fixation plane. The threshold disparity for perceiving depth was measured for different locations in the visual field before, during, and after the application of rTMS. We found a significant and prolonged decrease in the disparity threshold for depth perception following high-frequency rTMS in a limited area of the visual field contralateral to the stimulated cortex. This result establishes a direct link between depth perception and neuronal activity in human areas V2 and V3. It also suggests that high-frequency rTMS could be a valuable tool for validating the contribution of cortical areas to visual perception in humans.

43.507 Magnocellular and parvocellular pathways differentially modulate conscious perception with eccentricity: Evidence from Binocular Rivalry

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Conscious perception is modulated with eccentricity. The main explanation of this phenomenon is the progressive decrease in photoreceptor's density. Actually, cortical magnification factor is often used to equalize central and peripheral performance, but size is not enough to explain perceptual differences at large eccentricities. Here we used binocular rivalry in order to investigate how the information driven by magnocellular (M) and parvocellular (P) pathways is differentially modulated with eccentricity (until 24°), and which are the implications for conscious perception.

We made two rivalry experiments in order to stimulate preferentially M or P pathways. In the first experiment, two kinds of achromatic gabor patches were used with different physical properties (contrast, spatial and temporal frequency). In the second, we used red/green gabors in two different conditions: isoluminant (activating preferentially P pathway) and 4% contrast (activating preferentially M pathway). In both experiments, when two stimuli activating preferentially the M pathway were presented in central vision, fusion of both predominated significantly over rivalry. On the other hand, when two stimuli activating preferentially the P pathway were presented, rivalry was significantly higher than fusion. This supports the idea that M pathway is related with fusion and P pathway with rivalry. Moreover, in the M condition fusion decreased significantly with eccentricity, whilst no changes were observed in the P condition. Finally in a P versus M condition, rivalry predominated at all eccentricities, with ocular dominance of M over P stimulus, but fusion decreased significantly with eccentricity. Altogether, these results demonstrate that the information driven by M pathway is modified with eccentricity whilst it is not the case for P pathway. This suggests that the difference in conscious perception between central and peripheral vision is mainly due to a change in M pathway, giving new cues about why conscious perception is modified with eccentricity.

43.508 Neural Correlates of Motion-Induced Blindness in the Human Brain

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Motion-induced blindness is one type of bistable perception in which a perceptually salient target amidst a moving field of distracters repeatedly disappears and reappears. We investigated the neural correlates of this phenomenon in humans by measuring fMRI responses in visual cortex while subjects reported disappearances and reappearances of the target. Surprisingly, perceptual invisibility of the target was coupled to an increase in neural activity in early visual cortex and V5/MT compared to when the target was visible. This increase was restricted to cortical retinotopic regions corresponding to the spatial location of the target. In contrast, activity in the fusiform gyrus was time-locked to switches in perception. We suggest that these findings result from an active process of completion of the field of distracters that acts locally in visual cortex and might be coupled to extra-visual areas through the fusiform gyrus.

43.509 Early neural interactions can explain perceptual bi-stability modifications of stimulus timing, perceptual history, cross-modal influence and attentional control

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One of the most fundamental and unresolved problems in awareness research concerns the primitives involved in the phenomenal experience during perceptual bi-stability. Resolving this problem is critical for both computational theory and neurophysiological investigations into awareness.

We have developed novel paradigms, employing competing visual stimulation and competing auditive stimulation to study perceptual ambiguity resolution. We have demonstrated quantitatively, using a straightforward basic "first-principles" neural model, that neural gain modulation at early cortical stages, driven by top-down feedback, is sufficient to explain all reported data on perceptual decisions, including those for varying stimulus timing, history dependence, cross-modal influence and voluntary attentional control.

URL: http://www.phys.uu.nl/~vanee/

43.510 Sound enhances processing of emotional words under invisible conditions

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Recently there has been increasing evidence for high-level information being processed differently even though the stimuli are not consciously perceived (e.g., Jiang, Costello, & He, 2007). Here we examined whether emotional Chinese words can be processed under invisible conditions and whether this unaware visual processing is affected by a sound. The continuous flash mondrians (Tsuchiya, & Koch, 2005) were used in one eye to suppress the emotional Chinese two-character words in the other eye. The contrast of words was raised gradually, and the time needed for the word to release from suppression was measured. The words could be neutral, positive, or negative, and they were presented either upright or inverted, with or without sound. Results showed shorter RTs for upright than for inverted words, for emotional than for neutral words, and for words with sound than without sound. The sound-facilitatory effect is not due to alertness because the onset time of the sound and the time to release from suppression was asynchronous for at least 800 ms. These results imply that unlike emotional faces, words' knowledge are acquired, and yet emotional words can still be processed differently while they are invisible. The effect of sound modulation also supports our previous finding (You & Yeh, VSS 2007) that sound can boost the unaware visual process.

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43.511 **Meridional asymmetry of collinear interactions in the normal visual cortex**

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Maturation of neural connectivity is experience-dependent in such a way that the state of the visual input during the critical period can be inferred from the visual functions in adults. In meridional amblyopia, the visual input during the critical period was asymmetrical; hence, the perception in one meridian was blurred, but normal in the orthogonal one. Consequently, in adults, the contrast sensitivity and the lateral interactions (LI) are dramatically reduced along the blurred meridian, but practically normal along the orthogonal one. However, asymmetric visual input is common during normal development and young children tend to be astigmatic (with the vertical meridian being more blurred than the horizontal). This effect decreases and usually disappears with increasing age. Here we explored whether this visual asymmetry during the critical period shaped the development of the visual connectivity and induced a cortical asymmetry that was retained during adulthood in adults with normal vision. Subjects had corrected vision of 6/6 or better. Contrast sensitivity to Gabor patch and collinear facilitation were measured under monocular and binocular conditions using dichoptic glasses. We found significant differences in the LI between the horizontal and the vertical meridians which are not due to different detection thresholds of the target. Monocular LI along the horizontal meridian are higher by 58% than the vertical. In contrast, binocular LI along the vertical meridian are higher by 35% than the horizontal. We suggest that the vertical blur induced by the optical astigmatism during the “critical period” prevents the development of normal monocular LI along the vertical meridian. The decreased binocular summation in the horizontal meridian is probably caused by developmental alternations in the superposition of the corresponding points between the eyes. Alternatively, the reduced binocular facilitation along the horizontal meridian could result from higher inter-ocular suppression along this meridian.

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43.512 **The stimulus conditions for uniocular determination of perceived direction near unpaired regions**

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Hering’s laws state that the perceived direction of binocular objects is an average of their two monocular directions referred to the cyclopean eye. These laws fail to describe perceived direction where surfaces overlap and an unpaired region of the occluded surface is created. Erkelens et al Vis Res (1996) proposed that in the neighbourhood of these occlusions, directions are perceived from the perspective of the eye with the unpaired region rather than in an averaged direction. In evidence they showed that binocular lines close to the unpaired region of a background surface appeared aligned with the edge of the occluding surface when actually aligned according to the eye seeing the unpaired region. However the stimulus conditions fostering uniocular determination of perceived direction are little explored. In our first experiment the stimulus was a textured occluding square (98’) placed stereoscopically nearer than and central to a textured background. Observers vertically aligned a binocular line on the background with a fixed binocular line on the occluding surface. Alignment was an average of the monocular directions when the separation of the fixed line from the occluding edge was greater than approximately half the unpaired region’s width and uniocular for smaller separations. Alignment between the vertical edges of the square’s outline and the background line was found to be determined uniocularly even when both surfaces were devoid of texture. However when the horizontal edges of the textureless square’s outline were removed, alignment was consistent with direction averaging. These results localise the transition from averaged to uniocular direction to a small area adjacent to the unpaired region and indicate that the presence of an occluding surface rather than unpaired texture determines that direction is uniocular near unpaired regions. Further research indicates that the orientation of the occluding edge may also be critical.

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43.513 **Accommodative and vergence responses to conflicting blur and disparity cues in the developing visual system**

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Adults achieve clear and single visual experience using accommodation and vergence. While these systems are already coupled in early infancy very little is known about their interaction during development, even though it is implicated in forms of strabismus and is central to three-dimensional space perception. Here, we assessed the interaction under two conditions, i) where cues to accommodation and vergence (blur and disparity) were consistent with each other and ii) where these cues were in conflict with each other. Subjects from 4 months to 12 yrs of age viewed a high contrast cartoon binocularly while their accommodative and vergence responses were measured at 25Hz using photorefraction (PowerRefractor). In the cue-consistent condition, the target was physically moved between 80 and 31 cms (2D or MA). In the cue-conflict conditions, either -2D lenses or 2MA base-out prisms were placed before the eyes, with the target at 80 cms. The data revealed three characteristics. First, while subjects always responded in the cue-consistent condition, they responded more frequently to the prisms (mean 83.6% of trials) than to the lenses (60.5%) in cue-conflicting conditions. Second, the gains of both direct and coupled responses were smaller to lenses (accommodation: 0.55 +/- 0.25; vergence: 0.14 +/- 0.09) than to prisms (vergence: 0.69 +/- 0.37; accommodation: 0.30 +/- 0.11) [both $p<0.01$] and the direct response gains were smaller than the gains obtained under cue-consistent conditions (accommodation: 0.84 + 0.18; vergence: 1.13 + 0.14) [both $p<0.001$]. Third, the ratio of vergence to accommodation gain for the lenses was less than and poorly correlated with the subject’s AC/A ratio ($p<0.01$; r=0.08). Overall, these results indicate that the developing visual system responds to 2D or MA cue-conflicts by attempting to minimize both retinal blur and disparity, with some bias towards keeping the visual experience single rather than focused.

43.514 **Channel-specific, monocular adaptation to dynamic Mondrian patterns revealed during binocular rivalry**

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PURPOSE: An array of luminance-defined rectangles (“Mondrians”) changing shape and contrast irregularly over time induce strong interocular suppression1. To investigate the nature and locus of neural events underlying this potent stimulus, we measured the influence of channel-specific Mondrian adaptation on binocular rivalry.

METHODS: Observers dichoptically viewed orthogonally oriented gratings, one defined by chromatic contrast and the other by luminance contrast. A tracking procedure was used to measure durations of exclusive visibility of each rival grating during 30-second viewing periods. Immediately preceding some tracking periods, observers adapted for one minute to a dynamic Mondrian display tailored to favor activation of magnocellular (MC) or parvocellular (PC) channels. MC-biased adaptation employed dynamic, achromatic Mondrian patches each of which was one of two gray values (equal-energy-spectrum ‘whites’); PC-biased adaptation employed dynamic patches composed of two equiluminant chromaticities. Adaptation involved: 1) binocular exposure to achromatic or to equiluminant Mondrian patches, 2) same eye exposure in which achromatic (or equiluminant) Mondrian patches were presented only to the eye that viewed the luminance (or the equiluminant) grating during rivalry, 3) different eye exposure in which achromatic (or equiluminant) Mondrian patches were presented only to the eye that viewed the equiluminant (or luminance) grating during rivalry, or 4) exposure of both eyes to an uncontoured, mean luminance field (baseline).

RESULT AND CONCLUSION: Relative to baseline rivalry (no Mondrian adaptation), adaptation to achromatic Mondrians biased rivalry dominance in favor of the equiluminant grating; adaptation to equiluminant Mondrians biased dominance in favor of the luminance grating. This channel-specific adaptation effect was observed only in same-eye conditions, meaning that adaptation did not transfer interocularly. Evidently adaptation to dynamic Mondrians, whether targeting MC or PC channels, transpires at early stages of visual processing prior to binocular integration, perhaps contributing to their capacity to induce potent interocular suppression.

Tsuchiya & Koch (2005) Nature Neurosci.

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43.515 **Is Motion-induced blindness a perceptual scotoma?**

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Motion-Induced-Blindness (MIB) refers to the phenomenon in which perceptually salient targets, when superimposed on a global moving-dots pattern, disappear and reappear alternatively after prolonged viewing (Bonneh, Cooperman, & Sagi, 2001, Nature). Recently, New and Scholl (in press, Psychological Science) provide a functional account as to why MIB occurs. In their perceptual scotoma hypothesis, the disappearance of the target in MIB displays is attributed to the possibility that our visual system treats the target as being a perceptual scotoma in order to separate the invariant target from the distal surrounding changing background. Here we report counterexamples to argue against the perceptual scotoma account. First, we show that MIB occurs when the target and the background are both static, moving, or changing; naming, when the target is not invariant with respect to the background and thus an inference of scotoma of the visual system itself should not be made in the first place. Further, we show similar oscillation patterns of MIB and bi-stable figures such as Necker cube and the latter are by no means akin to any kind of perceptual scotoma. As the perceptual scotoma hypothesis cannot adequately explain these results, we suggest that MIB may be related to a more general mechanism of figural competition.

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43.516 **The Effects of Motion on Binocular Rivalry between Simple and Complex Images**

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There is ongoing debate as to whether binocular rivalry results from early competition between the two eyes or late competition between two percepts. Previous evidence that perceptual dominance durations are prolonged when simple stimuli engage in movement has been interpreted in terms of delayed local neural adaptation (Blake, Sobel & Gilrory, 2003). It is unclear whether this effect can be extended to rivalry between complex stimuli, which reach global levels of visual processing. Our study compared the effects of continuous stimulus movement on rivalry between simple checkerboard and complex face/house stimulus pairs (all of which were matched for mean luminance and contrast). The three characteristics of binocular rivalry under investigation were the median perceptual dominance durations, spatial coherence and suppression depth. Data collected from 25 participants indicated that, there was a significant interaction between image complexity and motion on perceptual dominance duration ($F (1, 24) = 12.09$ $p <0.05$), with movement related increases in duration for simple stimuli and decreases for complex stimuli. Similar motion by complexity interactions were observed for the spatial coherence ($F (1, 24) = 5.78, p <0.025$). and suppression depth ($F (1, 18) = 9.38, p <0.01$). We argued that such findings are more consistent with top-down perceptual switching mechanisms than with monocular adaptation mechanisms. It was concluded that if neural adaptation causes perceptual alternations, it probably does so at the level of the visual system at which stimuli are represented.

Receptive Fields and Maps

43.517 **Structural Theorems for Simple Cell Receptive Fields**

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Theorists interested in developing mathematical descriptions and computational models of human spatial vision frequently employ Gabor filters as basis functions. Due to some undesirable features of the Gabor function, in particular the fact that it does not integrate to zero for all spatial phases of the carrier wave, a variety of competing mathematical formulations has been proposed, which include the difference-of-Gaussians, the Laplacian-of-a-Gaussian, the log-Gabor and the Cauchy function, to name a few. Here, we mathematically derive a class of functions based on three cardinal response properties of simple cells. Specifically, receptive field models must satisfy the following criteria: 1) Their response to a spatially homogeneous stimulus must be zero; 2) There must exist a direction (orientation) which produces zero response to sinusoidal grating stimuli; and 3) The response to sinusoidal grating stimuli must be a monotonic function of orientation, increasing from zero to a maximum as orientation changes from the zero response direction. The class of receptive field functions satisfying these criteria includes, as its most representative case, a novel variation of the Gabor filter – the balanced-Gabor – which integrates to zero for all spatial phases of the carrier wave. The balanced Gabor filter possesses all of the desirable features of the standard Gabor model of simple cells and, by virtue of integrating to zero, obviates its chief deficiency.

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43.518 **The effects of spatial attention and population receptive field size estimation on fMRI topographic mapping signals**

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Classical phase-encoded fMRI mapping with rotating wedge and contracting/expanding ring stimuli is a useful method for identifying the visual field layout and boundaries of visual cortical areas in the human brain. However, recent analytical and methodological advances allow more precise and extensive mapping of topographic visual cortical areas. A new fMRI analysis technique (Dumoulin and Wandell, 2008) computes a receptive field size and visual space location for a given voxel based on the aggregate neural responses within that voxel. Also, a phase-encoded mapping task that employs covert visual spatial attention has revealed additional topographic areas in the intraparietal sulcus that were not identifiable using passive viewing alone (Silver et al., 2005). Measurement of population receptive fields results in greater spatial precision of retinotopic maps than standard phase-encoded mapping analysis (Dumoulin and Wandell, 2008). In addition, we have found that a task requiring sustained attention to a periodic stimulus results in larger and more reliable topographic mapping signals in a number of occipital and parietal cortical areas compared to either stimulus-based or attention mapping alone. A combination of these techniques, employing sustained attention to a high-contrast visual stimulus while measuring precise spatial tuning of neuronal populations, should enhance both SNR and spatial precision of fMRI visual field maps of topographic visual areas. This combined approach will also allow us to assess the effects of visual spatial attention on population receptive field sizes for all visual field locations across a number of visual cortical areas.

43.519 **7T Spin Echo Sequences Provide Improved Spatial Accuracy in BOLD fMRI Experiments**

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Functional magnetic resonance imaging (fMRI) provides a noninvasive method to study inferred neural responses to visual stimuli in humans. However, many experiments require the ability to localize this response to specific spatial locations in a visual scene rather than averaging the response over a large cortical area. In order to localize blood oxygen-level dependent (BOLD) responses on a fine spatial scale in primary visual cortex (V1), we used high resolution fMRI (1.5mm isotropic voxels). Four sets of target and flanking Gabor patches centered on the four corners of a square were presented at 3 degrees eccentricity (each patch subtended 0.75 degree of visual angle; target and flanker separated by 1 degree). Two separate block localizer scans with target alone and target with flanker conditions were used to define regions of interest (ROIs), and event-related scans were used to estimate the hemodynamic response to targets-alone, targets with flankers, and flankers-alone stimulus sets. The BOLD response to these stimuli was measured with a gradient echo (GE) sequence at 3 Tesla (3T) and a spin echo (SE) sequence at 7 Tesla (7T). At 3T, in an ROI defined by the target-alone localizer, the BOLD response to the flankers alone was just as strong as the BOLD response to the target stimuli. This indicates a failure of the 3T GE BOLD response to isolate stimuli whose cortical representation is separated by approximately 5mm on the cortex. With 7T SE BOLD, however, the stimuli were more clearly separable: the flanker-alone stimulus evoked a much weaker response in the target ROI than the target stimulus. SE techniques at 7T reduce large vein effects, thus allowing for improved spatial accuracy in BOLD signal experiments investigating neural response modulation at specific spatial locations in V1.

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43.520 **Retinotopic mapping of the human visual cortex at 7 Tesla magnetic field strength**

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Purpose: fMRI-based retinotopic mapping is a fundamental technique for the investigation of the human visual cortex. We acquired retinotopic mapping data at a magnetic field strength of 7 Tesla and tested whether high resolution retinotopic maps of the early visual areas can be obtained. Methods: Two subjects with normal vision underwent T2* MRI scanning of the occipital lobe during visual stimulation (7 Tesla, Magnetom, Siemens). We stimulated the retina with a portion of a phase reversing (6 reversals per second) circular checkerboard stimulus (8 deg radius; 62 cd/m2 mean luminance; 95% contrast) that stepped through polar angles or eccentricities of the visual field in accordance with established retinotopic mapping techniques (Engel et al., 1997). Seven 36 s cycles of the stimulus were presented for each condition. Every 2 seconds, 25 slices parallel to the calcarine sulcus were acquired. Three voxel sizes were tested: 2.5, 1.4, and 1.1 mm isotropic voxels. After motion and distortion correction, fMRI signals were projected to the flattened representation of T1 weighted images acquired at 3 Tesla (Trio, Siemens), Fourier analysed, and correlated with the stimulus fundamental frequency. Results: Retinotopic mapping yielded phase maps that allowed for the identification of V1 and other early visual areas for each voxel size tested. Mean correlation coefficients were determined for the representation of the horizontal meridian in V1 and found to increase from 0.57±0.09 to 0.92±0.03 with increasing voxel size. Conclusions: Retinotopic mapping benefits from the use of a field strength of 7 Tesla: The visual cortex can be sampled at a high resolution aiding a detailed description of the visual field representations. Alternatively, with 2.5 mm isotropic voxels, mapping beyond the early visual areas is facilitated, as a greater expanse of occipital and parietal cortex responds significantly than for the same measurement duration at lower field strengths.

URL: http://www.med.uni-magdeburg.de/fme/kauge/vpl/vpl_hoffmann.html

43.521 **A new method for determining neuron receptive field reference-frames**

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Mapping neuron receptive fields (RFs) only leads to an understanding of the role these neurons play in sensorimotor behavior if the proper reference-frame of each RF is determined as well. Our goal was to develop a method by which this reference-frame could be determined from the RF mapping itself. We developed this method using a data set that included single-unit recordings from 80 neurons in the intermediate superior colliculus of two head-unrestrained monkeys during performance of a visual saccade task. Using head-unrestrained animals represents an improvement over head-restrained animals in that head movements allow a more natural behavior and open up an additional reference frame in which neuron RFs might be represented. Because the torsional component of eye and head are significant in this condition, we recorded both positions in 3-D using dual search coils. We plotted RFs using both the final gaze and visual target directions relative to initial gaze fixation, in eye, head and space reference-frames. While the requirements of target fixation constrained both initial and final gaze directions, freedom of movement of both eye and head produced a natural variation in these orientations across successive trials. This meant that the RFs plotted in different reference frames would themselves be different. We modeled this using hypothetical RFs, and found that these variations produced a 'smearing' of the RF in all reference frames other than the proper reference-frame associated with the neuron's activity. A non-parametric fitting of each RF in the different reference-frames, and a Levine test comparing the variances of the residuals of these fits, produced a significant difference when eye and head orientation variability were of a size similar to that shown by monkeys performing saccade tasks, so that the proper reference-frame could be distinguished. We confirmed this using our actual neurophysiological data. Supported by: CIHR (Canada). JDC holds a Canada Research Chair.

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43.522 **V1 lesion projection zone signals in a subject with tunnel vision**

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Introduction: Visual cortex that is deprived of retinal input by macular lesions can respond to visual stimulation (Baker et al, 2005). These lesion projection zone (LPZ) signals depend on the task, not the stimulus (Masuda et al., 2008). It is unknown whether these LPZ signals arise only when the macula (or fovea) is lesioned. To address this question, we examined the V1 signals in a subject with tunnel vision, i.e. a peripheral visual field loss with a spared central region including the fovea.

Methods: We measured responses in visual cortex (fMRI) that were elicited by drifting contrast patterns. The subjects either viewed the stimuli passively or performed a stimulus judgment (one-back) task. One subject had retinitis pigmentosa (RP, approximate age of onset: 6); control subjects were presented with stimuli to simulate the tunnel vision of the RP subject.

Results: In all subjects we observed stimulus-synchronized fMRI signals in the posterior calcarine sulcus. This is the cortical region that normally represents the foveal projection zone. In the normal control subjects we did not observe any stimulus-synchronized signals in the anterior calcarine sulcus in either passive viewing or during the stimulus judgment task. When the RP subject performed the stimulus judgment, the stimulus-synchronized responses spread into the LPZ located in anterior calcarine sulcus.

Discussion: Task dependent signals can be elicited in the LPZ of subjects with an intact fovea. These results are consistent with the hypothesis that these task dependent signals originate from an imbalance of the feed-forward and the feed-back signals in the LPZ.

43.523 **Response of the human LGN to different temporal frequencies for achromatic, L/M opponent and S-cone opponent stimuli measured with high field fMRI**

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Aims. We compare the responsiveness of the human LGN to different temporal frequencies (2-16Hz) for stimulation of each of the two cone opponent systems (L/M and S-cone) and the achromatic system. For comparison, measurements were also obtained from cortical area V1. Methods. MR images were acquired on a 4T Bruker MedSpec scanner. Stimuli were sinewave counter-phasing rings (0.5cpd, 2, 4, 8 Hz for chromatic stimuli and 2, 8 & 16 Hz for achromatic stimuli) that selectively activated the L/M cone opponent (RG), S cone opponent (BY) or achromatic (Ach) systems. Stimuli were presented in a temporal Gaussian envelope (s=125ms) at high cone contrasts (11% Ach; 4% RG; 30% BY). The LGNs of 6 subjects were localized in separate scans using broadband stimuli. V1s were mapped previously (Mullen et al., Euro. J. Neuroscience, 2007). We performed region of interest analyses on all LGNs and V1s and results are based on average time courses. Results. For achromatic stimuli, the human LGN shows a declining response with increasing TF (2-16Hz), which also occurs but is less marked in V1. For RG stimuli, the LGN shows some loss of response across TF from 2 to 8Hz, whereas the V1 response is unaffected by TF. For BY stimuli, the response shows some peaking at 4Hz in the LGN, but has no dependence on TF in V1 (2-8Hz). Conclusions. We find that for our stimuli the BOLD response of the LGN is optimal at low temporal frequencies (2-4Hz) for both achromatic and chromatic stimuli. This contrasts with previous results for achromatic stimuli which show a rise in response with increasing temporal frequency (Kastner et al., J. Neurophysiol., 2004).

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43.524 **Spatiotemporal Properties of LP-Pulvinar Visual Receptive Fields**

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The lateral posterior-pulvinar complex (LP-pulvinar) of the cat is divided into the lateral (LPl), the medial (LPm) and the pulvinar nuclei. Each subnucleus entertains reciprocal connections with, among other areas, area 17 and PMLS cortex. While the RF properties of neurons in the LPm and LPl have been previously described, the techniques did not allow an in depth study of the temporal dimension. This is unfortunate as it is unclear how, if at all, the LP-pulvinar modifies information along cortico-thalamo-cortical loops. The goal of this study was to characterize spatiotemporal properties of the RF of LP-pulvinar neurons using the 2D reverse correlation technique. We recorded single unit activity in the LPm, LPl and pulvinar of anaesthetized cats. No clear distinction in RF characteristics between neurons in the LPm or LPl was observed. We found that 25% of the cells were exclusively dark-excitatory (DE), more than 50% of the cells were bright-excitatory (BE) and DE, and only 9 cells were activated by gratings but did not responded significantly to this test. The latencies of the peak responses were distributed between 45ms to 155 ms. Only 44% of neurons had a synchronous response to both stimuli, while 18% of the cells showed a "bi-lobe" temporal response, as it was previously found in PMLS. Of the BE/DE cells, 72% were complex-like as both subregions were superimposed spatially. Clear inhibitory subregions were observable in time or space in only five cells. Overlapping spatiotemporal RFs are consistent with known area 17 projections to the LPl. However, a high proportion (81%) displays response dynamics that cannot easily be explained by cortico-thalamic projections. This suggests that LP-pulvinar cells receive multiple visual inputs, at different time delays, allowing diversity in RF dynamics. Supp: CIHR to CC.

43.525 **A simple model of motion integration in primate visual area MT**

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Because of their small receptive fields, neurons in area V1 can convey only limited information about the velocity of a moving object. This "aperture problem" is thought to be resolved in the middle temporal area (MT), where receptive fields cover much larger regions of visual space. However, the accuracy of MT responses depends critically on both the spatial structure of the stimulus and the temporal interval over which the response is measured. When probed with plaid stimuli, many MT neurons fail to integrate the motion signals properly, whereas with stimuli consisting of tilted bars there is little error in the response of the vast majority of MT neurons. In all cases the correct motion direction is signalled after a delay of roughly 60 ms.

We simulated a model in which MT neurons simply integrate the output of V1 neurons, which inhibit each other in a manner similar to that proposed by models that use divisive normalization. We found that the spatial structure of the inhibitory pool was critical for obtaining accurate results. Specifically, when the inhibition was aligned with the preferred orientation of a given V1 cell, the cell became powerfully endstopped: It was responsive to line-endings or short bars and its receptive field size depended on stimulus contrast. This assumption proved to be sufficient to capture the accurate motion computation observed for tilted bars in MT, as well as the temporal dynamics of the responses. By varying the directional bandwidth of the MT integration stage, we were able to capture the range of pattern motion selectivity seen in MT with plaid stimuli (as in Rust et al., 2006). This suggests that a simple model can capture the majority of results on motion integration in MT, provided that the inhibition at the V1 stage contains appropriate spatial structure.

43.526 **Not so fast there: A re-examination of the pattern versus component classification system used to distinguish Middle Temporal (MT/V5) neurons**

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Some neurons in area MT of the primate brain have been classified as 'component direction selective' (CDS) and others as 'pattern direction selective' (PDS) using direction tuning tests with grating and plaid stimuli (Movshon et al., 1985). However, a large proportion (~35%) of the neurons in these tests are consistently judged 'unclassed' (U) because they do not fall clearly into either of the two classification zones. Movshon et al., specifically pointed out that the unclassed neurons should not be regarded as an 'intermediate' category because they could simply be the by-product of tests and statistics that lack the sensitivity to clearly distinguish the two classes. Despite this admonition, researchers today often refer to this class as 'intermediate' and the role of the unclassed neurons remains a mystery. We decided to investigate the sensitivity issue raised by Movshon et al., in an attempt to understand the nature of the unclassified neurons. Using a model of MT pattern neurons (Perrone, Vision Res., 2004; Perrone & Krauzlis, ECVP, 2007) we examined the factors that have an impact on the classification of model neurons. We found that the speed of the test stimuli can have a significant influence on the classification of the PDS-type model neurons. A 10% difference between the model neuron's tuning speed and the plaid speed was often sufficient to shift the normalized pattern correlation coefficient rating (Smith et al., 2005) from PDS to U. MT direction tuning studies typically do not systematically assess the speed tuning of the neuron and so the likelihood of a speed mismatch (and hence misclassification) is high. We conclude that many 'unclassified' MT neurons could in fact be perfectly functioning pattern units and concur with Movshon et al.'s conclusion that the testing procedure could be blurring the boundary between the CDS and PDS types.

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43.527 **Application of reverse correlation to the study of visual and extraretinal signals in the macaque superior colliculus**

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The reverse correlation method has often been used to map the spatiotemporal receptive fields of visual neurons. For many visual neurons, the receptive fields are also modulated by extraretinal signals, including those related to attention, arousal, and eye movements. We have therefore adapted the reverse correlation method to characterize visual receptive fields in the context of saccadic eye movements. The technique was used to study neurons in the macaque superior colliculus, where pre-saccadic changes in the size and position of visual receptive fields have been reported previously (Wurtz and Mohler, 1976; Walker et al. 1995). Our stimulus was a sparse pattern of randomly-positioned black and white spots, presented against a gray background. The black and white spots occupied 2-5% of the display, and their positions were changed randomly at a frame rate of 85Hz.

We mapped the receptive fields of neurons in the superficial and intermediate layers of the superior colliculus in one monkey during fixation as well as during visually guided saccades. We found that pooling over 700 to 1000 saccades provided in most cases a signal of sufficient strength to study pre-saccadic changes in receptive fields with a temporal resolution of around 50ms. In data from 85 neurons we found that many receptive fields changed their characteristics beginning about 100ms before saccades. In most cases an overall reduction of activity was observed, similar to the perceptual suppression of vision that occurs around the time of a saccade. Surprisingly, we did not observe any changes in receptive field position, even though such receptive field shifts are known to occur in the superior colliculus (Walker et al. 1995). We are currently probing this paradox to better delineate the advantages and disadvantages of reverse correlation for characterizing the interaction of extraretinal and visual signals in single neurons.

Acknowledgement: Supported by CIHR.

43.528 **Contribution of spike timing in contrast and motion direction coding by single neurons in macaque area MT**

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We assessed the performance of three spike train metrics, Dspike (Victor and Purpura, 1996), the vector product metric of Schreiber et al (2003), and a rate code metric (Dcount), on computer simulated spike trains and single unit recordings from area MT of awake macaques. During the experiment, the animal responded to a direction change on a moving random dot pattern (RDP) located inside the cells' receptive field. In different trials we changed the RDP direction and contrast. We collected data from 102 single neurons in area MT of two animals and compared the similarity of spike trains elicited by different stimulus attributes using the three metrics. We then calculated stimulus clustering information entropy of the spike trains subject to the different metrics. We also derived the performance an ideal observer using the spike trains metrics to perform a 2AFC task, and applied the model to the simulated and physiological data.

The computer simulation results demonstrated that overall, the vector product metric was most sensitive to spike timing changes in frequency, but that Dspike was most sensitive to spike timing codes in which the power spectra of the spike trains are the same. There was significantly higher clustering entropy in the recorded spike trains for both direction (mean H=.16 vs H=.35) and contrast (mean H=0.25 vs H=0.46) using Dspike, than a rate code. This was reflected in the better performance of the ideal observer using the Dspike metric instead of a rate code for both directions (mean Pc=0.63 vs 0.71) and contrast (mean Pc=0.65 vs 0.74). The vector product metric yielded intermediate values. Combined these results suggest a potential functional advantage to spike time coding by MT neurons which is not based on temporal frequency changes.

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43.529 **The dynamics of V1 population response to instantaneous changes in direction of stimulus motion**

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Under natural viewing conditions, circuits in primary visual cortex (V1) must represent the information contained in a continuous stream of images that often contains abrupt changes in stimulus properties. Here we use voltage-sensitive dye imaging to explore how changes in the direction of stimulus motion are represented in the dynamics of V1 population response. Full-field random dot patterns whose direction of motion changed instantaneously from 0 to 180 degrees are used as visual stimuli.

In order to characterize the direction of motion specified by the cortical activity pattern, population response profiles were generated by convolving stimulus evoked VSD maps with the direction preference map for a given region of cortex. We found that dynamics of the population response vary as a function of direction deviation angle. For direction deviation angles smaller than 90°, the peak direction sweeps smoothly from the initial direction to the final direction. For direction deviation angles larger than 112.5°, the peak direction transiently deviates away from the direction of the second stimulus, then exhibits a step function that transiently overshoots and then settles on the final direction. Dynamics of peak amplitude also vary as a function of direction deviation angle. There is often a “notch” during the transition which is largest when the direction deviation angles are near 90°.

The dynamics of the population response predict distortions in the perceived direction of stimulus motion that depend on the angle of deviation. For a small direction deviation angle, the perceived motion trajectory is predicted to be smoother than the real stimulus trajectory. In contrast, for a large direction deviation angle, the perceived motion trajectory is predicted to be sharper than the real stimulus trajectory. Preliminary results from studies of human perception suggest distortions in the perception of motion trajectory that are consistent with these predictions.

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43.530 **Choice Probability and Reaction-Time Correlations in Macaque V1**

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Behavioral responses in near-threshold perceptual tasks and response times in reaction-time tasks are highly variable. Some of this behavioral variability is likely to come from variability in the relevant sensory representations. Indeed, trial-to-trial covariations between neural and behavioral responses have been observed in several extrastriate areas, but it is unclear whether they can also occur in V1. To address this question, we examined the relationship between V1 responses and the behavior of macaque monkeys performing a reaction-time visual detection task. Monkeys detected a small peripheral Gabor patch whose contrast varied from trial to trial around perceptual threshold. The target appeared on half of the trials and detection was indicated by a saccade to the target location. We used metal microelectrodes to simultaneously measure single units (SU), multi-units (MU) and local field potentials (LFP) from V1 of three monkeys. In general, our results were similar for all three measurements. We first computed the trial-to-trial covariations between behavioral choices and V1 activity during a fixed interval shortly after stimulus onset. Weak but significant covariations, or choice probabilities, were observed in target present trials (i.e., responses to targets of identical contrast tended to be higher in hits than in misses). No similar effect was found in target-absent trials. We also examined the covariations between V1 activity and reaction times (RT), using a sliding window to integrate neural responses. Starting shortly after target onset, we observed weak, but significant, negative correlations between neural responses and RT (i.e., RT tended to be shorter in trials where the response was higher). The significant RT correlations occurred earlier, and were shorter lived, in easy trials than in difficult trials. Overall, our results demonstrate a surprisingly tight link between V1 responses and behavioral performance, suggesting a central role for V1 in reaction-time visual detection tasks.

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Tuesday Sessions

Tuesday, May 13, 8:30 - 10:15 am
Talk Session, Vista Ballroom

Processing in Time and Space

Moderator: Concetta Morrone

8:30 am

51.11 A New Temporal Illusion Occurring Early in the Visual System

Christopher R. L. Cantor[1] (dalek@berkeley.edu), Clifton M. Schor[1,2]; [1]Program in Vision Science, University of California at Berkeley, [2]School of Optometry, University of California at Berkeley

In a temporal order judgment (TOJ) task, observers view asynchronously presented pairs of short-duration visual objects and report which one occurred first. Typical stimuli are ultra-brief (temporally broadband) rectangular pulses, and thresholds can approach 3 ms when a pair of identical pulses is used (Westheimer & McKee, 1977).

A different stimulus configuration results in a striking misperception of temporal order. Our observers view pulses with a narrower temporal bandwidth (e.g. temporal Gabors) and perform TOJ for stimulus pairs with differing temporal frequency content. This manipulation produces bias in the perceived asynchrony between high and low temporal frequency stimuli, with high temporal frequencies appearing delayed up to ~100 ms.

We believe these effects occur early in the magnocellular visual pathway, and present a model that shows how the biphasic temporal impulse responses of magnocellular ganglion cells could account for our data. We have also designed a novel motion illusion (analogous the Campbell-Robson contrast sensitivity chart) in order to allow viewers to directly experience the magnitude of this perceptual asynchrony.

Westheimer, G., & McKee, S. P. (1977).

Perception of temporal order in adjacent visual stimuli. Vision Research, 17(8), 887-892.

8:45 am

51.12 Dynamics of Non-retinotopic Form Perception Revealed by a Masking Paradigm

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Purpose. When a figure moves behind a stationary slit, observers report seeing the figure as an integrated whole although there is no extended retinotopic image (anorthoscopic perception). Using visual masking, we tested whether these figures are of perceptual origin or a result of a cognitive process (e.g., observers can infer shape using salient features such as the wheel of a car) and whether any part of the figure is represented non-retinotopically beyond the boundaries of the slit.

Methods. In the main experiment, a 5x5 square grid array moved (5.7 deg/sec) behind a slit (21 arcmin wide) in the presence or absence of a briefly flashed mask which overlapped neither with the slit nor with the path of the moving grid. Observers were required to make a same/different judgment between the moving grid and a subsequently presented stationary comparison grid. In the control experiment, rather than moving the grid, each column of the grid was sequentially flashed in the slit.

Results. In the main experiment, performance was significantly degraded in the presence of the mask. The analysis of the effect of the mask on individual columns of the grid reveals that the mask was most effective for a column presented 60 ms prior to the presentation of the mask. Our control experiment showed that these results are not contaminated by attentional capture, masking of the slit area, and/or cognitive strategies. Given that the mask appears to exert its effect on spatial regions beyond the slit, our results support the idea that the grid stimulus is represented non-retinotopically beyond the boundaries of the slit.

Conclusions. Anorthoscopic percepts are not of a cognitive origin and are represented in a spatially extended manner in a non-retinotopic coordinate system. Our results also show that masking can occur in non-retinotopic coordinates.

9:00 am

51.13 Clocking Saccadic Remapping

Amelia Hunt[1] (ahunt@wjh.harvard.edu), Patrick Cavanagh[1,2]; [1]Vision Sciences Lab, Harvard University, [2]Laboratoire de Psychologie de la Perception, Université Paris Descartes

When the eyes move, some cells in visual areas (FEF and LIP, among others) begin firing in anticipation of visual stimuli that will fall in their receptive fields once the saccade has landed (e.g., Duhamel, Colby, & Goldberg, 1992). This anticipatory firing can begin up to 50ms before the eyes begin to move. One consequence of this "remapping" may be (as Deubel & Schneider, 1996, have reported) that subjects think they are looking at the target location before their eyes actually arrive there. To investigate the timing of this shift in the apparent direction of gaze, we presented a ticking clock in the periphery as the saccade target. As soon as they heard a beep, subjects shifted fixation to the clock and reported the time on the clock when their eyes arrived. The reported time was earlier than the actual time on the clock by an average of 39ms (±21.8 ms). In a control condition, the clock moved to fixation (mimicking the retinal motion of the saccade without the eye movement). In this case, the reported time was later than the actual time on the clock by 27ms (±13.2 ms). Finally, when the clock's timing hand was not shown until the clock arrived at fixation, there was no longer a difference between saccade and control conditions. We conclude that there is a systematic anticipation of perceived direction of gaze that is consistent with the timing of saccadic remapping in visual cortices.

Acknowledgement: Tom Carlson and Hinze Hogendoorn

9:15 am

51.14 Spatiotopic selectivity for location of events in space and time

Maria Concetta Morrone[1,2] (concetta.morrone@hsr.it), Paola Binda[1,3], David Charles Burr[4,2]; [1]Università vita-salute S Raffaele, Milan, Italy, [2]Dep of Psychology, University of Wester Australia, Australia, [3]IIT, Genova, Italy, [4]Dipartimento di psicologia, Università di Firenze, Italy

Accurate timing over the sub-second scale is essential for a range of human perceptual and motor activities, but the mechanisms for encoding this time scale remain poorly understood. A series of experiments from our laboratory indicates that perception of time is tightly linked to perception of external position. Firstly, adaptation to fast drifting gratings cause temporal distortions that are spatially specific in external spatial coordinates, implicating craniotopic receptive fields (Burr et al., Nature Neuroscience, 2007). Compression of perceived duration (interval separation between distinct events) occurs for stimuli presented perisaccadicaly, at the time when craniotopic receptive fields are being updated (Morrone et al., Nature Neuroscience 2005). To understand better these phenomena, we measured perceived time of stimuli during saccades, with a cross-modal temporal-order-judgment and a bisection technique to study time perception: subjects reported whether a flashed bar appeared earlier or later than a single beep, or the midpoint of two beeps (200 ms separation). Time perception was considerably distorted during saccades: flashed bars were perceived either earlier or later than fixation control-trials, depending on when they were presented relative to the saccade. These results explain well the time compression, and also the temporal reversals between two visual stimuli during saccades. The temporal distortions also depended on perceived spatial position. While making temporal judgments, subjects also reported the perceived position of the bar. The magnitude of temporal distortion correlated neither with the physical position of the target, nor with the amount of perceived perisacaddic spatial displacement; instead it correlated well with the perceived vicinity of the position of the stimulus to saccadic targets. All these results reinforce the evidence that the localization of visual events in space and in time are mediated by neurones with craniotopic receptive fields and that these alteration are instrumental in achieving perceptual stability.

9:30 am

51.15 Spatial and temporal binding in the human pulvinar

Robert Ward[1] (r.ward@bangor.ac.uk), Isabel Arend[1], Robert Rafal[1]; [1]Wolfson Centre for Clinical and Cognitive Neuroscience, School of Psychology, Bangor University, UK

Largely on the basis of its interesting anatomy, the pulvinar has been hypothesized to play a useful role in visual attention. The pulvinar is the largest nucleus of the thalamus and is notable for its hub-like connectivity: it has extensive reciprocal connections with the cortex, including occipital, parietal, temporal, and frontal areas. This architecture might facilitate tasks in which one cortical area must modulate the activity of another. Furthermore, gradients of connectivity have been found within the non-human primate (NHP) pulvinar, where nearby cortical areas project to nearby areas of the pulvinar. Of most interest here is a gradient running roughly from anterior to posterior pulvinar. Highly spatiotopic areas, like striate and extrastriate cortex, connect more anteriorly; areas with less spatial orgranisation, like IT, connect more posteriorally.

So how might this detailed anatomical picture relate to attentional function in humans? Some previous human lesion studies have tended to group diverse pulvinar lesions together. Here we studied spatial and temporal feature binding in three patients, focusing on the location of the lesion and the connectivity that was likely to be disrupted. Based on NHP anatomy, we expected that anterior compared to posterior lesions would be more likely to disrupt connections with highly spatiotopic cortex. Consistent with this hypothesis, we found that lesion to the anterior pulvinar mainly disrupted the ability to bind visual features to a location in space, whereas lesion to the posterior pulvinar produced deficits in binding to a point in time. These results suggest correspondence with the neural anatomy of the pulvinar, and its gradient of connectivity to spatially organized cortex. We discuss our findings within the scope of neural network models of visual attention, in which the pulvinar facilitates communication between different brain areas.

Acknowledgement: This work was funded by grant C501417 from the Biotechnology and Biological Sciences Research Council (BBSRC)

09:45

51.16 Seeing light vs dark lines: psychophysical performance is based on separate channels, limited by noise and uncertainty

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

Visual detection performance (d') is usually an accelerating function of stimulus contrast, which could imply a smooth, threshold-like nonlinearity in the sensory response. Alternatively, Pelli (1985 Journal of the Optical Society of America A 2 1508-1532) developed the 'uncertainty model' in which responses were linear with contrast, but the observer was uncertain about which of many noisy channels contained the signal. Such internal uncertainty effectively adds noise to weak signals, and predicts the nonlinear psychometric function. We re-examined these ideas by plotting psychometric functions (as z-scores, with high precision) for two observers (SAW, PRM). The task was to detect a single, vertical, blurred line at the fixation point, or to identify its polarity (light vs dark). Detection of a known polarity was nearly linear for SAW but very nonlinear for PRM. Randomly interleaving light and dark trials reduced detection performance and rendered it more nonlinear for SAW, but had little effect for PRM. These effects occurred for both single-interval and 2AFC procedures. The whole pattern of results was well predicted by our Monte Carlo simulation of Pelli's model, with only two free parameters – the levels of uncertainty and noise. SAW (highly practised) had very low uncertainty. PRM (with little prior practice) had much greater uncertainty, resulting in lower contrast sensitivity, nonlinear performance, and no effect of external (polarity) uncertainty. For SAW, identification was about $\sqrt{2}$ better than detection, implying statistically independent channels for stimuli of opposite polarity, rather than an opponent (light-dark) channel. These findings strongly suggest that noise and uncertainty, rather than sensory nonlinearity, limit visual detection, and we conjecture that uncertainty decreases with intensive practice.

10:00 am

51.17 Does my butt look big in this? Horizontal stripes, perceived body size and the Oppel-Kundt illusion

Peter Thompson[1] (p.thompson@psych.york.ac.uk); [1]Department of Psychology, University of York, UK

It is popularly believed that wearing horizontal stripes makes us look fatter than we are. This appears to contradict two well-known illusions: the Oppel-Kundt illusion shows that a filled extent looks longer than an unfilled extent and secondly the Helmholtz square illusion shows that a square comprising horizontal lines appears taller than one of identical size comprising vertical lines. These effects are very closely related and both suggest that the wearing of horizontally striped clothes should make us look taller and thinner. Indeed Helmholtz claimed that "ladies' frocks with cross stripes on them make the figure look taller". Recent work by Taya & Miura (2007) suggests that a resolution of this paradox may lie in the difference between 2-D pictures and 3-D bodies. Using 2-D images of vertically-oriented cylinders they demonstrated that there was a significant positive correlation between the apparent 3-D depth of the cylinder and an illusory shrinkage in the cylinder's width. These results suggest that the wearing of vertical stripes makes us look slimmer by way of providing cues to the 3-D nature of our bodies and that this effect outweighs the 'fattening' 'Helmholtz square' effect of the vertical stripes. . We have (1) confirmed Helmholtz's findings that a square composed of horizontal lines looks taller than one made of vertical lines; (2) determined that when the horizontal and vertical stripes are presented in the context of 2-D images of patterns on women's clothing the illusion is negated and (3) demonstrated that patterns that accentuate 3-D information and use horizontal stripes will make us look even slimmer. These results will be discussed in the context of the possibility that (1) the belief that wearing horizontal stripes makes us look fat is a recent myth and (2) fat people just like wearing horizontal stripes.

Tuesday, May 13, 8:30 - 10:00 am
Talk Session, Royal Palm Ballroom 4-5

Perceptual Organization 2

Moderator: Joseph Brooks

8:30 am

51.21 Factors influencing perceived occlusion between amodally completable objects

Barbara J Gillam[1] (b.gillam@unsw.edu.au), Barton L Anderson[1], Tatjana Seizova-Cajic[1]; [1]School of Psychology, University of New South Wales, Australia

Although amodal completion is known to occur under conditions of occlusion it is not known whether perceived occlusion in interrupted objects is determined by the same factors as good continuation. We measured the effects on perceived occlusion of gap size and contrast polarity, both of which influence good continuation. Stimuli were sets of 5 rectangles at varying near vertical orientations, also varying in length, width and separation and interrupted by a horizontal gap. The degree to which the horizontal gap was perceived as an occluding surface was compared across stimuli using the method of paired comparison. In Experiment 1 we used two gap sizes (17' and 52') and three luminance arrangements on a grey background. Stimuli were either all black, alternating black and white with the same contrast polarity across the gap, or alternating with opposite contrast polarity. Multiple randomly generated versions of each stimulus were created. For all stimuli, perceived occlusion was significantly stronger for the large gap than the small gap. Change in luminance polarity across the gap generally reduced the sense of occlusion but significantly more for the small gap. Experiment 2 tested the possibility that change of contrast (rather than polarity) reduced the sense of occlusion in Experiment 1. Using only the small gap, we compared opposite polarity with same polarity conditions controlling for contrast differences between components (both relative to each other and relative to the background). Contrast change across the gap did impair perceived occlusion but significantly less than polarity change. We conclude that unlike amodal completion, the sense of occlusion at gaps in continuing objects is greater for large gaps than for small gaps. The considerably stronger effect of polarity change on perception of small gap occlusion may indicate a greater role of good continuation in that case than for large gap occlusion.

Acknowledgement: ARC Grant RM02837 to B.G. and B.A.

URL: http://perception.psy.unsw.edu.au/vss2008.html

8:45 am

51.22 Interaction between local and global border-ownership signals on a closed figure composed of small triangles

Masayuki Kikuchi[1] (kikuchi@cs.teu.ac.jp), Taku Saito[1]; [1]School of Computer Sceince, Tokyo University of Technology

Previous study had reported that collinearly placed short line segments which had border-ownership attribute (i.e., figural side) could easily be integrated into a long contour when they had the same ownership polarity, but they could hardly be integrated when their ownership polarities spatially alternate (Kikuchi & Oguni, ECVP2005). This study performed psychophysical experiments investigating the perception of the closed contours represented by such small line segments with border-ownership attribute. The experimental method was based on path-paradigm (Field, Hayes, & Hess, Vision Research, 1993). Instead of Gabor patches, small equilateral triangles were used as stimulus elements, as used by the previous study by Kikuchi & Oguni. A path was composed of twenty triangles, embedded in background (randomly placed triangles in 16x16 grids). Each path-triangle participated in the global contour so that one of the three edges in the triangle was on a global smooth curve. All paths had circular shape. Unlike the preceding study (Kovacs & Julesz, PNAS, 1993), two types of closed contours can be defined in our experiment according to the ownership polarities. Type I: global ownership polarity is inward of the circle, but local ownership polarity is outward, corresponding to "hole". Type II: both global and local ownership polarities are inward of the circle. Each trial in our experiment had two successive stimulus screens, and only one of them had the path. Subjects' task was to answer which screen included the path. We compared the correct rates of path-detection for above two types of contours, and obtained the result that type II contours were salient but type I were not, for all three subjects ($p<0.01$). This result indicates that there seems interaction between local and global ownership signals on global closed contours, and that salient perception of the contours needs the coincidence of global and local ownership polarities.

Acknowledgement: Supported in part by a Grant-in-Aid #19700648 from MEXT Japan

9:00 am

51.23 Figure-Ground Segmentation Can Occur Without Attention

Ruth Kimchi[1] (rkimchi@research.haifa.ac.il), Mary A. Peterson[2]; [1]Department of Psychology, University of Haifa, [2]Department of Psychology, University of Arizona

The question of whether or not figure-ground segmentation can occur without attention is unresolved. Many traditional theories assumed it could, but the evidence is scant and open to alternative interpretations. Recent research indicating that exogenous attention can influence figure-ground segmentation raises the question anew. We tested this question by asking participants to perform a change-detection task on a small target matrix made up of random black and white pixels. When different, only a single pixel changed, rendering the task sufficiently demanding to absorb attention. The target matrix was presented on a task-irrelevant scene of alternating regions organized into figures and grounds by convexity. Independent of any change in the target matrix, the figure-ground organization of the scene backdrop changed or remained the same. The edges in the scene backdrop always changed across successive displays, regardless of whether or not figure-ground organization changed, to control for the possibility that a change in scene organization could be detected from local changes in edges per se. Changes in scene figure-ground organization produced congruency effects upon speed and accuracy of the target-change judgments. These effects arose despite inattentional blindness to the scene backdrop. When probed with surprise questions, participants could report neither the figure-ground status of the region on which the target appeared in the preceding display or whether the figure-ground organization of the scene had changed on the preceding trial. When attending to the scene backdrop, participants made these reports highly accurately. These results clearly demonstrate that figure-ground segmentation can occur without focal attention.

9:15 am

51.24 Putting figure-ground organization and perceptual grouping in context

Joseph Brooks[1] (joseph.brooks@ucl.ac.uk), Jon Driver[1]; [1]Institute of Cognitive Neuroscience, University College London

Gestalt psychology inspired wide interest in processes of perceptual grouping and figure-ground organization. But while often mentioned together in textbooks, these two topics have rarely been directly related. Figure-ground organization is usually discussed in terms of local properties on one or the other side of an edge that may determine the side to which that edge becomes assigned. Perceptual grouping is usually discussed in terms of linking otherwise discontinuous elements in an image. Here we address whether figure-ground assignment might be affected by grouping relations between discontinuous edges. Specifically, we tested for 'context' effects, whereby the figural assignment of one edge might induce a corresponding figural assignment for a separate but perceptually-grouped edge. We used both subjective report and also an objective, short-term edge-matching task to confirm that this can indeed apply consistently. Thus, contextual information can affect figure-ground assignment via perceptual grouping.

Acknowledgement: Funded by the UK Royal Society International Post-doctoral Fellowship Scheme

URL: http://www.ucl.ac.uk/~ucjtjeb/context/

9:30 am

51.25 Decoding orientation-selective responses to real and illusory contours

Frank Tong[1] (frank.tong@vanderbilt.edu), Yukiyasu Kamitani[2]; [1]Psychology Department, Vanderbilt University, [2]ATR Computational Neuroscience Laboratories, Kyoto, Japan

To what extent are real and illusory contours represented in a similar manner by the visual system? Much evidence indicates that extrastriate area V2 responds well to illusory contours, but the role of V1 in illusory contour perception is still debated. Using decoding methods that we recently developed (Kamitani & Tong, Nat Neurosci, 2005), we measured orientation-selective responses in the human visual cortex to real and illusory contours. Subjects performed a demanding letter discrimination task at central fixation while real or illusory gratings were presented in the periphery. Illusory gratings consisted of abutting segments of real tilted lines (45 or 135 deg) that formed higher-order vertical or horizontal patterns. Orientation discrimination performance of each visual area was assessed by using a linear classifier to categorize their activity patterns according to the viewed orientation. We found that individual visual areas (V1-V4) could discriminate the orientation of real gratings with high accuracy (~90% correct, chance level 50%). In comparison, orientation-selective responses to illusory contours were much weaker but still reliable, as indicated by moderate classification accuracy (65-70% correct). Interestingly, training on illusory orientations led to accurate classification of real orientations (~90% correct) for all visual areas. This indicates that the pattern of orientation-selective responses evoked by real and illusory gratings are very similar but simply weaker for illusory stimuli. Finally, we tested whether the real orientation component contained within illusory stimuli could be decoded. Whereas V1 and V2 could accurately distinguish real orientations embedded in illusory contours, higher areas performed poorly, suggesting that the presence of the illusory contours disrupted their sensitivity to real contours. Taken together, these findings indicate that V1 and higher areas are sensitive to the orientation of illusory contours, but that early areas (V1-V2) maintain greater sensitivity to the real components that define the illusory stimuli.

Acknowledgement: Research support: NEI R01-EY14202 to FT and Nissan Science Foundation Grant to YK.

09:45

51.26 Cortical dynamics of figure-ground segmentation: Shine-through

Gregory Francis[1] (gfrancis@psych.purdue.edu); [1]Psychological Sciences, Purdue University

When a brief offset vernier target is followed by a bar grating of non-offset vernier elements, the target is sometimes not masked but instead is perceived as being in a foreground plane separate from the mask elements in the background plane (Herzog & Koch, 2001). We analyzed the dynamics of the 3D LAMINART (Cao & Grossberg, 2005) cortical model of depth perception and found that it explains the appearance of shine-through for these stimuli. The model explanation proposes that shine-through is due to a combination of false binocular disparity matches between the target and the central element of the mask, and a weakening of between-disparity-plane competition that occurs from spatial competition and boundary grouping. Simulations of the model demonstrate that it closely matches empirical data on the properties of shine-through, including effects of the number of elements in the mask, the influence of a gap in the mask grating, and long-range effects from elements around the mask grating. The model is contrasted with an alternative explanation of shine-through, and novel mask conditions are identified that allow for empirical tests of the model hypotheses.

Tuesday, May 13, 10:30 am - 12:15 pm Talk Session, Vista Ballroom

Vision for Action

Moderator: William Warren

10:30 am

52.11 Mirror-like representation of observed actions

Lior Shmuelof[1] (lior.shmuelof@mail.huji.ac.il), Uri Hertz[2], Ehud Zohary[1,2]; [1]Neurobiology Department, Hebrew University, Jerusalem, [2]Interdisciplinary Center for Neural Computation, Hebrew University, Jerusalem

The anterior intraparietal cortex (aIPS) is known to be involved in visually guided grasping. This region is also active when observing grasping movements. Here we investigate whether the viewpoint of the observer affects aIPS activation, as well as the speed of action imitation.

Ten subjects observed video clips of the right or left hand making object grasping movements. In one set of clips the hand was shown from an egocentric point of view (i.e. the observed actions are similar to those seen when one performs them). In the other set, the clips were shown from an allocentric point of view (as one would see when observing his own actions in the mirror). The results indicate that the fMRI activation in the aIPS shows a contralateral preference for the observed hand when seen from an egocentric point of view (i.e. the right aIPS is significantly more active during observation of left hand clips than right hand clips. In the left aIPS, the preference was the opposite). Interestingly, for the allocentric point of view, the ipsilateral hand is favored.

Subsequently, we looked for the behavioral correlates of this mirror-like cortical representation: Subjects observed sequences of finger tapping movements made by either the right or left hand from an egocentric or an allocentric point of view and had to imitate them as fast as possible with their right hand. Imitation of the right egocentric and left allocentric clips was significantly faster than imitation of the left egocentric and right allocentric clips, mirroring the patterns of activation in the aIPS. Additionally, egocentrically viewed actions were imitated faster than allocentric ones. The two experiments demonstrate a mirror-like representation of actions, which may stem from the inherent spatial compatibility that exists between our actions and their reflection in the mirror.

10:45 am

52.12 The phantom pulse effect: rapid left-right mirror reversals evoke unusual sensations of phantoms, movements, and paresthesias in the limbs and faces of normals and amputees

David Peterzell[1,2,3] (peterzel@psy.ucsd.edu); [1]University of California, San Diego, [2]VA San Diego Healthcare System, [3]San Diego State University

Ramachandran, Altschuler and others have shown that a simple mirror reflection of a moving intact limb causes phantom sensations in normal observers, and reduces phantom limb pain in some amputees. However, mirror therapy is ineffective for many amputees, and neural mechanisms underlying phantom sensations are not fully understood. While attempting to develop more powerful mirror treatments for phantom limb pain, I have discovered that stroboscopic motion and mirror reversals greatly amplify mirror effects in upper-limb amputees and some normal individuals. The "phantom pulse" has been generated in two ways. The first involves using a real-time video image of the observer that flickers between a normal image and a mirror-reversed image at rates varying from 0.5 to 2 cycles/sec (with an 0.2-sec delay). The second involves using Ramachandran's simple mirror with a strobe light, in a dark room. For both methods, movement of one limb causes powerful phantom sensations and a sense of movement in the opposite limb, leading to permanent pain reduction in some amputees. Approximately 50% of normal observers experience mild to moderate phantom-like phenomena using these methods. The reversal or flicker rate that optimizes effects occurs at approximately 1 cycles/sec for most individuals. Normal individuals typically experience some combination of the following in their fingers and hands: tingling, numbness, tickling, pressure, heat, cold, or involuntary movement. In some, these sensations move gradually from the wrist to the shoulder. In perhaps 1 or 2% of individuals, the face tingles. In these most powerful instances, the individual is unable to close just one eye when instructed to "wink." Use of a temporally-modulated stimulus may enable researchers to (1) conduct psychophysical investigations of mirror-phantom phenomena, and (2) examine physiological correlates these effects using EEG and FMRI. We speculate that neurons with similar transient temporal properties contribute to these profound effects.

11:00 am

52.13 Are latency differences between slant cues visible in the online control of our movement?

Christa van Mierlo[1] (c.vanmierlo@fbw.vu.nl), Eli Brenner[1], Stefan Louw[1], Jeroen Smeets[1]; [1]Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands

When we place a cup on a table we not only need to traverse the distance between the cup and the table, but also make sure that at the end of the movement the cup has the same orientation as the table. We estimate both distance and orientation with binocular and monocular cues, which are processed independently with different neural latencies. This latency difference might become relevant if information is changing, such as during ones' movements. Movements can be corrected at short latency to a change in the environment. Are such corrections the sum of corrections to changes in the individual cues or a full reaction in response to the first indication of a change?

To investigate this, we created a virtual environment in which subjects had to place a cylinder on a virtual surface. The slant of the virtual surface could change right after movement onset and was either simultaneously in binocular disparity and monocular cues or only in one of the cues. Subjects' adjustment might be based on the latest estimate of slant or on detecting the transient in surface orientation. We therefore removed the transient on half of the trials by blocking vision for 100 ms before the slant change.

Subjects corrected their movement to accommodate the changed surface slant. This correction was 55 ms faster for monocular cues than for binocular disparity. Removing the transient delayed the response to the monocular cues by 80 ms, without affecting the response to the binocular cue. Corrections to slant changes happening simultaneously in both cues were the sum of corrections to changes in the individual cues. So we have access to the monocular transient and to monocular and binocular slant, but simply use the first one signaling a change when we have to adjust an ongoing movement.

11:15 am

52.14 Development of optimal integration for self-motion and landmark cues in human navigation

Marko Nardini[1] (m.nardini@ucl.ac.uk), Peter Jones[2], Rachael Bedford[3], Oliver Braddick[3]; [1]Dept Psychology, University College London, UK, [2]School of Informatics, University of Edinburgh, UK, [3]Dept Experimental Psychology, University of Oxford, UK

Mammalian navigation depends both on visual landmarks and on self-generated (e.g. vestibular and proprioceptive) cues that signal the organism's movement from one moment to the next. Previous

studies have found that under conflict, landmarks can reset estimates of self-motion, or be integrated with them. We asked whether humans combine these cues optimally, given their relative reliability, and whether children, who use both kinds of information from a young age, combine them as adults do. In a dark arena with illuminated peripheral landmarks, participants attempted to return an object to its original place, given (i) non-visual self-motion information only, (ii) visual landmarks only, or (iii) both. In the "self-motion only" condition, participants responded in the dark. In the "landmarks only" condition, participants were disoriented by turning before responding. In the "both" condition landmarks were available and participants were not disoriented. In a further "conflict" condition (iv), landmarks were covertly rotated by 15°, creating a conflict between self-motion and landmark information that enabled us to assess how the two were weighted relative to each other. When self-motion and landmark information conflicted, adults and children aged 4 - 8 years weighted them optimally given their relative reliability. However, only adults were Bayes-optimal in reducing variability in their location estimates when both information sources were available and consistent, whereas children's variability was not lower than with either information source alone. These results indicate that in human navigation, development of individual representational systems greatly precedes development of the capacity to combine multiple sources of spatial information optimally within a common reference frame. Further, optimal weighting of conflicting spatial cues precedes ability to combine them to reduce variance.

11:30 am

52.15 Optic flow recalibrates the direction of walking but not throwing

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

Understanding the visuo-motor calibration of spatially-oriented movements is central to an understanding of perception and action. We investigate whether adaptation of the mapping between visual target direction and walking direction transfers to the direction of underhand throws.

In an adaptation phase, participants repeatedly walked to a target in a virtual environment while the heading direction specified by optic flow was displaced 10 deg to the right of the actual walking direction (Bruggeman, Zosh, & Warren, Current Biology, 2007). Within in a few trails, they adapted and walked straight toward the target. Rushton (2004) and others have argued that the exposure to displaced flow leads to adaptation of the visual straight ahead. In contrast, we hypothesized that optic flow acts to recalibrate the visuo-motor mappings from perceived target direction to initial and ongoing walking direction. On the former hypothesis, adaptation of the straight ahead should affect any spatial-oriented movement, including throwing to the target. On the latter hypothesis, adaptation should affect only walking whereas throwing should remain unchanged.

We tested these hypotheses by evaluating walking and throwing direction before and after adaptation. Participants first threw a ball to a visually specified target (they could not see the ball's trajectory and landing position) and then walked with their eyes closed to the target, as if to retrieve the ball. Prior to adaptation participants throw and walk in the same direction. However, after adaptation they walked approximately 5 deg to the left of the target, missing it by about .8 m. But their throws remained on target. Surprisingly, participants were not able to retrieve their own throws! Thus, optic flow recalibrates the visual-locomotor mapping, not the direction of visual straight ahead.

Acknowledgement: Supported by NIH EY10923

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

11:45 am

52.16 Visual and vestibular discrimination of heading azimuth and elevation for upright and side-down observers

Paul MacNeilage[1] (pogen@berkeley.edu), Dora Angelaki[1]; [1]Washington University (Dept. of Anatomy & Neurobiology)

Heading is the direction of observer translational relative to the stationary environment. For short duration movements in well-lit environments, heading may be estimated from both visual and vestibular cues. The visual cue to heading is the location of the focus of expansion in the optic flow field. The vestibular cue to heading is the direction of inertial acceleration signaled by the otoliths. Prior research has focused on visual discrimination of heading azimuth (heading in the horizontal plane). There have been few studies of visual discrimination of elevation, and fewer comparable studies of non-visual heading discrimination. To investigate human ability to estimate heading under more general conditions, we measured heading discrimination thresholds for azimuth and elevation in visual-only and vestibular-only conditions with observers oriented upright and side-down relative to gravity. Subjects were asked to discriminate heading azimuth or elevation relative to straight-ahead in a two-interval-forced-choice task. Experiments were conducted on a 6DOF Moog motion base with attached 90 X 90 deg visual display. The movement was a 1 sec Gaussian velocity profile with peak velocity and acceleration of 0.3 m/s and 1.13 m/s2, respectively. The visual scene depicted a 3D cloud of frontoparallel triangles rendered in stereo using shutter glasses. Visual thresholds were significantly lower than vestibular, and upright thresholds were generally lower than side-down. Visual-only results revealed that upright observers are equally sensitive to heading azimuth and elevation, but that side-down observers are better at discriminating head-centric azimuth (elevation relative to gravity). Vestibular-only results revealed that observers are better at discriminating head-centric azimuth, regardless of body orientation. In other words, vestibular sensitivity to heading depends more upon the direction of acceleration relative to the head, than relative to gravity. Gravitational and inertial accelerations are physically equivalent, so this result suggests that otolith sensitivity may not follow Weber's Law.

Acknowledgement: NSBRI Postdoctoral Fellowship

12:00 pm

52.17 A dynamical model of pursuit and evasion in humans

Jonathan A. Cohen[1] (Jonathan_Cohen@brown.edu), Michael E. Cinelli[1], William H. Warren[1]; [1]Department of Cognitive & Linguistic Sciences, Brown University

Our steering dynamics model can accurately simulate human locomotor behavior with respect to environmental objects: stationary goals and obstacles (Fajen & Warren, 2003), moving targets (Fajen & Warren, 2007) and moving obstacles (Cohen, Bruggeman, & Warren, VSS 2005). Thus far, these objects have been non-intentional physical entities moving on fixed trajectories. The aim of the present research is to extend our investigation to intentional, interactive agents. Specifically, we seek to model situations in which two intentional agents interact in a range of pursuit and evasion scenarios.

Ten pairs of participants interacted with one another in 4 different scenarios: (a) target interception, (b) moving obstacle avoidance, (c) mutual evasion, and (d) pursuit-evasion. In general, one participant acted as a pursuer while the other acted as an evader en route to a goal; in the mutual evasion scenario both participants avoided one another while en route to separate goals. Head positions were recorded using an inertial/ultrasonic tracking system (IS-900).

Surprisingly, the steering dynamics model generalized to the interactive scenarios simply by linearly combining existing components for target interception and moving obstacle avoidance. This finding demonstrates the generality of the constant bearing strategy that underlies both components, and indicates that evasion does not require a qualitatively different strategy. Small parametric adjustments improved the model fit, shedding light on subtle differences in locomotor behavior elicited by intentional and non-intentional objects. Future research will investigate this difference by manipulating the intentional properties of targets and obstacles in both real and virtual environments.

Acknowledgement: Supported by NIH EY10923

Tuesday, May 13, 10:30 am - 12:15 pm
Talk Session, Royal Palm Ballroom 4-5

Object Perception 2

Moderator: Karin James

10:30 am

52.21 Self-generated rotations of 3D objects during initial learning results in automatic motor cortex recruitment during subsequent visual recognition

Karin James[1] (khjames@indiana.edu), Scott Mueller[1]; [1]Psychological and Brain Sciences, Indiana University

Visual object recognition benefits from learning via self-generated rotations of 3D computer generated objects versus learning objects by watching the same rotations generated by another, unseen, participant. Here we show that during visual object recognition, the motor cortex is active only when viewing objects that have been learned with self-generated action. Thirteen subjects studied computer generated novel and familiar objects in two ways. Half of the objects were studied 'actively' by rotating them with a trackball on a computer monitor, whereas the other half were shown rotating without active engagement from the participant. The rotations of these 'passively' studied objects were recorded from a previous participant's self-generated rotations. In a subsequent test phase, participants were scanned, using fMRI, while they performed an old/new recognition task on the active and passively studied objects. Active study resulted in greater activation in motor regions of the brain when compared with passive study. This effect surfaced only when learning the appearance of novel 3D objects, and not during active and passive study of known, or familiar 3D objects. In addition, learning effects (old vs new items) occurred for both active and passive study (and for novel and familiar objects) in the visual association cortex. These results demonstrate that a) motor experience is stored in the brain and re-activated during visual recognition and b) both types of study result in the recruitment of visual association regions during recognition and c) that the motor activation seen here may facilitate visual recognition. This is the first demonstration of empirically manipulated active learning of objects resulting in motor system activation during a visual task. Such a conclusion suggests that the automatic activation of motor cortex during viewing of some objects is due to motor learning and not to the perception of implicit affordances.

10:45 am

52.22 A speed-dependent inversion effect in dynamic object matching

Benjamin Balas[1] (bjbalas@mit.edu), Pawan Sinha[2]; [1]Laboratories of Cognitive Neuroscience, Children's Hospital Boston, [2]Department of Brain and Cognitive Science, MIT

The representations employed by the visual system for dynamic object recognition remain relatively unclear, due in large part to the lack of sufficient data constraining the nature of the underlying encoding processes. In particular, very little is currently known about the extent to which recognition of a moving object is invariant to spatial or spatiotemporal stimulus manipulations. In the current study, our goal was to begin a line of investigation in this vein on the limits of invariant recognition for isolated dynamic objects.

We examined the limits of invariant recognition for unfamiliar moving objects using a simple same/different matching task. Observers were asked to evaluate whether pairs of sequentially presented rigidly-moving objects differed in identity subject to a spatial manipulation (inversion) and a spatiotemporal manipulation (speed change). We find evidence of a speed-dependent inversion effect, such that inversion only incurs a matching cost for objects that move relatively slowly. Furthermore, we observe a deleterious effect of speed change between sample and test stimuli. This indicates that the speed of appearance change is encoded by the visual system for recognition, consistent with previous work regarding "spatiotemporal signatures" as a model for dynamic object recognition. However, we also find that the effect of speed change on matching has an interesting temporal asymmetry: matching a "fast" sample object to a "slow" test object is harder than matching a "slow" sample to a "fast" test stimulus. Taken together, these results suggest distinct modes of processing for fast-moving and slow-moving objects and thus have important consequences for previous proposals regarding the representation of moving objects. We discuss the current data in the context of an emerging model of dynamic object perception.

Acknowledgement: BJB was supported by an NDSEG fellowship

11:00 am

52.23 Dissociating the effects of viewpoint disparity and image similarity in mental rotation and object recognition

Olivia Cheung[1] (olivia.cheung@vanderbilt.edu), William Hayward[2], Isabel Gauthier[1]; [1]Vanderbilt University, [2]University of Hong Kong

Mental rotation (MR) is often measured in a task where participants judge the handedness of rotated objects, and is revealed by a viewpoint cost - a linear reduction in performance with an increase of viewpoint disparity for the objects. Similar viewpoint costs are also often found for object recognition (OR), in tasks where participants match the identity of rotated objects. These findings led to speculations that MR might be the mechanism underlying OR. However, recent studies dissociate the two tasks (Gauthier et al., 2002; Hayward et al., 2006). If viewpoint costs are dissociable in MR and OR, we may ask whether they arise because of the same or different factors. Specifically, viewpoint disparity is usually confounded by image similarity in these tasks - images become dissimilar with an increase in viewpoint difference. Here, we investigated the effects of viewpoint disparity and image similarity in MR and OR using novel objects rotated around the vertical axis. Subjective similarity ratings for image pairs that differed by 40°, 80°, 120° and 160° were collected and used to dissociate the two factors. In a Similarity condition, the viewpoint disparity was fixed and image similarity was manipulated. In a Viewpoint condition, viewpoint disparities were manipulated while similarity was fixed. In a sequential matching paradigm, participants performed the MR or OR tasks in both Similarity and Viewpoint conditions. Performance was better for similar than dissimilar image pairs for both tasks, but the effect was larger for OR than MR. In contrast, when similarity was controlled, a viewpoint cost was only found for MR but not for OR. These results demonstrate different causes of the viewpoint costs in the two tasks: while MR largely relies on 3-D mental transformation procedures that depend on viewpoint disparity, OR is based predominantly on matching similarity of image features.

Acknowledgement: This work was supported by grants from the Research Grants Council of the Hong Kong Special Administrative Region (China), NSF and the James S. McDonnell Foundation.

11:15 am

52.24 Differential Learning Processes for Categorization

Rubi Hammer[1,2] (rubih@alice.nc.huji.ac.il), André Brechmann[4], Frank Ohl[4], Gil Diesendruck[5], Daphna Weinshall[1,3], Shaul Hochstein[1,2]; [1]Interdisciplinary Center for Neural Computation, Hebrew University, Jerusalem, Israel, [2]Neurobiology Department, Institute of Life Sciences, Hebrew University, Jerusalem, Israel, [3]School of Computer Sciences and Engineering, Hebrew University, Jerusalem, Israel, [4]Leibniz Institute for Neurobiology, Magdeburg, Germany, [5]Gonda Brain Research Center and Department of Psychology, Bar-Ilan University, Ramat-Gan, Israel

Category learning is a fundamental cognitive process enabling the creation of simplified representations of objects/events. We focus on comparison processes for category learning – learning categories by comparing pairs of exemplars identified to be from the same category (same-class exemplars) vs. pairs from different categories (different-class exemplars). We previously found that these two comparison processes differ dramatically: In the context of learning to categorize novel complex stimuli, training with different-class exemplars depends on pair selection and may require directions for use. On the other hand, same-class exemplars are generally more informative and their use more intuitive. We now report two additional characteristics of learning from same- and different-class pairs. Firstly, while the ability to learn from different-class exemplars develops in late childhood (age 10-14), learning from same-class exemplars seems to be present already in early childhood (6-10). We tested younger and older children and adults on a categorization task, using either same- or different-class exemplar pairs for defining categories. Younger children were unable to execute the different-class comparison strategy. In a related fMRI study, we tested adult participants in three conditions: category learning from same- or from different-class exemplars and a control task, using the same stimuli, but where participants performed a same/different judgment on background shapes. fMRI findings suggest that brain areas associated with complex object processing (V4, LOC), are dramatically more engaged during category learning. At the same time, frontal areas (left and right inferior frontal gyrus) are activated exclusively during the categorization task. Same- vs. different-class exemplar use leads to nuance differences in fMRI activation (when performance level is matched). We conclude that largely the same cortical areas are used for categorization by same- vs. different-class exemplars, though the mechanisms within these areas and degree of their use may differ, underlying different behavioral and developmental effects.

Acknowledgement: This study was supported by a

11:30 am

52.25 **Categorical priming: using continuous flash suppression in an object categorization task**

Jorge Almeida[1,2] (jalmeida@wjh.harvard.edu), Bradford Mahon[1,3], Ken Nakayama[2], Alfonso Caramazza[1,3]; [1]Cognitive Neuropsychology Laboratory, Harvard University, [2]Harvard University Vision Sciences Laboratory, [3]Center for Mind/Brain Sciences, Università degli Studi di Trento, Polo di Rovereto, Italy

Neural specificity in the ventral object processing stream for manipulable objects is thought to reflect visual object recognition, whereas specificity in the dorsal stream for manipulable objects is thought to reflect visuomotor processing required for manipulating and grasping objects. We investigated whether the outputs of the dorsal stream affect object categorization, using a combination of priming techniques. Previous research has demonstrated that pictures of tools presented under continuous flash suppression (CFS) do not activate ventral temporal regions, whereas they activate the same dorsal stream regions as do visible tools (Fang and He, 2005, NN, 10, 1380-1385). In contrast, stimuli presented under backward masking do activate ventral temporal regions (Dehaene et al., 2001. NN, 4(7), 752-758). In Experiments 1 and 2, animal and tool prime pictures were presented under CFS, and were immediately followed by visible images of animals and tools, and participants were required to indicate the category of the visible stimulus by means of a button response. D-prime measures confirmed the invisibility of the primes. In both these experiments we obtained a categorical priming effect restricted to the domain of tools – participants were faster to categorize target pictures of tools, but not animals, when presented with congruent primes compared to incongruent primes. This category-related priming effect is not due to differences in the two stimulus sets in terms of their general ability to lead to priming. In Experiment 3, backward masking paradigm was used over the same items as in Experiment 2, and a priming effect was obtained for both categories. We argue that the pattern of findings across the experiments is related to the reduction in neural activity in ventral temporal areas for stimuli presented under CFS. These data indicate that the outputs of dorsal stream processing are relevant to category-level judgments of subsequently presented tool stimuli.

Acknowledgement: Acknowledgment: We wish to thank Petra Pajtas for her help collecting data. The research reported here was supported by NIH Grant DC04542 to AC. JA was supported by a Fundação para a Ciencia e a Tecnologia Grant SFRH/BD/28994/2006. BZM was supported by a NSF Graduate Research Fellowship.

11:45 am

52.26 **A Bayesian Model of Visual Search and Recognition**

Lior Elazary[1] (lelazary@yahoo.com), Laurent Itti[1,2]; [1]Computer Science, University of Southern California, [2]Neuroscience, University of Southern California

Visual search and recognition in humans employ a combination of bottom-up (data-driven) and top-down (goal-driven) processes. Although many bottom-up search and recognition models have been developed, the computational and neural basis of top-down biasing in such models has remained elusive. This paper develops a new model of attention guidance with dual emphasis: a single common Bayesian representational framework is used (1) for learning how to bias and guide search towards desired targets, and, (2) for recognizing targets when they are found. At its core, the model learns probability distributions of an object's visual appearance having a range of values along a number of low-level visual feature dimensions, then uses this learned knowledge both to locate and to recognize desired objects. The model is tested on three publicly available datasets, ALOI, COIL and SOIL47, containing photographs of 1,000, 100 and 47 objects taken under many viewpoints and illuminations (117,174 images in total). Model performance for recognition is compared to that of two state-of-the-art object recognition models (SIFT and HMAX). The proposed model performs significantly better and faster, reaching 89% classification rate (SIFT: 25%, HMAX: 76%) when utilizing 1/4 of the images for training and 3/4 for testing, while at the same time being 89 and 279 times faster than SIFT and HMAX, respectively. The proposed model can also be used for top-down guided search, finding a desired object in a 5x5 search array on average within 4 attempts (chance would be 12.5 attempts). Our results suggest that the simple Bayesian formalism developed here is capable of delivering robust machine vision performance.

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12:00 pm

52.27 **Auditory but not visual cues facilitate visual object detection**

Gary Lupyan[1] (lupyan@cornell.edu), Michael Spivey[1]; [1]Department of Psychology, Cornell University

Does knowing what one is about to see make it easier to see it? The answer may depend on the source of the knowledge. A great deal of evidence indicates that allocating visual attention to a stimulus or location improves reaction times (Posner, Snyder, & Davidson, 1980), detection sensitivity (Hawkins et al., 1990) and perceived contrast (Carrasco, Ling, & Read, 2004). Higher-level knowledge also seems to influence visual perception. For instance, processing verbs representing directions of motions increases sensitivity to congruent motion in random-dot kinematograms (Meteyard, Bahrami, Vigliocco, in press). Here, we show that hearing, but not seeing object names facilitates visual object detection in what may be a top-down effect of verbally presented object-names on visual processing.

Participants completed an object detection task in which they made an object-presence or -absence decision to uppercase letters presented briefly (50 ms) at or near fixation. Participants heard (Auditory condition) or saw (Visual condition) cues on 50% of the trials informing them of what letter to expect on the upcoming trial. The auditory cues consisted of recorded letter names (e.g., "emm") and the visual cues consisted of letters of the same size and in the same position as the to-be-detected stimulus. Both cue types were presented for 650 ms. When present, the stimulus appeared 1600 ms after cue offset and was masked by a random mask for 750 ms.

Only the auditory cues increased sensitivity (d') compared to baseline no-cue trials. Additional experiments showed that facilitated object detection following auditory cues: a) persisted when the exact position of the to-be-detected stimulus was unknown, b) could not be attributed to general arousal due to auditory input, and c) the increase in sensitivity was specific to the cued letter. Moreover, participants who reported more vivid visual imagery (VVIQ: Marks, 1973) showed greater facilitation following auditory cues.

Tuesday, May 13, 8:30 am - 12:30 pm
Poster Session, Royal Palm Ballroom 1-3

3D Stereopsis and Motion
Attention: Interactions with Memory
Attention: Theoretical and Computational Models

3D Stereopsis and Motion

53.301 **Contextual disparity variation does not influence distance scaling in a three-dimensional shape judgement task**

Lisa O'Kane[1] (lmo1@st-and.ac.uk), Paul Hibbard[1]; [1]St Andrews University

Binocular disparity varies approximately inversely with the square of distance. This relationship could potentially be exploited by the visual system as a cue to viewing distance, which could be useful in the interpretation of the shape and size of objects. Previous work has suggested that the range of disparities presented to an observer might be used as a cue to distance, and therefore might influence the perception of three-dimensional shape (Glennerster et al,1998). We extend this idea by examining the effect of the magnitudes of disparity information available in the surround onperceived depth from disparity. The stimulus consisted of three dots vertically aligned on the screen. The distance in depth of the central dot from the other two was defined by disparity, and was adjusted by the observer until it appeared equal in length to the base of the triangle. The triangle was surrounded by a surface that was sinusoidally modulated in depth. Shape settings were made for different magnitudes of disparity variation in the surround, over a range of viewing distances. Observers added more depth to the stimulus at further distances than at the closer distance. However, observers' settings did not change with the pattern of disparity present in the local reference surface. We conclude that the degree of disparity variation in a local reference frame, despite providing a potential source of statistical information to distance, does not affect settings of depth made by observers.

Acknowledgement: BBSRC

53.302 **Contextual Bias of Slant Perception in Unreliable Context**

Katinka van der Kooij[1] *(k.vanderkooij@fss.uu.nl), Susan te Pas*[1]; [1]*Utrecht University, Helmholtz Institute*

Introduction: The visual perception of a shape is influenced by its context. One example is the slant contrast effect, where slant is perceived in the direction opposite to neighboring slants. Contextual interactions can, in theory, be explained by weighted linear combination of direct and indirect (contextual) shape cues. We test the predictions of such Bayesian models by external noise methods, influencing the weights assigned to contextual shape cues. We start with the 'Slant Estimation' model. According to this theory, slant contrast occurs when there is conflict between shape cues, such as disparity and perspective (van Ee, Banks & Backus, 1999). Therefore, the bias increases with the weight of the non-disparity cue in the context. As weights add up to 1, this brings forth the counter-intuitive prediction that increased variability in the contextual disparity cue enhances the bias. Here we answer the question how the slant contrast effect is affected by uncertainty in the contextual stimuli.

Methods: We presented a central surface between two larger inducing surfaces. Slant was defined by retinal disparity. We varied the slant difference between the flankers in the reference and test interval. In addition, we added different levels of shape noise to the inducers (none, medium, high). Observers had to decide which of the two intervals contained the central surface with the highest slant. In this way we could determine the slant contrast effect in all conditions. Additionally, we tested discrimination thresholds of the central surface in the different noise conditions.

Results: Slant discrimination thresholds were significantly lower for stimuli with added noise. However, when such correlated shape noise was added to the inducers in a slant contrast stimulus, the bias did not increase.

Conclusion: We conclude that slant perception in context with added noise does not follow the predictions of the Slant Estimation Model.

53.303 **Context shapes estimation of 3D structure in human visual cortex**

Tim Preston[1] *(tjp541@bham.ac.uk), Zoe Kourtzi*[1]*, Andrew Welchman*[1]*;* [1]*School of Psychology, University of Birmingham*

In estimating the three-dimensional (3D) properties of the world the brain combines ambiguous sensory signals with prior information about the structure of the environment. The abundance of depth aftereffects suggests that the brain constantly adapts to the changing statistics of the visual input. Here, we show that observers' perceptual judgements of disparity-defined shapes are influenced by the adaptive 3D context in which these shapes are viewed, and that fMRI responses in extrastriate visual cortex are modulated by this context. Observers viewed Mach card stimuli that were disambiguated with differing amounts of binocular disparity and reported their perception of 3D shape (convex or concave). Manipulating the context in which these shapes were viewed by presenting a concave or convex Mach card (adaptor stimulus) prior to each test stimulus affected the observers' reports of perceived 3D shape. In a concave context, perception of the test stimuli was biased towards a convex interpretation whereas in a convex context perception was biased towards a concave interpretation. We used an event-related fMRI adaptation paradigm to measure fMRI responses relating to this aftereffect in human visual cortex. Changing the 3D context resulted in fMRI selective adaptation in higher dorsal (V3A, V3B/KO, V7 and hMT+/V5) and ventral areas (VP/V3, V4 and LO) but not early visual areas. That is, we observed higher fMRI responses for test stimuli with different rather than the same 3D shape as the adaptor stimulus. In accordance with the behavioural aftereffect we observed similar fMRI adaptation effects in these areas when the test stimulus contained zero disparity. These findings suggest that fMRI activity in higher visual areas relates to perceived depth and is shaped by contextual information about the structure of the environment.

53.304 **Relationship between the Helmholtz shear of vertical meridians and disparity statistics in natural scenes**

Yang Liu[1] *(young76@mail.utexas.edu), Alan Bovik*[1]*, Lawrence Cormack*[2]*;* [1]*Department of Electrical and Computer Engineering, University of Texas at Austin,* [2]*Department of Psychology, University of Texas at Austin*

The theoretical vertical horopter is a line passing through the fixation point and perpendicular to the horizontal plane, when the fixation is symmetric and on the horizontal median plane. However, the empirical vertical horopter measured psychophysically deviates from the true vertical, as its top inclines backward with an angle. Thus the two corresponding retinal images of the empirical vertical horopter also deviate from the theoretical corresponding vertical meridians of the two eyes. The average angle between the two empirical vertical meridians is 2 deg, which is called the Helmholtz shear of empirical vertical meridians. Explanations were proposed that this shear has an ecological value by bringing the ground to vertical horopter to aid in navigating the world. Further evidence was found in cats and owls. They have a much larger shear than humans, which matches their typical height and fixation distance.

We investigated the relationship between the distribution of environmental distances and fixation distances to the Helmholtz shear of the human vision system. The scene distances along the vertical median plane are especially interesting, since the empirical vertical horopter is located on the vertical median plane. We measured binocular disparities from range maps of outdoor and indoor natural scenes (Yang & Purves, 2003) along the vertical median plane, assuming the fixations to be symmetric and horizontal. We found that the disparity distribution of the vertical median plane within a 60 deg range of elevation (±30 deg below and above fixation) has a close relationship with theoretical binocular disparities between two empirical vertical meridians below eye level. The disparity distributions above eye level do not agree with the Helmholtz shear. But it is easy to prove that a closer fit exists if more fixations are deployed on the ground, which seems plausible during many real life activities.

53.305 **Comparing perceived affordances to size and distance estimates in a virtual environment**

Sarah H. Creem-Regehr[1] *(sarah.creem@psych.utah.edu), Benjamin R. Kunz*[1]*, William B. Thompson*[2]*;* [1]*Department of Psychology, University of Utah,* [2]*School of Computing, University of Utah*

Multiple studies have reported that visually directed actions beyond near-space are performed in virtual environments (VEs) as if distances were perceived as 20%-50% smaller than intended. Although there is a general subjective sense that VE spaces seem smaller than real spaces, there has been little systematic work looking at other spatial dimensions in VEs beyond distance. Measuring perceived affordances is a way to assess body-based space perception in the context of action without requiring real movement. We demonstrate the feasibility of using affordance judgments to probe spatial perception in VEs and compare perceived affordances with perceived size and distance to the same targets. Judgments were made in a virtual classroom viewed through a head-mounted display. Two poles were always present, varying on each trial in diameter, spacing, and distance from the viewpoint. In a within-subject design, standing participants first performed a size judgment by holding out their hands to indicate the apparent spacing between the columns. The screen was blanked, new columns appeared at a different distance with either very narrow or wide spacing, and subjects requested the columns to be moved closer together or farther apart until they felt that they were just wide enough to walk through without turning their shoulders. After another screen blank, a third set of poles appeared. Participants closed their eyes and walked to the apparent location between the two poles. Affordance judgments of passability averaged 1.3x actual shoulder width, a ratio more conservative than that seen in comparable real world results (Warren and Whang, 1987, 1.16x shoulder width). Size judgments averaged 13% overestimation and were constant across distance. Consistent with prior work, distance was underestimated by about 20%. The utility of using affordance judgments in VEs and implications of the apparent discrepancy between scaling of size and distance judgments will be discussed.

Acknowledgement: This work was supported by NSF grant 0121084.

53.306 An fully automatic technique for Head Mounted Display calibration

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Any Head Mounted Display (HMD) must be calibrated if it is to provide a realistic representation of space. This is especially true in visual psychophysics experiments which require accurate rendering of objects at specified 3D locations. Previous attempts at calibrating HMDs have involved human observers making position judgements which are error-prone and only work for see-through HMDs.

Instead, we placed a camera inside a stationary HMD and recorded images of objects placed in the world. The camera also recorded a superimposed regular array of dots generated by the HMD, allowing the image locations of objects to be re-expressed in the coordinate frame of the HMD image. The position and orientation of the HMD and world objects were recorded by a 6 degrees-of-freedom tracking system. We used standard camera calibration techniques to recover the optical parameters of the HMD (not the camera) and hence derive appropriate software frustums for rendering virtual scenes in the binocular HMD. Recovered parameters comprised the aspect ratio, focal length, centre pixel, optic centre location, principal ray, and radial and tangential distortion parameters to provide a full description of the left- and right-display frustums.

We quantified the improvement in calibration by measuring re-projection errors between real world and virtual points rendered to appear at the same spatial location and found less than 1 pixel root-mean-square error. We have applied the same method to the calibration of a non-see-through HMD. This requires the camera's location to be constant while an image of the HMD grid is taken (HMD on) and then an image of the world is taken (HMD removed).

We thus present an accurate, robust and fully automated method based on established camera calibration techniques which are applicable to both see-through and non-see-through HMDs.

Acknowledgement: Supported by Wellcome Trust and The Royal Society
URL: http://virtualreality.physiol.ox.ac.uk/research.html

53.307 Absolute and relative cues for distance investigated using immersive virtual reality

Ellen Svarverud[1] (e.svarverud@rdg.ac.uk), Stuart J Gilson[2], Andrew Glennerster[1]; [1]School of Psychology and Clinical Language Sciences, University of Reading, UK, [2]Department of Physiology, Anatomy and Genetics, University of Oxford, UK

In the absence of looming cues, observers ignore large changes in the size of a virtual scene around them and have large biases in size judgments as a result (Glennerster et al, 2006, Current Biology 16, 428-432; Rauschecker et al, 2006, Journal of Vision, 6, 1471-1485). At first sight, these results suggest that observers have poor access to information about absolute distance from stereo and motion parallax. However, we show here that under similar conditions observers have low thresholds when asked to detect the expansion/contraction of the scene.

In an immersive virtual reality environment, subjects viewed a static scene binocularly and with motion parallax from free head movement. The scene changed size after a blank ISI. The centre of expansion was the cyclopean point, so all objects in the scene remained the same angular size. The task was to identify whether the target object (and the rest of the scene) was closer or farther away in the second interval. Thresholds for this task (Weber fractions 10-33%) were best when the target was close to the observer and were invariably lower than when the target was presented alone, without the scene.

We also measured thresholds for detecting changes in the location of an object relative to the scene, while its absolute distance remained constant. As expected, these relative thresholds improved with the proximity of the target to neighbouring objects. In a separate experiment, subjects judged the change in distance of an object presented in two intervals while, independently, the scene changed in size by a factor of between 0.25 and 4. The pattern of biases could be predicted from the absolute and relative thresholds measured in the previous experiments, showing that observers did not use absolute and relative cues independently.

Acknowledgement: Supported by University of Reading and The Wellcome Trust
URL: http://virtualreality.physiol.ox.ac.uk/research.html

53.308 A laminar cortical model of stereopsis and 3D surface perception of complex natural scenes

Yongqiang Cao[1] (yqcao@bu.edu), Stephen Grossberg[1], Eugene Zaydens[1]; [1]Department of Cognitive and Neural Systems, and Center of Excellence for Learning in Education, Science, and Technology, Boston University

How does the visual cortex process complex natural scenes? The 3D LAMINART model has been developed to explain many data from psychophysical experiments in terms of how laminar cortical mechanisms interact to create 3D boundary and surface representations (e.g., Cao & Grossberg, 2005, Spatial Vision; Fang & Grossberg, 2007, Spatial Vision; Grossberg & Yazdanbaksh, 2005, Vision Research). Here the model is extended to show how the same mechanisms, properly refined, can explain how the brain generates 3D surface representations in response to complex natural scenes. The model describes how monocular and binocular cortical cells interact with later stages of 3D boundary formation and surface filling-in in the LGN and cortical areas V1, V2, and V4. It proposes how interactions between layers 4, 3B, and 2/3 in V1 and V2 contribute to stereopsis, and how binocular and monocular information combine to form 3D boundary and surface representations. The major challenge for processing natural scenes is that the 3D boundaries are often unconnected and incomplete, and that cluttered surface regions incorporate many possibilities of false binocular matches. The main new developments are: (1) feedback interactions between V1 binocular cells and V1 surface cells help with initial depth assignments, notably how V1 surface filling-in helps to enhance V1 monocular and binocular boundaries; (2) feedback between V2 boundaries and surfaces completes broken boundaries and eliminates false binocular matches; and (3) a V2 disparity filter in both the boundary and surface processing streams together help to generate correct 3D surface representations. The model hereby provides a unified approach to providing both a quantitative explanation of data about 3D stereopsis and surface perception of psychophysical displays, as well as a system for 3D processing of natural scenes in computer vision applications.

Acknowledgement: Supported in part by the National Science Foundation (SBE-0354378)

53.309 Depth from motion and/or disparity in natural and simulated environments: Do cues-to-flatness matter?

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Most research in depth-cue combination is based on psychophysical measurements derived from single- and combined-cue computer-simulated (CRT, LCD, etc.) displays. It has been argued that depth-underestimation in single-cue stimuli may arise from flatness cues resulting from pixilation, reduced blur gradient and accommodation due to simulated monitor viewing. When depth-cues are seen in isolation a larger weight may, in fact, be given to the flatness cues and therefore, the single-cue stimuli may appear flatter. To address this issue, we conducted a series of experiments with projectively-equivalent stimuli presented in natural and simulated environments. Stimuli were slanted around the vertical-axis and viewed in three conditions: stereo-only, motion-only, and combined stereo and motion. In the stereo-only condition, the surface was static and viewed binocularly. In the motion-only condition, the surface was viewed monocularly while oscillating around the vertical axis. In the combined-cue condition, the surface was seen binocularly with oscillatory motion. In either a 2-Alternative Forced Choice (2AFC) staircase procedure or an adjustment task, observers compared the depth to the width of the perceived stimuli. Points of Subjective Equality (PSEs) for both natural and simulated viewing conditions were found to be highly consistent with each other: In both viewing conditions, single-cue stimuli were perceived as having less depth than combined-cue stimuli. Moreover, at near viewing distances, combined-cue stimuli were overestimated, whereas single-cue stimuli were underestimated.

53.310 Mechanisms of 3D Motion: Integration of disparity and motion cues

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Relatively little is known about the neural computation of 3D motion (compared with that of 2D motion and static disparity). The perception of 3D motion has been shown to rely upon a combination of a disparity-based cue (disparity changes over time), and a velocity-based cue (velocity differences seen by the two eyes). To better understand the mechanisms underlying 3D motion processing, we performed a series of psychophysical experiments to measure the spatial characteristics of 3D and 2D motion perception.

We employed 3D dynamic random dot stereograms (3DRDS) and manipulated both the 3D or 2D motion strength and the spatial and temporal structure (e.g., stimulus area, dot lifetime). 3DRDSs consisted of dots randomly positioned within an annular volume. Brownian dot motion was created by randomly sampling motion orientation from a radial Gaussian distribution in the x-z plane, centered on the motion direction for that particular trial. The magnitude of z-motion for each dot was then derived from the sine of the Gaussian sample. Motion strength was controlled by varying the standard deviation of the Gaussian direction distribution.

We measured accuracy in a motion direction-discrimination task as a function of motion strength and stimulus eccentricity for both 3D and 2D displays. Overall, thresholds were lower for 2D displays than 3D displays, replicating the phenomenon of stereomotion suppression (Tyler, 1971). 2D motion discrimination accuracy did not depend strongly on stimulus eccentricity. However, 3D motion accuracy decreased with eccentricity, but at a rate far less severe than one would expect from eccentricity effects on stereoaccuity. Such dissociations can reveal the relative precedences of the velocity- and disparity-based cues across the visual field. The characterization of spatial profiles of sensitivity provides a means for characterizing how multiple perceptual cues are integrated to compute 3D motion.

53.311 **Interposition, minimal depth, and depth-from-disparity**

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In the context of the renewed interest for the combination of ordinal and metric cues to depth (Burge et al. JOV 2005; Burge et al. ECVP 2007), we presented the bar-in-the-box effect (Gerbino & Fantoni ECVP 2007). Consider a pictorial display involving only interposition and perspective, in which a bar crosses an open box, so that the front face of the box occludes the bar, which in turn occludes the back face of the box. Despite the lack of optical specification, most observers perceive the bar just behind the occluding surface in the foreground, consistent with a tendency towards minimal depth. We evaluated the strength of such a tendency in two experiments in which the box and the bar were both specified by binocular disparity. Observers judged whether a textured bar of variable disparity was closer to the front vs. back face of an untextured box. Were used different boxes, keeping their height and inclination constant, but varying their width/height ratio to change their binocular structure: the hole between front and back faces was present in both eyes, in one eye only, or absent in both eyes. In Experiment 1 the bar height co-varied with disparity, simulating a bar aligned with the medial axis of the box, while in Experiment 2 the bar was aligned with the line of sight. The perceived depth of the bar was smaller than the depth-by-disparity, showing a strong minimal-depth bias in binocular hole and no-hole conditions; while minimal depth did not overcome disparity in the monocular-hole condition. Configural factors – like the tendency to minimize depth in ambiguous displays and the presence of monocular features – affect perceived depth beyond what one might expect on the basis of the metric information provided by disparity, demonstrating their relevance in unambiguous conditions.

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53.312 **A new theory of structure-from-motion perception**

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Humans can recover 3-D structure from the projected 2D motion field of a rotating object. This phenomenon is called structure from motion (SFM). Current models of SFM perception are limited to the case in which objects rotate about a frontoparallel axis. However, as our recent psychophysical studies showed, frontoparallel axes of rotation are not representative of the general case. Here we present the first model to address the problem of SFM perception for the general case of rotations around an arbitrary axis. The SFM computation is cast as a two-stage process. In the first stage the structure perpendicular to the axis of rotation is computed from the component of the retinal speeds perpendicular to the axis of rotation. In the second stage a correction to the depth structure from the first stage corrects for the rotational axis's slant. This computation results in an object shape that is invariant with respect to the observer's viewpoint. The model provides quantitative predictions that agree well with current psychophysical data for both frontoparallel and non-frontoparallel rotations. It also challenges previous claims about depth-order violations and inconsistencies in recovered object structure.

53.313 **Interactions between eye-movements and prior assumptions for 3-D shape from motion**

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The effects of pursuit eye-movements on perceived depth from motion can generally be explained by reductions in translational velocity with invariance of motion shear. We report some interesting new effects of pursuit eye-movements on perceived 3-D shape.

A starry night pattern that provides no cues for shape-from-texture was folded into one cycle of vertical or horizontal sinusoidal corrugation, rotated between +/- 30 degrees for 3 sec around its orthogonal axis through the zero-crossings, and viewed monocularly in perspective. On each trial, a fixation dot was either set in the center, or moved across the central extent of the stimulus left to right, right to left, top to bottom, or bottom to top. Two observers reported the shape (concave or convex) of each half cycle for 10 trials in each condition.

For the vertical corrugation with central fixation, both observers perceived two convex half-cycles rotating in opposite directions, violating a rigidity assumption, but consistent with the motion-perspective assumption that higher local velocities indicate nearer segments. However, while pursuing fixation dots moving in any of the four directions, observers perceived rigid corrugations with the top rotating downwards, suggesting a prior preference for an object falling towards rather than away from the observer. For the horizontal corrugation, with central fixation both observers perceived a rigidly rotating corrugation, but the corrugation appeared invariably convex on top to one observer and concave on top to the other, irrespective of the simulated phase and rotation direction. Horizontal pursuit eye-movements did not alter the percepts. However, for upwards pursuit, the upper half-cycle was perceived as convex like a ledge, and for downwards pursuit, the lower half-cycle was perceived as convex like a base by both observers.

Different directions of voluntary eye-movements thus seem to activate different ecologically relevant prior expectations for object shape and motion.

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53.314 **Cue Integration Outside Central Fixation: A Study of Grasping in Depth**

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Humans frequently rely on information from across the visual field for navigation and object manipulation. Information from the periphery is useful for planning saccades and goal-directed movements prior to visual fixation and for performing tasks without direct fixation such as adjusting the radio while keeping one's eyes on the road. We performed three experiments that examined how we use aspect ratio, a monocular cue, and horizontal disparity, a binocular cue, to estimate 3D orientation when grasping targets at various retinal eccentricities and depths relative to fixation. We measured subjects' 3D orientation thresholds separately for these cues at 0°, 7.5°, and 15° of retinal eccentricity and then compared the predictions of an optimal Bayesian cue integrator based on these thresholds to how subjects used these cues to perform an object prehension task with targets at different retinal eccentricities. We then quantified how subjects integrated the cues for grasping targets up to 1° of horizontal disparity from the theoretical horopter. Thresholds increased for both cues as the retinal eccentricities of the targets increased. In the grasping task, we found that subjects relied equally on the cues for targets under visual fixation but that they relied more on monocular information with increasing retinal eccentricity; at 15° of retinal eccentricity, aspect ratio influenced grasp orientations five times more than horizontal disparity. These results matched the predictions of the Bayesian integrator. Similarly, when subjects grasped targets at different depths from the fixation point, they relied more on aspect ratio as the distance of the targets from the horopter increased; at 1° from the horopter, subjects' orientation estimates were based entirely on monocular information. Our results showed that how information across the visual field influences visually-guided movements depends on its reliability relative to information from other cues and positions across the visual field.

53.315 **Depth interval perception: Comparing binocular stereopsis with motion parallax in "action space"**

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Motion parallax is widely regarded as providing metric depth information that is equal or superior to that obtained from binocular stereopsis -- in part because it is assumed to be fairly robust with viewing distance. But excellent depth-recovery from motion parallax may be limited to very near "personal" space, where most motion parallax experiments are done. For example, Ono et al. (1986) found that although motion parallax produced rigid depth percepts in very near space, simulated objects appeared to become non-rigid as viewing distance was increased past a meter or so. We sought to investigate the perception of empty intervals between objects. To ensure there were no artifacts of temporal lag, we created a "cloud chamber" in which fibrous clouds could be suspended on invisible wires in front of a back-lit matte blue screen. A volume of space 2 - 4 m from the observers was used -- the near part of "action space" (Cutting & Vishton, 1995). Naive subjects viewed pairs of clouds that were offset in depth (and offset slightly horizontally, to avoid occlusion), and estimated the depth separation between them. Static binocular viewing was compared with dynamic monocular viewing where the extent of lateral head motion (12.5 cm) was twice the typical interocular distance. Despite the theoretical advantages accorded by doubled parallax, the gain of perceived depth separations from motion parallax was only about half that from binocular stereopsis. This inferiority of motion parallax corresponds to our own subjective experiences: At these distances, monocular motion parallax from lateral sway produces the impression of relative motion, not depth, between objects. Whether object-directed action would show greater evidence of depth sensitivity remains to be seen.

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53.316 **Influence of central and peripheral visual field on the postural control when viewing an optic flow stimulus**

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Purpose: During upright stance condition, vision is known to have an important role in maintaining posture. Central vision is essential for details and motion perception while peripheral vision is primarily specialized for motion perception. However, little is known about their respective roles for postural control in optical flow conditions. In the present study, different visual field areas were stimulated to examine the roles of central and peripheral vision in the control of posture.

Methods: Body sway amplitude (BSA) and instability index (II; velocity RMS) were recorded in a group of 19 healthy young adults maintaining upright stance while immersed in a full-immersive virtual environment. The visual stimulation was a 3D tunnel, either static or moving sinusoidaly in the anterior-posterior direction. There were nine visual field conditions: four central conditions (4, 7, 15 and 30°); four peripheral conditions (central occlusions of 4, 7, 15 and 30°); and a full visual field condition. The virtual tunnel respected all the aspects of a real physical tunnel (i.e. stereoscopy and size increase with proximity).

Results: Results showed no significant effect of visual field on postural reactivity for the static condition. By contrast, dynamic visual flow reveals a significant increase of postural reactivity when stimulating peripheral visual field (wider than 7°) compared to central. There was no significant difference between the peripheral and full visual field conditions.

Conclusions: Under static conditions, central and peripheral vision appear to have equal importance for the control of stance when using a stimulus that equally stimulates these areas. In the presence of an optic flow, peripheral vision has a crucial role in the control of stance, since it is responsible for a compensatory sway, whereas central vision may have an accessory role related to spatial orientation.

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53.317 **Aging and the perception of slant from optical texture, motion parallax, and binocular disparity**

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In this study, we compared younger and older observers' ability to judge slant from texture gradients, velocity gradients, and disparity gradients. The observers viewed planar surfaces that were presented at four different slants (20, 35, 50, & 65 degrees from fronto-parallel). The observers viewed the surfaces through a circular occluding aperture. The resulting visible patterns subtended 21.8 degrees of visual angle. Each of the older (aged 61 to 82 years) and younger observers (aged 18 to 26 years) made five judgments for each experimental condition. The observers made their judgment on each trial by adjusting the slant of a palm board until it matched the perceived slant of the depicted surface. In general, the older observers' judgments of slant were just as accurate as those produced by the younger observers. In all cases, the observers' perceived slants increased as a function of the actual slants. The rate of increase in perceived slant relative to changes in actual slant (i.e., the slope of the best-fitting regression lines) was higher for the texture gradients than for the velocity and disparity gradients. The results indicate that texture gradients contain a large amount of information about surface slant and that they are just as informative (and may even be more informative) than either velocity or disparity gradients.

53.318 **The effects of sex and age upon the perception of 3-D shape from deforming and static boundary contours**

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A single experiment was designed to investigate how younger and older observers perceive 3-D shape from deforming and static boundary contours (i.e., silhouettes). On any given trial, observers were shown two randomly-generated, smoothly curved 3-D objects, and were required to judge whether they possessed the "same" or "different" shape. The objects presented during the "different" trials obviously produced different boundary contours. The objects presented during the "same" trials also produced different boundary contours, because one of the objects was always rotated in depth relative to the other (about a Cartesian vertical axis) by either 5, 25, or 45 degrees. Each observer judged 30 pairs of objects for a total of 12 experimental conditions (360 total trials). These conditions were formed by the orthogonal combination of 2 motion types (moving vs. static boundary contours), 2 display types (objects depicted either as silhouettes or with texture and lambertian shading), and 3 angular offsets (5, 25, & 45 degrees). The observers' discrimination ability was measured using d'. The results showed that overall, there was no effect of age: older observers performed just as well as younger observers. There was, however, a main effect of sex: males performed better than females, regardless of age. This superiority in performance for males was higher for objects depicted as silhouettes than for objects depicted with texture and shading (thus triggering a sex x texture interaction). Increases in the magnitude of the angular offset led to deteriorations in discrimination performance. The effect of the increases in angular offset, however, was different for the younger and older age groups, and was also different for males and females. Overall, the results reveal that human observers can effectively utilize the information present in boundary contours to support their perception of 3-D shape, and that this ability persists throughout life.

Attention: Interactions with Memory

53.319 **Strategic interactions between visual working memory and perceptual attention as revealed by eye movements**

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Theories of attention suggest that objects represented in visual working memory will automatically guide attention to memory matching items (Desimone & Duncan, 1995). Empirical tests of this proposition have shown mixed results, with some studies showing increases in response time to the search array when a memory matching item is present in the array (e.g.,Soto, Heinke, Humphreys, & Blanco, 2005) while others show no effect or a RT benefit when memory matches are present in the search array (e.g., Downing & Dodds, 2004). One possible explanation for these disparate results comes from the suggestion of Woodman & Luck (2007) that the contents of working memory can be used flexibly, or strategically, based on task demands. In the current experiment, we extend prior paradigms by recording eye movements during the task to directly measure overt attention. In addition, we compared a baseline session to an instructional condition in subjects were told either to emphasize speed in the search task or accuracy in the memory task. Results from behavioral and eye-tracking data converge to suggest that the instructions lead to differences in strategy based on whether search speed or memory accuracy was emphasized. These results add support to the hypothesis that working memory guidance of attention is flexible and under strategic control as suggested by Woodman and Luck (2007).

Desimone, R., & Duncan, J. (1995) Annual Review of Neuroscience, 18, 193-222.

Downing, P. E., & Dodds, C. M. (2004) Visual Cognition, 11, 689-703.

Soto, D., Heinke, D., Humphreys, G. W., & Blanco, M. J. (2005) Journal of Experimental Psychology: Human Perception and Performance, 31(2), 248-261.

Woodman, G. F., & Luck, S. J. (2007) Journal of Experimental Psychology: Human Perception and Performance, 33, 363-377.

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53.320 **Correlations between Visual Short-Term Memory and Attentional Capacity Limits**

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Both attention and visual short-term memory (VSTM) appear to be limited in capacity by the same underlying mechanisms. Both have shown capacity limits of 4 ± 1 objects (Pylyshyn and Storm, 1988; Yantis, 1992; Cowan 2001; Scholl and Xu, 2001; Luck and Vogel, 1997) and the inferior parietal sulcus (IPS) activates in a capacity limited manner for both processes. However, these findings have been for group averaged data, and both attention and VSTM capacities show large individual differences, with individual subject capacities ranging from 2-5 objects (Oksama and Hyönä, 2004; Vogel and Machizawa, 2004). Thus, it is unknown whether the capacities are actually interrelated, or are simply a coincidence of averaging groups of subjects together. In order to examine whether these capacities are truly related, we compared individual subject's capacities on both an attentional and VSTM task completed in the same testing session. We used a multiple object tracking (MOT) paradigm, in which subjects tracked 3-6 balls, to determine attentional capacity, and a change blindness paradigm similar to those used throughout VSTM literature, in which subjects had to remember 4, 6, or 8 objects, to determine VSTM capacity. We found that while the capacities are similar in some subjects, overall, there was weak to no correlation between the two. This finding is surprising given the amount of overlap seen between the two processes (Awh & Jonides, 2001; Awh et al, 2006; Downing, 2000; Todd et al, 2005). Our supposition is that there are certain underlying processes, such as target selection, encoding, and maintenance, and distractor suppression, that may be highly correlated between the two processes that that these underlying processes are driving the weak correlation we have seen, along with the overlap seen by others.

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53.321 **Attentional Bias Toward Items in Working Memory: Early but not Reflexive**

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Soto and colleagues (Soto, Heinke, Humphreys and Blanco, 2005; Soto & Humphreys, 2007) claim that people reflexively and involuntarily fixate objects which match the contents of working memory (WM). To investigate this issue, we ran two experiments to test the limits of this hypothesis. The first experiment was a variation on a card trick; we used eye movements to attempt to identify a subject's card. Subjects picked three cards to remember and then viewed multiple displays, each consisting of three cards. When a memory card appeared in a display, subjects' first eye movements went directly to the card on 2/3 of the trials, providing evidence for an early bias towards items held in WM. However, this bias interacted with, rather than supplanted, a long-term bias toward viewing items from left to right; people made a majority of first eye movements to the left, even when the memory card appeared on the right. Results suggest that the WM effect interacts with rather than supersedes long standing biases. A second experiment investigated how WM bias and short-term biases interact. In this experiment, people held objects in memory while performing an anti-saccade task. We manipulated whether or not the signal to generate the anti-saccade matched the contents of WM. In aggregate, there was no difference in the number of pro-saccade errors between these conditions, suggesting that short-term biases due to explicit task demands supersede the bias to look towards items in WM. The WM bias, however, was evident within a subset of our subjects who performed poorly, in general, at the anti-saccade task. These results are consistent with the view that attention is biased towards items in WM; however, this bias is not completely automatic and reflexive. It interacts with long-term biases associated with visual routines and short-term biases associated with task set.

53.322 **Executive working memory load does not interfere with the rapid resumption of an interrupted visual search**

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Rapid resumption refers to an observer's ability to rapidly resume a visual search following an interruption (Lleras, Rensink & Enns, 2005; 2007). Lleras et al. proposed that this ability stemmed from observers having performed some perceptual processing of the target based on the display information before the interruption, even though this pre-processing did not reach conscious awareness and thus did not allow participants to respond until after the search display had been re-presented. In Ahn and Lleras (VSS 2007) we showed that the pre-processing did not involve visuo-spatial working memory resources, since loading visuo-spatial working memory did not lead to a reduction in rapid resumption rates, even though it lead to slower response times overall. The present study explored whether executive working memory is involved in the perceptual pre-processing of the target. To do so, we manipulated the executive working memory load while participants performed an interrupted search task. In the dual-task condition, participants had to re-order 4-randomly chosen letters while they completed the interrupted visual search task, and performance was compared to a single-task condition in which participants only performed the interrupted search task. Our results showed that in the dual-task condition, response times were substantially delayed compared to the single-task condition. This detrimental effect of executive memory load was only found when observers were asked to perform the reordering task, and was absent in a control condition in which participants simply had to maintain the information in verbal working memory, which did not require the use of executive working memory. In spite of a general slowed down in response times in the dual task condition, the proportion of rapid resumption responses was unaffected by this working memory load, paralleling the results of Ahn & Lleras (2007) with visuo-spatial working memory.

53.323 **The Search for Memory: Visual Short-Term Memory Capacity Predicts Performance During Visual Search Tasks**

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During the last decade, there have been repeated attempts to answer the question of whether visual search is supported by memory. Horowitz and Wolfe (1998) were the first to demonstrate that search with or without memory is equally efficient implying that visual search has little or no memory component. Since then, the evidence has been mixed. We argue that the inconsistent findings are a result of an insufficient operational definition of memory effects during visual search. To overcome this issue, we propose a simple formula to estimate the number of search items held in memory. Previously, we have applied this approach to a preview search task and demonstrated that the number of items that could be inhibited was roughly equal to the capacity of visual short-term memory (VSTM). Here, we revisit Horowitz and Wolfe's study to test whether VSTM supports visual search more generally. We presented participants with search displays in which either all of the search items were moved randomly around the display, thereby disrupting the potential effect of memory, or displays in which 0 to 7 of the total search items remained static, allowing the previously searched static stimuli to be stored in memory. At large set sizes, the efficiency of search in the static condition was similar to that of the dynamic condition, in line with the results of Horowitz and Wolfe (1998). However, at set sizes below the estimated capacity of visual short-term memory (i.e., 4), the search slope in the static condition was significantly smaller. Using our formula, the estimated number of items held in memory during visual search peaked at roughly four items. In addition, this estimate was moderately correlated with the capacity of VSTM obtained in a change-detection task. Thus, we provide further evidence that VSTM supports the representation of search items.

53.324 An unattended stimulus attribute leaves its mark on short-term visual memory

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Attention makes it possible to filter stimulus attributes that are not task-related. To examine attentional filtering of information for short-term visual memory we used stimuli generated by superimposing horizontal and vertical Gabor patches. On each trial, subjects saw and tried to remember a pair of sequentially-presented study items, which were followed by a probe. Subjects judged whether the probe's spatial frequency matched that of a study item. For half the subjects, the vertical component only was task-relevant; for other subjects, the horizontal component was task-relevant. All stimuli were scaled for individual subjects' discrimination thresholds.

For the task-relevant orientation, recognition judgments and latencies varied systematically with the summed similarity of the probe to each study item, which is consistent with our lab's previous work with visual and auditory stimuli. But the task-irrelevant orientation exerted an effect of its own. When probe and study item frequencies matched not only the task-relevant orientation, but also the task-irrelevant one, recognition performance was boosted by about 20%, and responses were speeded.

To illuminate the mechanism by which the task-irrelevant attribute exerts its influence, we used NEMO, a noisy-exemplar model of recognition (Sekuler & Kahana, 2002, 2007). Fitting data to alternative forms of NEMO dissociated the influences of (i) summed probe-item similarity and (ii) inter-item homogeneity, another variable known to influence recognition. Task-irrelevant information contributed only to summed similarity, suggesting that attentional resources are needed for the computation of inter-item homogeneity. This finding is consistent with previous speculation that inter-item homogeneity affects the decision criterion rather than memory strength.

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53.325 The Role of Visual Working Memory in Object-Based Attentional Selection

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Previous research has demonstrated that visual attention can be spatial or object-based, and that visual working memory (WM) has both spatial and object components. Oh and Kim (2004) demonstrated that loading spatial WM interfered with visual search efficiency but loading object WM did not, suggesting that spatial attention and spatial WM engage similar resources. The present study investigated the effects on object-based attention of loading object WM versus spatial WM. Three tasks were performed in separate blocks (memory baseline, object baseline, dual-task); during all tasks, participants rehearsed aloud a set of digits to prevent verbal rehearsal. In the memory baseline, four to-be-remembered colored squares could appear in eight possible locations and eight possible colors. Subjects a made speeded response to a test probe indicating its match/mismatch to the color (Experiment 1) or location (Experiment 2) of one of the items in WM. In the object baseline (Duncan, 1984), two overlapping objects (a line and box) appeared that could each vary on two dimensions: line tilt (left/right) and texture (dashed/dotted), box size (large/small) and gap location (left/right). Subjects monitored two dimensions either from the same or different objects and made a speeded response indicating the attribute of one of the monitored dimensions. In the dual-task condition, subjects performed both tasks concurrently. As expected from past literature, there was an accuracy cost (reflecting object-based attention) when subjects monitored dimensions from different objects compared to the same object. Compared to the object baseline, there was greater cost in the dual-task condition when color but not location was maintained in WM, even though maintaining location was more difficult as reflected in higher Experiment 2 RTs. These findings suggest that spatial WM and object WM influence object-based attention differently, and that object WM and object-based attention engage similar resources.

53.326 Object- and feature-based priming in visual search

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Two contrasting accounts for priming in visual search have been proposed. The main difference between the two is the level of perceptual processing at which the priming effects are assumed to occur, whether priming is assumed to operate through the selective facilitation of features or at the level of selection of objects for response. The aim with the experiments here was to contrast these accounts. In the first two experiments observers performed a search for the odd diamond among two distractor diamonds. Each diamond had two colors but the configuration of colors within the diamonds was different for the two experiments, configurations previously shown to lend themselves differently well to object formation. The results show that priming can be both feature- and object-based depending on the topological properties of the stimuli in each case. This was confirmed in a third study where a quite dissimilar stimulus set was used to address the same question yielding similar results as before. Priming is thus shown to operate at various levels of perceptual processing, a result consistent with new findings from neuroimaging and neuropsychology.

53.327 The Interaction between Global and Local Scene Features in Contextual Cueing

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In contextual cueing experiments, participants are sensitive to the repetition of contextual elements during visual search, resulting in faster search through familiar arrays than through novel arrays (Chun & Jiang, 1998). Studies using random arrays of simple objects have found that contextual cueing is driven primarily by memory for local elements near the target location (Olson & Chun, 2002). In contrast, studies using real-world scene stimuli have found that contextual cueing is driven primarily by memory for global scene features (Brockmole et al., 2006). Here we investigated whether the context provided by global scene structure and the context provided by local search elements can be used independently to cue target location or whether both are integrated within a holistic scene representation. Participants performed a feature negative search within a 3-D rendered search display. At the center of the display was a local search array consisting of vertically oriented "dumbbell" objects. The target was missing one dumbbell segment, and participants reported which segment was missing. This local search array was embedded within a 3-D rendered real-world scene. The search array and scene were spatially segregated, allowing us to manipulate the local search context and the global scene context independently. We found that repeated local context produced contextual cueing even when global scene context did not predict target location. However, repeated global scene context did not produce contextual cueing when local array context did not predict target location. Although we did not find contextual cueing on the basis of global context alone, when both global and local cues were informative, contextual cueing was disrupted if either context was changed in a transfer block. This suggests that although contextual cueing was driven primarily by local information, global and local context were integrated into a holistic scene representation.

53.328 Implicit learning of attentional guidance modulates visual preference

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We examined whether implicit learning in a visual search task influences observers' preferences for the displays presented in the task. We used a contextual cueing task to let participants implicitly learn efficient attentional guidance in a display. There were three types of displays: displays in which both a target position and configuration of distractors were fixed (predictive displays), displays in which the entire display configuration was consistent but the target position was changed (non-predictive displays) and displays that were created for each presentation (novel displays). After the displays were learned through repetitive presentations in a visual search task, participants were asked to evaluate how "good" they thought the displays were (the participants were free to use their own criterion of "goodness", e.g., composition, balance, attractiveness, etc.). The result demonstrated that preference value was higher for the non-predictive displays than for the novel display, suggesting that a mere exposure effect was produced by the repetitive presentation of the whole display configuration. But more importantly, the preference value for the predictive displays was higher than that for both the non-predictive and the novel displays, indicating that occurrence of contextual cueing improved not only search efficiency but also preference rating of the display. As the participants could not explicitly discriminate the repeated displays from the novel displays, the results suggest that implicit predictability of a visual display may modulate preference of the display.

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53.329 **The effect of previously exposed configurations on the affective ratings and the difficulty ratings of target detection**

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The contextual cueing effect (CC) refers to the phenomenon in which visual search performance is faster for targets appearing in previously exposed configurations than for targets appearing in new configurations. We investigated whether the learned configurations affect other types of response such as affective evaluation. Participants were asked to search T-target among rotated L-distractors. The mean reaction time showed a typical CC. Then, participants were asked to evaluate how much they like the repeated or new configurations (Experiment 1), or how much they feel the difficulty of target detection (Experiment 2). The results showed that both the liking and difficulty ratings for the repeated configurations were lower than those for the new configurations.

53.330 **Search is enhanced with visual abstinence: Delaying initial saccade latency in familiar scenes improves search guidance**

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How does memory retrieval contribute to eye guidance while experience is accumulating in familiar environments? Observers performed a search task in which they had to locate the person in the scene (photographs of urban environments). Critically, the delay between scene onset and initial eye movement was manipulated: one group of observers remained at central fixation for 300 ms prior to moving their eyes, while another group remained at central fixation for 1300 ms. Trials ended when the target was fixated for 750 ms. Over 8 blocks of search, some scenes were repeated and some were novel. On a final "test" block, the delay duration was either lengthened (for short-delay group) or shortened (for long-delay group). We compared how search time for familiar scenes improved over repetition.

As scenes became increasingly familiar, observers who remained at central fixation for 1300 ms showed a larger search improvement than observers who remained for 300 ms. Interestingly, this benefit manifested in the second half of the experiment. Eye movement measures showed no significant difference between the groups for blocks 1-4. For blocks 5-8, however, lower search times, fewer fixations, and shorter cumulative saccade distance were exhibited by the group with longer time for memory retrieval before search initiation. Importantly, the final "test" block showed no difference between the groups, indicating that short-delay observers had the capacity to manifest very efficient search if given sufficient time for memory retrieval. One additional finding of our study showed an impact of memory on the latency of initiating the first saccade in the scene. Observers in both groups showed a small but progressive decline in initial saccade latency (54 ms over blocks 1-8). These results suggest that achieving memory retrieval prior to initiating search, particularly early in learning, may enhance the efficacy of eye guidance in familiar environments.

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53.331 **How many mean sizes can we represent?**

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The current study investigated how many mean sizes one could extract in multiple sets. We presented two to five sets of five different sizes in a display. Each set was defined by different colors. In Experiment 1, the display presented for 250 ms and was immediately followed by the probe display in which two randomly chosen colors from the previous display were presented. The participants had to compare which probed set had larger mean size. Participants' performance decreased as the number of sets increased. However, their performance remained above chance even when the number of sets was five. Furthermore, when we separately analyzed the largest mean-size pairs, the effect of set size disappeared. In Experiment 2, we increased the ISI to 1 second and found that this delay did not affect participants' performance. In Experiment 3, we added a pre-cue condition to investigate why the performance dropped as the set size increased. Participants' accuracy was higher in the pre-cue condition than in the post-cue condition. Their accuracy decreased as the set size increased in the post-cue condition, whereas it remained the same in the pre-cue condition. However, when we selected only the largest mean-size pairs, there was no difference between the pre-cue and the post-cue condition. These results suggest that the effect of set size observed in all three experiments may be due to the difficulty of selection, rather than the capacity of visual system. In other words, when the selection was easy as in the largest mean-size pairs, participants' performance did not decrease as the set size increased. Our results suggest that one could simultaneously extract 5 mean sizes accurately and maintain them for 1 second, which is more than the capacity of visual working memory.

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53.332 **Abstract Learning of Attentional Set**

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Does past experience shape the strategies we use to select visual information? Recent studies have made such a claim, based on results from the "option trial" procedure (Leber & Egeth, 2006), in which observers can choose from multiple strategies to search for a consistently-colored target (e.g., red) in a temporal stream of all-gray nontargets. That is, they can search narrowly for the specific target feature while ignoring non-matching stimuli (because the target feature is always known), or they can search more broadly for any oddball (because the target is always a feature singleton). The strategy used by observers on such trials has been shown to be largely determined by previous strategy use. For instance, when observers are required to search specifically for red in a 30-minute training phase preceding the option trials, they tend to continue searching specifically for red on the option trials. In the current work, we questioned whether such results constitute the transfer of the abstract search strategy, as previously argued, or if they instead reflect a lower-level phenomenon of "feature-specific learning." By this latter account, observers gain considerable experience searching through the particular set of features presented during training, which biases them to continue using the initial strategy simply because of low-level perceptual improvements. For example, rather than learning to search for the consistent target feature, whatever it may be, observers may have merely improved their sensitivity to searching specifically for red. To remove any potential contribution of feature-specific learning, we replaced the entire set of stimulus colors from the training phase to the test phase of option trials. Here, the past experience effect still obtained, supporting the notion that observers do indeed bring their previous experiences with "abstract" search strategies into their task challenges of the present.

53.333 **Awareness of Visual Impairment in Mild AD**

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Objective: To evaluate self-awareness of visual impairment and determine cognitive predictors of awareness in AD.

Methods: 68 participants with early AD (mean age=74.22) underwent cognitive tests. Vision impairment was defined by scores >1 SD poorer than nondemented control (N=135, mean age=70.21) scores on Useful Field of View (UFOV) Contrast Sensitivity (CS) tests. The VFQ-25 questionnaire provided a standardized self-report of visual impairment. A composite measure used 7 key questions (#2, 5, 6-10; 0-4 scale). We also evaluated questions more specific to UFOV (#7/10 on visual search of a crowded shelf/ the periphery) and CS (#2/5/6 on eyesight/reading/seeing up close).

Results: 57/68 AD subjects had UFOV impairments and 51/68 had CS impairments. Across all AD subjects there were no significant Spearman correlations between self-report of impairments on the VFQ and visual deficit magnitudes, suggesting overall lack of awareness. Subsequently we indexed awareness by plotting deficit magnitude for UFOV and CS against self-report for the VFQ responses. Diagonal lines through scatter plots of vision test scores versus VFQ responses modeled the ideal situation in which greater deficits produce more complaints. Distance between a data point and the diagonal line indexed awareness. Visual and verbal memory, executive functions and overall cognitive function scores predicted awareness of UFOV and CS impairments based on the composite and specific questions from the VFQ ($P<0.05$, all cases).

Conclusions: AD impairs visual functions and awareness of those impairments. This unawareness (a.k.a, anosognosia) may reflect a metacognitive failure to develop an accurate internal representation of current visual ability due to impaired encoding and monitoring of recurrent instances of failure in everyday visual activities. Primary deficits in memory and executive function contribute to this unawareness.

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53.334 **How sleep influences our memory for faces**

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Mounting evidence implicates sleep in the consolidation of learnt memories. It has to be shown if sleep helps consolidate memory for face identity, a form of memory critical for appropriate social interactions in humans. We investigated how sleep facilitates the consolidation of face recognition memory and whether it can selectively consolidate memories of behaviorally significant stimuli. In the presentation phase, observers passively viewed faces on green or blue backgrounds, which were respectively categorized as highly significant (S) or not (nS). Remembering correctly the S (nS) faces on the test gained the observer 20 (1) points. In the test phase, observers saw old and new faces randomly mixed on a gray background and judged if they remembered seeing each before. Sixty-four participants were classified, according to the times of presentation and test, into four equal-sized groups—i) PM-AM, ii) AM-PM, iii) PM-PM (24 hours), and iv) AM-AM (24 hours). Memory strength (d') was evaluated for each group. We tested the following explanatory factors for our results: sleep occurrence, occurrence of sleep after presentation, occurrence of sleep before test, duration between presentation and test, occurrence of visual stimulation, occurrence of visual stimulation after presentation, and occurrence of visual stimulation before test. We found that the occurrence of sleep before test was the key factor in explaining the facilitatory effect of sleep on memory for face recognition: PM-AM and AM-AM groups had similar d's that were significantly higher than the d's of AM-PM and PM-PM groups, which were similar to each other's. We also found that assigning behavioral significance to certain faces did not improve their recognition. Our findings thus suggest that sleep does not consolidate one's memory for faces but rather sleep prior to test shelters the memory for faces from interference (exposure), and exposure to faces while awake might disrupt it.

Attention: Theoretical and Computational Models

53.335 **The magical number 4 in visual cognition**

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Performance across a wide range of tasks, such as memorizing spatial positions, tracking multiple objects, performing a visual search, memorizing the visual appearance of objects, or rapid counting, often seem to suggest that the visual system can localize, track, search, memorize, or count 3-4 objects at once. These findings place a strong constraint on the architecture of visual attention, suggesting that visual selection relies on a fixed number of mechanisms that each deal independently with a single object.

We argue that at least three sets of data are inconsistent with this conclusion. First, there is substantial between-subject variance in these capacity limits, and training can change these limits even within a single subject. Second, the number of items that can be selected is not fixed: we will present data showing that in each case, there is an alternative limiting factor that actually limits performance. For example, in the case of concurrent selection or object tracking, changing the limiting factor (object crowding) can shift the magic number from 1 to 8. Third, the limiting factor can vary depending on the task, and ranges from crowding to limited representational space, temporal decay, and measurement noise. Unlike a fixed number of objects, these signature constraints can distinguish between cognitive systems (e.g., attentional selection is influenced by the position of attended items in the visual field, whereas visual working memory is not).

The existing data appear to be inconsistent with the notion that a single, unitary system limits processing in all of these visual tasks to a fixed number of items. In place of magical number theory, we propose an information/resolution based model of visual attention, in which attentional capacity is more accurately characterized both in terms of the number of items attended and the accuracy or precision with which they are selected.

53.336 **Selective attention and uncertainty**

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Is selective attention discrete or continuous? Are items either 'selected' or 'not selected', or might they be selected to varying degrees? If multiple items are visually selected to varying degrees, how is a response selected? Tasks used to study selective attention require the detection of co-occurrences in space or time between potential targets and a presented cue. Typically, experimenters make these tasks difficult by limiting stimulus fidelity. These manipulations increase the uncertainty inherent in the co-occurrence detection. This uncertainty may be represented on any given trial, such that a number of items are selected to varying degrees (within-trial variability) – equivalent to representing a probability distribution over likely targets. Alternatively, this uncertainty may be manifest as variability across-trials – on any trial an item is either selected or not, but which item is selected varies across trials. We asked subjects to make multiple responses on a given trial and analyzed the conditional distributions of guesses to assess the degree to which within- and across-trial variability contribute to the final distribution of reports. We assessed this for the case of temporal selective attention (RSVP task), as well as spatial selective attention (reporting a cued item from a spatial array). In both cases we find that the final distribution of reports is driven by within-trial variability. Thus, on any given trial, subjects 'select' a number of items to varying degrees, effectively forming a probability distribution over likely targets. Subjects then randomly sample from this probability distribution to make their responses. These results have implications for theories of selective attention – particularly, boolean map theory, as well as the phenomena of binding and crowding. Furthermore, the finding that people represent probability distributions at a given instance of time, and produce responses by sampling, has implications for cognition more broadly.

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53.337 **The role of Fourier phase information in predicting saliency**

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Global amplitude spectra from the discrete Fourier transform (DFT) have proven useful in studying behavioral and computational aspects of visual object and scene recognition. Here, we investigated whether Fourier phase (rather than amplitude) spectra may be useful for another purpose, namely guiding attentional selection. We developed a simple model which produces salience maps from phase information alone, by (1) downsampling images by one or more factors, (2) computing the DFT of each downsampled image's luminance, (3) normalizing each complex DFT value to unit amplitude while retaining its phase, (4) computing the inverse DFT, (5) squaring the result, and (6) combining the maps resulting from each downsampling factor. Salience maps from this model significantly predicted the free-viewing gaze patterns of four observers for 337 images of natural outdoor scenes, fractals, and aerial imagery. For fractals and aerial imagery, this phase-based model was significantly better (paired t-test, $p<0.0005$), by a large margin, at predicting observers' gaze than were previous saliency (Itti&Koch 1998) and enhanced saliency (Peters et al 2005) models. However, for the outdoor scenes, the phase-based model was significantly worse ($p<0.001$) than these previous models. Additionally, we found that retaining some amplitude information, in the form of a "spectral residual" (Hou&Zhang 2007), did not improve gaze prediction for any of the image categories. Natural images tend to have $1/f$ power spectra, so forcing a flat Fourier amplitude spectrum is similar to scaling the amplitude everywhere by f, equivalent to a spatial derivative. However, this derivative-like aspect cannot completely explain our results, because the image category with the most $1/f$-like spectrum (outdoor scenes) was the one for which the phase-only model fared worst. Just as Fourier amplitude can form a computational basis for scene categorization (Torralba 2003), our results establish Fourier phase information as one possible computational basis for spatial attentional selection.

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53.338 **The Focus of Expansion Acts as a Cue for Visual Attention**

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In everyday vision, human observers sequentially shift focal attention as well as their gaze across the scene. It is well known that a number of low-level, task-independent cues, such as intensity, color, orientation and motion, as well as top-down, task-dependent information drive covert and overt attention. The extent to which qualitative features of the optical flow field, in particular the focus of expansion (FOE), are salient and thereby attract attention is not known. This is an important question as the visual cues on our retina in daily life, especially while walking or driving, contain global motion fields. To study this, we recorded eye-movements in human observers at 1000 Hz using an Eyelink1000 tracker while subjects viewed image sequences and performed associated tasks. In the first experiment, subjects viewed dynamic natural scene and were asked to rate their preferences for the images. The entire image started zooming toward one of four predefined points, FOEs, on the screen for 1 sec following stimulus onset. Subsequently, the image remained static for another 1 sec. We observed an immediate and a significant attentional bias toward the FOE in all the subjects. The bias peaked at around 300 msec and persisted throughout the entire 2 second trial with decay. In the second experiment, subjects viewed a search screen which contains a target letter, T, and 47 distracter letters, L's, and were asked to find the target letter. Even under this demanding eye-movement task, a significant attentional bias toward the FOE was observed. The bias was less persistent than the letter search trial but also peaked at around 300 ms. These results suggest that the FOE, a qualitative feature of global motion fields, plays a role as a cue for human attention mechanisms and strongly biases our attention.

Keywords: visual attention, global motion, focus-of-expansion, eye movement

53.339 **Binary versus Graded Filters for Selectively Attending to Dots of Different Contrasts**

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Previously we established that in estimating the centroids of sparse dot-clouds, observers are able to apply attentional filters that select dots based on the sign of dot contrast, giving equal weight to all pertinent dots (dots darker than the background, lighter, or all dots). To further investigate these top-down attentional filters, we examined whether they could be made sensitive to contrast amplitude. Participants indicated with mouse-clicks the locations of centroids for briefly flashed, sparse clouds comprising either 8 or 16 dots of various intensities, attending to either (i) dots darker than the background, (ii) dots lighter than the background, or (iii) all dots present, with a variation to our original instructions. Whereas observers previously attempted to weight all pertinent dots equally, in the current study observers were instructed to weight pertinent dots in proportion to their contrast amplitudes, assigning more weight to dots with extreme contrasts. For example, in the attend-to-dark condition, observers were required to estimate the centroid of only the dots darker than the background, giving the greatest weight to black dots, slightly less to dark gray, etc. Three conditions were tested: (i) to find the centroid of only the dots darker than the background, giving the most weight to black dots, (ii) to find the centroid of only the dots lighter than the background, giving the most weight to white dots, and (iii) to find the centroid of all of the dots present, with the most weight assigned to the extreme black and white dots. The observed graded-attention filters differed only slightly from those observed under equal weighting instructions. This suggests that observers do not have access to separate attention filters that operate on a gradient scale.

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53.340 **Contrast Modulation by Spatial Attention for the Perception of Figure Directions**

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Spatial attention alters figure-ground perception as we often experience in ambiguous figures. Physiological studies have reported that figure-ground process begins from border-ownership (BO) selective cells in V1/V2. We investigated the role of spatial attention applied to early vision with a computational model consisting of V1, V2, and Posterior Parietal (PP) modules. The PP module is designed to represent spatial attention that could be considered as a saliency map based on luminance contrast. In the model, spatial attention alters contrast gain in the V1 module so that it enhances local contrast. The change in contrast signal then modifies the activity of BO-selective neurons in V2 because BO is determined solely from surrounding contrast. The simulation result showed that the direction of figure (DOF) could be flipped in ambiguous stimuli, depending on the attentional location. Although the activities of model BO cells were modulated, their DOF did not alter for unambiguous stimuli. To evaluate the model quantitatively, we carried out psychophysical experiments to measure the effects of attention on the perception of BO for ambiguous random-block stimuli, and then compared the results with those of corresponding simulations. The model showed good agreement with human perception for modulation magnitude and its variance among stimuli. When the stimulus included a familiar shape such as a square, human determination of BO shifted in the direction of the familiar shape, whereas our model did not exhibit such a shift. However, there was no significant difference in the modulation magnitude between the model and psychophysical data. This disagreement in BO shift, and agreement in modulation magnitude seems natural if spatial attention works without the influence of familiarity or feature-based attention in early vision. These results suggest that the activity of BO-selective neurons could be modulated significantly by spatial attention that alters local contrast gain in early vision.

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URL: http://www.cvs.cs.tsukuba.ac.jp/

Tuesday, May 13, 8:30 am - 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

Faces: Wholes, Part, Configurations and Features
Motion: Biological Motion

Faces: Wholes, Part, Configurations and Features

53.401 **Individuation training but not categorization training leads to configural processing of non-face objects**

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Experience plays an important role in the specialization of the visual system for different object categories. Support comes from training studies showing that several hours of individuation experience with novel objects ('Greebles') result in behavioral and neural phenomena similar to those found for face perception (Gauthier et al., 1997, 1998). Surprisingly, it is unknown whether such training effects are specifically caused by experience individuating objects or whether other kinds of experience might be equally potent in causing these behavioral and neural changes. The current study compared two types of training to probe the effects of different kinds of object recognition experience. Two groups of participants went through training procedures that either emphasized individuation or categorization of a set of novel objects ('Ziggerins'). The Ziggerin set contains 6 classes each with 12 individuals. Individuation training involved learning to uniquely identify each Ziggerin, similar to the demands of previous Greeble studies. Categorization training involved learning to rapidly categorize kinds of Ziggerins. Like the earlier Greeble studies, individuation training resulted in more improvement in recognition at the individual level than at the category level, and resulted in an increase in holistic and configural processing as measured using a composite paradigm (Young et al., 1987). Perceptual expertise individuating a set of novel objects specifically causes those objects to be processed in a more holistic and configural manner. In contrast, categorization training resulted in a larger improvement in recognition at the category than individual level, and led to little or no evidence for holistic or configural processing. Experience with novel objects in a task that does not require individuation was insufficient to produce face-like effects. Our finding that individuation training and categorization training have different behavioral consequences provides more support for an important role of experience in the specialization of the object recognition system.

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53.402 **Context Influences Holistic Processing of Face and Non-face Objects in the Composite Task**

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The composite paradigm is a selective attention task that measures holistic processing (HP) by assessing how well participants can selectively attend to half of an image. HP measured in this paradigm is larger for faces than other objects, and larger for aligned than misaligned test faces. Prior work has argued for a decisional component of HP because HP is affected by test but not study face configuration (aligned/misaligned) when these conditions are randomized (Richler et al., submitted). Here, using faces and novel objects (Greebles), we investigate whether study configuration exerts a contextual or strategic effect with faces and Greebles that may be uncovered by blocking study conditions. For faces, HP is modulated by test configuration, presumably because aligned faces are processed holistically as a result of expertise. However, studying misaligned items requires a wider spread of attention, so it may be difficult to subsequently narrow attention to selectively attend to half of the test item. Thus, HP of faces and Greebles may depend on the attentional context within the trial, elicited by the study configuration. Indeed, we found that blocking study configuration influenced the magnitude of HP for faces (E1). HP was also obtained in Greeble novices in a blocked design but only when study items were misaligned (E2). However, when study Greeble conditions were randomized, HP was obtained in both study conditions (E3), presumably due to the mere presence of study-misaligned trials. Furthermore, the context effect on HP for Greebles was induced by task-irrelevant faces in a dual-task paradigm (E4). Finding holistic effects under certain conditions in the randomized and dual-task designs but not blocked experiments suggests that these effects are driven by a change in strategy, not a perceptual limitation. Together, these results suggest that HP is not solely perceptual, as it can be modulated by contextually-induced strategy.

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53.403 **Abnormal eye fixations on personally familiar faces following acquired prosopagnosia reveal a lack of individual holistic face perception**

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Selective impairment of face recognition following brain damage, as in acquired prosopagnosia, may cause a dramatic loss of diagnosticity of the eyes area of the face and an increased reliance on the mouth for identification (Caldara et al., 2005). To clarify this phenomenon, we measured eye fixation patterns in a pure case of prosopagnosia (PS, Rossion et al., 2003) during her identification of personally familiar faces (27 children of her kindergarten). Consistent with previous evidence, the normal control (her colleague) identified the faces within two fixations located centrally, just below the eyes. This pattern of fixations remained unchanged even by increasing difficulty by presenting anti-caricatures. In contrast, the great majority of the patient's fixations were located on the mouth, confirming the abnormally reduced processing of the upper area of the face in acquired prosopagnosia. Most importantly, the prosopagnosic patient also fixated each eye spontaneously in between the first and last fixation, making more eye movements than the normal control. This spontaneous fixation on the eyes also rules out a behavior of avoidance of the eyes, as observed in autistic or bilateral amygdala patients. Rather, these results support a high-level perceptual account according to which acquired prosopagnosic patients have lost the ability to represent multiple elements of an individual face as a perceptual unit (holistic face perception). To identify a given face they focus very precisely on each local feature rather than seeing the whole of a face from its diagnostic center (i.e. the "center of mass" of the face, just below the eyes). The upper area of the face is particularly less attended to and less relevant for the prosopagnosic patient because it contains multiple features that require normal holistic perception in order to be the most diagnostic region. Consequently, prosopagnosic patients develop a more robust representation of the mouth, a relatively isolated feature in the face that may contain more information than any single element of the upper area of the face.

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URL: http://www.nefy.ucl.ac.be/Face_Categorisation_Lab.htm

53.404 **Personally familiar faces and holistic processing**

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It is generally acknowledged that familiar faces are processed in a qualitatively different manner to unfamiliar ones. However, since the majority of previous investigations have employed either famous faces or simply familiarized subjects with stimuli, little is known about how personal familiarity influences face perception. We investigated the effect of personal familiarity on the discrimination of single inter-feature distances within both upright and inverted faces (experiment 1) as well as on the discrimination of the geometric configuration of features within upright faces (experiment 2). Inversion led to poorer discrimination of vertical changes within faces—but only for subjects familiar with the stimuli. Furthermore personal familiarity was associated with superior discrimination of subtle changes in facial geometry. Both experiments point towards familiarity increasing sensitivity for information considered to rely on holistic processing.

We exploited the fact that subjects can name personally familiar faces to overcome response biases traditionally associated with same-different judgments in the composite paradigm. Specifically we examined the hemisphere dependence of holistic processing by presenting misaligned and aligned composite stimuli in the left or right visual field (experiment 3). Poorer performance--associated with alignment of top and bottom parts--was observed only for stimuli presented within the left visual field. To our knowledge this is the first demonstration of right hemisphere involvement in holistic processing without any contribution of performance bias.

53.405 **Using general recognition theory to investigate the Thatcher illusion**

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The phenomenology of the Thatcher illusion is often used as a demonstration of configural processing. Thatcherised faces are created by inverting the eyes and mouth within the context of the face. When faces are upright, this produces a grotesque appearance. However, when faces are inverted, perceived grotesqueness disappears. The Thatcher illusion is traditionally thought to arise because participants compute configural relations when faces are upright, but rely on featural processing when faces are inverted. This study investigated whether evidence of configural processing of Thatcher faces could be found using constructs defined by general recognition theory (Ashby & Townsend, 1986). Churches were used as control stimuli. Participants were presented with

upright and inverted faces and churches that had the eyes (windows) inverted, the mouth (door) inverted or both the eyes (windows) and the mouth (door) inverted, and observers responded with judgments about both features. The results showed violations of informational independence, informational separability and decisional separability suggesting that the Thatcher illusion is underpinned by a strong form of configural processing.

53.406 **The crowding effect and perceptual and decisional holism in the visual processing of faces**

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Two experiments examined the extent to which holism in visual perception can be revealed by way of the presence or absence of visual crowding. Martelli, Majaj, and Pelli (2005) used crowding—increases in threshold for contrast as a function of eccentricity—to propose an operational definition for holism: that holistic perception of an object is implicated if it can be identified when the entire object is presented within an isolation field (an area proportional to one-half eccentricity). This operational definition is considered from the perspective of general recognition theory (GRT, Ashby & Townsend, 1986), a theoretical rather than operational approach to defining holism. In this study, participants performed forced-choice identification tasks for two sets of face stimuli presented under conditions modeled on those used by Martelli and colleagues. In Experiment 1, participants identified one feature (the nose) presented alone or in a face context, and then three types of paired features in faces (the eyes and nose, eyes and mouth, or nose and mouth). In Experiment 2, participants performed the same identification tasks, but the stimuli were altered to increase critical spacing between the features, separating them into their own isolation fields. The experimental results replicated the threshold patterns documented by Martelli et al.: in Experiment 1, threshold data showed evidence for the benefit of a facial context in foveal presentation, and impairment in peripheral presentation, while in the Experiment 2 threshold data, both benefit and impairment were eliminated foveally and peripherally when critical spacing isolated the facial features. However, the GRT results from Experiments 1 and 2 revealed perceptual and especially decisional violations in both foveal and peripheral presentations, a disparity between current operational and theoretical definitions of holism which suggests that the crowding effect cannot serve to define holism in face perception.

53.407 Reassessing the architecture of same-different face judgments

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Given the holistic nature of faces, Wenger and Townsend (2001) proposed that face information processing would be supported by a facilitatory parallel system, meaning that all features are processed simultaneously. However, there is an apparent contradiction between this working definition and Bradshaw and Wallace's (1971) claim that face recognition is a serial process, wherein features from two faces are sequentially compared. Using a same-different face recognition paradigm, they found that as the number of diagnostic face features increased, processing time decreased. Although, these results are predicted by standard serial models, their primitive techniques could not distinguish true serial processing and the parallel models that mimic serial processing. With the methods of systems factorial technology (SFT; Townsend & Nozawa, 1995), we can characterize any human information processing system in terms of architecture, stopping rule, independence, and capacity. SFT provides a rigorous framework for assessing Bradshaw and Wallace's (1971) claim of seriality; given the intuitions of Wenger and Townsend's (2001) hypothesis we predict that same-different face recognition is a process of parallel comparison. In a set of experiments incorporating the double-factorial paradigm, we factorially manipulated the number of critical features, relative similarity of face pairs, and presense/absense of non-diagnostic context features. Different face pairs consisted of identical facial surrounds with internal features morphed to be more (66%) or less (33%) similar. Measuring the same-different judgment response times, we first replicated Bradshaw and Wallace's data. Information processing modeling revealed a positive survivor interaction contrast and an over-additive mean interaction contrast. This is the signature combination of parallel, self-terminating processing. Thus, our results resolve the apparent contradiction and add a new dimension to Wenger and Townsend's (2001) configural processing system; not only are the features within a configural object processed simultaneously, but also the comparisons between configural objects are performed in parallel.

53.408 Discrimination, bias and focused attention in the composite face effect

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In the composite-face effect subjects attempt to recognize one face-half when it is aligned or misaligned with the other half. In same/different experiments, subjects are less likely to perceive that one half is the same in the aligned than the misaligned condition, which others argue represents interference from the whole facial configuration in aligned stimuli. However, it is unclear whether this is due to reduced discriminability or a criterion shift. Furthermore, the contribution of focusing attention on one face-half is unknown. We had 18 healthy subjects perform two composite face tests, each with one block of aligned faces and another of misaligned faces. Each trial consisted of a composite face viewed for 200 ms, followed by a second composite face shown at 50% larger scale, also for 200 ms. In the first test, subjects indicated if one half of the face was the same or different in the two images, while disregarding the other face-half. Half of the subjects responded to the upper face-half and half to the lower face-half. In the second test, subjects indicated if EITHER the top or bottom half of the face was the same. The same composite faces were used in both tests, with order counterbalanced. We calculated hit rate, false alarm rate, d′ and c′ (criterion bias). Face-alignment had a significant effect on c′ but not on d′, an effect that derived mainly from the condition of attending to one face-half. When subjects attended to both halves, hit rates decreased and false alarms increased, resulting in a decrease in d′; also, in this condition alignment did not have an effect on any variable. We conclude that the composite effect is due to a shift in criterion bias rather than discriminability, and that focused attention on one face-half is critical.

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53.409 The composite face effect is still not correlated with face identification accuracy

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Many researchers assume that face recognition is driven by configural processing. This assumption, however, is rarely tested in a direct way. Here we examine whether an observer's level of configural processing can predict his or her face recognition performance.

Last year we reported data demonstrating a lack of correlation between the magnitude of the composite face effect (CFE) and accuracy on a face identification (FI) task (VSS Abstract #601, 2007). The CFE task required subjects to make same-different judgments about top halves of faces while bottom halves were either aligned or misaligned (blocked). The FI task was to determine if the target was present in the lineup and, if so, to select the face that matched the target. The idea behind the study was that if CFE taps into a process that helps with face recognition in naturalistic contexts, then there should be a correlation between the magnitudes of CFEs and accuracies on face identification tasks.

Here we report two follow-up experiments that compared CFEs and accuracies on two different FI tasks. The CFE task was administered three times per subject. One FI task was a 10-AFC task with unlimited viewing time of 1 target and 9 distractors; the second FI task was a 4-AFC task that limited the viewing time of the target face to 200 msec, which matched the stimulus duration used in the CFE task.

There were large but stable individual differences on the CFE task and on both FI tasks. The correlations between the magnitude of the CFE (accuracy or RT) and accuracies in the two FI tasks were not significant ($r \leq 0.25$, $p \geq 0.5$). These results indicate that the mechanisms that produce the composite face effect may not facilitate accurate face identification, thus the common assumption that face recognition is driven by configural processing should be reassessed.

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53.410 Effects of viewing condition and age on the functionality of eye movements for face recognition memory

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How do eye movements influence recognition memory for faces? Henderson et al. (2004) recently found that younger observers performed better when they studied faces under free-view conditions (in which no restrictions were placed on eye movements) and then tested under free-view conditions, compared to when observers studied faces under fixed-view conditions (in which fixations were restricted to a small central area of the face) and then tested under free-view conditions. Henderson et al. concluded that eye movements are functional: they help to encode faces in a way that facilitates subsequent recognition. However, it is possible that free-viewing during study lead to better recognition simply because the same mode of viewing was used in the test phase. The current experiment examined this idea in younger (age = 19) and older (age = 70) subjects. Viewing conditions (fixed and free) were combined factorially with the phase of the experiment (study and test), yielding four conditions. In the study phase, 24 faces were each presented for 10 secs, and subjects were instructed to remember the faces. In the test phase, 48 faces were each presented until observers responded whether a face was previously studied (50%) or novel (50%). 12

older and 12 younger subjects were tested in each condition. There was a main effect of condition: recognition (d') was significantly better in the two conditions that allowed free viewing during the study phase (F(1, 40)=8.01, p=0.007), irrespective of the type of viewing in the test phase. The main effect of age and the age x condition were not significant. Our findings support Henderson et al.'s claim that eye movements during study improve later recognition, and further show that this functionality persists with aging.

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53.411 **Classification images measured in a same/different face discrimination task**

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Classification images (CIs) have revealed that observers rely on a small number of pixels near the eye/brow region to discriminate faces (Sekuler et al., 2004). However, one criticism of the application of CIs in this situation is that the paradigm may allow subjects to use strategies that are not used in naturalistic situations. In particular, the methods used in the previous CI experiments may have made it easier for subjects to rely on only a small set of pixels to discriminate the stimuli. One way of addressing this problem is to use CIs to determine the pixels used to perform a same/different face discrimination task. A same/different task can potentially use a very large set of faces, and therefore make it more difficult for subjects to rely on a single feature to respond accurately. We therefore measured CIs in four subjects in a same/different face discrimination task. In our initial experiment, we used only two faces so that our results could be compared to previous CI experiments. Each trial consisted of two, 500 ms intervals separated by an ISI of 500 ms. Each interval contained a face embedded in white Gaussian noise, and the subject's task was to determine if the two faces were the same or different. Face contrast was adjusted to yield correct responses on approximately 71% of the trials. CIs were calculated from the squared, pixelwise difference between the noise fields shown on 'same' trials. Significant pixels were clustered near the eyes and nose. This result shows the validity of the same/different CI method for investigations of face perception, and that results from the same/different method provide similar results to those found using the standard CI paradigm. Currently, we are measuring CIs in same/different tasks that incorporate more faces, and multiple poses of the same face.

53.412 **The use of the eyes for human face recognition explained through information distribution analysis**

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Introduction: During face recognition human gaze predominantly centers on the eye region (Barton et. al., 2006), with human decisions preferentially based on the eyes' visual information (Schyns et. al., 2002; Peterson et. al., 2006). The reason behind this strategy, however, is largely unknown. We previously showed using ideal observer analysis that the eye region contains the greatest amount of objective diagnostic information (Peterson et. al., 2007). The purpose of this study was to quantitatively measure the relationship between the amount of visual information contained within each feature region and the efficiency with which human recognition strategy exploits these conditions. Methods: We photographed 40 Caucasian students (20 female) in tightly controlled conditions (holding expression, distance, orientation and lighting constant). We equated face size and contrast energy. We created masks to occlude background, hair, ears and neck, as well as either the eyes, nose, mouth or chin. The task entailed randomly sampling a face and a feature to exclude, embedding the image in white Gaussian noise, and asking the observer to make an identification. Results: Consistent with findings from a much larger sample (1000 faces; Peterson et. al., 2007), ideal observer analysis showed the eyes were the most diagnostic feature, followed by the mouth, nose and chin. More importantly, humans followed the same trend; however, performance when the eyes were blocked was impaired to a much greater degree for humans than for the ideal observer. Conclusion: The eyes are, objectively, the best region to use when making a face identification. Here, we have shown that human recognition strategy not only follows this trend, but exacerbates it. Given the eye region's domination of attention during normal human interaction, a strategy that over-weights this region may be a simple adaptation to an optimal strategy.

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53.413 **Removing individual features from famous faces: The development of a novel test**

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Exploring the impact that individual features have upon face recognition can provide insight into the areas of prosopagnosia, unimpaired face recognition ability and eyewitness identification. We tested the recognition abilities of 96 psychology undergraduate students on a series of eight famous faces within the categories of sports professionals, royals, actors, musicians, politicians and models. Stimuli were selected from celebrities who were living and had currently featured or been featured regularly in the international media over the past two decades. Each set of faces had either eyes, noses, mouths, external features (hair and ears), all internal features removed or remained unchanged (6 conditions in total). Images were displayed in colour and subtended 17.7 degrees. Each face was presented for 160ms (with an upper response level set at 10s) and reaction times for face recognition and naming were recorded. We found that removing hair had the greatest effect in impairing recognition; and considered the remaining features in terms of the perceptual hierarchy facilitating recognition. From these results, a novel test of famous face recognition has been developed. This test is a 4AFC task, where a series of 8 target famous faces are identified, some with features removed; with data providing insight into how individual features affect recognition within a variety of different cohorts (for example, whether individuals within specific cultural groups, sexes, age ranges, focus more on certain features than others). This technique can produce standardised versions of the test that are sensitive to their respective cohorts' perceptual experience, age and ethnicity. Versions of the test can also be constructed and applied in a clinical setting with the potential of yielding insight into prosopagnosia in terms of where fragmentation occurs in the perceptual process.

53.414 **Faces in noise**

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Symmetric noise patterns can give rise to strong and frequent impressions of faces along the vertical axis of symmetry (Paras et al. VSS 2006). These illusory faces invariably include a pair of eyes as the dominant feature, suggesting that a percept of eyes may be an important trigger feature for face perception. Here we examined the stimulus properties (e.g. contrast polarity or spatial scale) that can be perceptually interpreted as eyes, and how this interpretation influences the perception of other regions in the image. Stimuli were grayscale images of filtered asymmetric noise. In a subset of images a pair of Gaussian spots was added to the noise along the horizontal or vertical midline. The horizontal - but not vertical - pair causes most images to appear organized as a face. This suggests that the presence of "eyes" may engage a face processing mode leading to perceptual completion of a face, and we explore this by examining how different areas of the image are classified in the presence or absence of eyes. Interpreting the noise as a face may allow the images to be more perceptually informative and discriminable, even though the dots leading to this interpretation do not add any explicit information for the discrimination. To test this, in further experiments we compare recognition accuracy for sequences of noise images in the presence or absence of eyes.

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53.415 **Time-Costs for Recognizing Degraded Images**

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One of the most impressive aspects of human visual processing is our ability to recognize objects despite severe degradations in image quality. In this study, we focused on the recognition of impoverished facial images. We were specifically interested in examining the latency of recognition as a function of the extent of degradation to derive clues about the dynamics of processing. We used degradations involving resolution reduction on building and face images. Participants were asked to perform either basic-level recognition, or subordinate recognition with celebrity faces. Perhaps not surprisingly, subjects were able to distinguish faces from buildings, with near-perfect performance and in constant time, for all levels of degradation used. However, the subordinate recognition latency results exhibited an interesting pattern. We found a strong monotonic increase in time to recognition as a function of the level of degradation. These results have at least two important implications. First, the finding that basic-level classification latency was unaffected by image degradations, while subordinate-level recognition latency was significantly affected, suggests that these two tasks might, at least under some circumstances, be dissociable. This degradation-induced temporal decoupling of the two processes can be exploited to identify their neural correlates (see Morash et al., VSS 2008). Second, the increased recognition latencies provide tentative support for the idea that purely feed-forward theories of recognition are likely to be incomplete as accounts of human processes, since they would not predict large latency differences across conditions. It is unclear precisely what processes account for the increased time-costs. One possibility is that recognition of degraded images might involve a time-consuming iterative exchange of information between high and low-level visual areas, which effectively implements a 'hypothesize and verify' kind of analysis strategy.

53.416 **Blurry faces are sometimes recognized better than high-resolution faces**

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It is known that humans can recognize familiar faces at relatively low resolution (e.g., 16x16 pixels or 8 to 16 cycles per face), indicating a transfer of face learning from high-to low-resolution images. It is not known, however, whether learning blurry faces is followed by better recognition of high-resolution faces or blurry faces. This is particularly relevant to people with low vision who wish to recognize faces learned prior to the onset of eye disease and who also wish to learn new faces in the presence of reduced acuity. It may also be relevant in normal vision when learning faces of people at a distance (near the acuity limit) and then recognizing them close up. We had normally-sighted subjects learn a set of 20 new faces with and without blur. During the learning phase, each face was presented for 2 seconds. After a 2-minute retention interval, subjects' recognition performance was measured with and without blur using a temporal 2AFC-paradigm. Learning and test conditions were counterbalanced across subjects. A set of unfamiliar Korean characters was also learned using the same procedure. We found that blurred faces are recognized better than high-resolution faces if face learning occurred in the presence of blur (81% vs. 69% accuracy; $t(9) = 2.57$, $p = 0.03$). However, the same pattern did not occur for unfamiliar Korean printed characters, that is, even when the characters were learned with blur, recognition was no better for blurry characters than for high-resolution characters (77% vs. 74%; $t(9) = 0.44$, $p = 0.67$). Perhaps, the blur used for this study was not severe enough to affect the visual characteristics used to learn and recognize Korean characters. Our findings suggest that the visual characteristics which are useful for learning and recognizing blurred faces may not be the same as those for learning and recognizing high-resolution faces.

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53.417 **Don't blink, you are being watched: Effects of direct gaze on attentional blink**

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Eye contact is very important in social interactions, but are people more attentive to faces that look at them than to other stimuli? The present study examined this question by comparing viewers' ability to detect faces and objects in an attentional blink paradigm. The faces compared were either looking directly at the camera and therefore at the participant (direct gaze) or not (averted gaze). Participants watched one or two intact pictures among scrambled ones. They reported whether the target picture (T1) was a female face, a male face, or an object. A second image (T2) appeared on half of the trials with various SOA. Participants were asked to detect the presence of the second image. The results revealed a smaller attentional blink for faces than for objects, indicating that the viewers paid attention to faces more than to objects. Moreover, when comparing direct gaze and averted gaze faces in the T1 and T2 positions the following overall effects where obtained. A direct gaze face at T1 led to a stronger attentional blink suggesting that a direct gaze face held the viewers' attention more. On the other hand, a direct gaze face at T2 led to a weaker attentional blink suggesting that direct gaze captured attention better.

53.418 **Hemispheric specialization for face processing revealed by use of Thatcherized and feature distorted faces**

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Despite striking homogeneity in facial features and structure, humans effortlessly recognize faces across variable exposure conditions. Inversion makes face processing difficult; one explanation is that face perception involves encoding configural information (relationships among features) rather than features per se, and that configuration is unrecoverable from inverted faces. Functional imaging studies and observations of brain-damaged patients show the brain's right hemisphere is particularly sensitive to face configuration. We investigated right hemispheric sensitivity to face configuration using the Thatcher Effect, whereby faces with inverted eyes and mouths are perceived as grotesque when upright but not when inverted. One eye or one eye and the mouth were Thatcherized in faces cropped to ovals to remove hair and clothing features. Display duration was 120 ms. Participants rated bizarreness on each trial. We predicted higher ratings for left eye than right eye manipulations because of the contralateral projections of the visual fields to the brain, but only for upright and not inverted faces. This side by orientation interaction was robust and moderated by age; 8-10 year olds showed the smallest side difference in rated bizarreness for upright displays. Performance of 11-13 year olds was the same as college students. Stronger right-handedness was associated with greater rating bizarreness for upright left-sided than right-sided manipulations in the youngest group. Other results are forthcoming: We obtain bizarreness ratings after manipulating features (iris and teeth) on sides of the face. We present results from strongly left-handed participants. Also, we manipulate side and information type (configural, featural) independently in a same-different task with pairs of sequentially presented faces; information in the second face is manipulated for 20 ms at different times during the display. By examining lengthened correct same responses, this latter task can reveal relative time courses in utilizing featural and configural information by the hemispheres.

Motion: Biological Motion

53.419 **Perception of Biological Motion Across the Visual Field**

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There is conflicting evidence about whether stimulus magnification is sufficient to equate the discriminability of point-light walkers across the visual field. Ikeda, Watanabe and Blake (2005, Vision Research) found that peak noise tolerance was always highest at fixation and concluded that biological motion was unscalably poor in the periphery. By contrast, Gibson et al. (VSS, 2005) found that in the absence of spatiotemporal noise, stimulus magnification was sufficient to equate point-light walker direction discrimination (left vs right, i.e., ±90° from the line of sight) across the visual field.

We measured the accuracy with which observers could report the directions of point-light-walkers moving ±4° from the line of sight. Accuracy was measured over a seven-fold range of sizes at eccentricities from 0 to 16°. All observers achieved 100% accuracy at the largest stimulus sizes (20° height) at all eccentricities. The psychometric functions at each eccentricity were shifted versions of each other on a log size axis. Therefore, by dividing stimulus size at each eccentricity (E) by an appropriate $F = 1 + E/E2$ (where E2 represents the eccentricity at which stimulus size must double to achieve equivalent-to-foveal performance) all data could be fit with a single function. The average E2 value was .97 (SEM = .19, N = 3). This value is close to that found by Gurnsey et al. (2006, Journal of Vision) in a structure-from-motion task (E2 = .61) but contrasts with the average E2 value of 3.5 found by Gibson et al. (VSS, 2005).

In the absence of spatiotemporal noise, size scaling is sufficient to equate discrimination of biological motion across the visual field. The average E2 in this task is smaller than that found by Gibson et al. (2005), showing that task difficulty has an effect on the magnification needed to compensate for eccentricity-dependent sensitivity loss.

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53.420 Neural encoding of walking direction in biological motion: Evidence from direction-specific adaptation and functional neuroimaging

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Two questions were addressed in the current study: are there neurons tuned to specific directions of point-light biological motion, and if so, in which areas of the brain are these neurons located? We used a visual selective adaptation method to investigate the first question. After visual adaptation to point-light walkers oriented 45 degrees to either the left or right of the front direction, subsequently presented walkers oriented near the front direction were perceived to walk in a direction pushed away from that of the adapted direction. This aftereffect can be obtained with spatially non-overlapping adapting and test stimuli. These results support the existence of biological motion selective neurons tuned to specific walking directions in the human visual system. Next, we measured cortical responses using event-related fMRI while observers viewed the same biological motion sequences, oriented 45 degrees to the left, 45 degrees to the right, or in the front direction. Regions of Interests (ROIs) potentially involved in processing biological motion (pSTS, EBA, hMT+, and LO) were identified with independent localizer scans. Although fMRI response amplitudes could not differentiate the different walking directions in any of the ROIs, spatial patterns of activation across voxels revealed that the pSTS and the hMT+ contained information about the walking direction in biological motion. In contrast, activation patterns in the EBA could differentiate different global forms of the body, i.e., front view vs. profile views. Evidence from an additional control experiment as well as from published studies reveals that directional encoding in the hMT+ is not unique for biological motion. We conclude that there are neurons tuned to different walking directions in point-light biological motion, and that the pSTS is the likely site of these neurons in the human visual system.

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53.421 Gait-Specific Adaptation Depends on Body Configuration

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Adaptation effects from prolonged or repeated exposure to particular visual stimulus features have been shown for motion and color, as well as higher-order stimulus dimensions such as face identity. More recently, adaptation effects from viewing particular biological motion patterns, such as male or female gait, have been reported. Here we examined if adaptation to gait relies on form cues, such as body configuration, or if the local trajectory of individual limbs is sufficient. Participants (N=16) viewed an animated figure walking with a gait that consisted of a spatiotemporal morph between gait styles captured from two different human actors. The walking figure was configured either as intact, or apart with the limbs and torso separated but maintaining the same motion trajectory as the intact figure. Using a double staircase procedure we determined the point of subjective equality (PSE) between the two gaits for intact and apart test walkers, before and after 2mins (plus 5secs/trial top-up) adaptation to one of the gaits. Adaptation to intact or apart figures was conducted in sessions separated by at least 48hrs. Results revealed strong within-stimulus adaptation, with the intact walker adapting the intact test walker, and the apart walker adapting the apart test walker. However, there was asymmetric transfer across the two configurations, as the intact walker adapted the apart test walker, but the apart walker did not adapt the intact test walker. These findings cannot be explained by weaker adaptation to the apart walker in general. Instead they show that when there is conflict between the configural cues of adaptor and test stimuli, observers show a preference for the intact stimulus. While prior exposure to the local motion trajectory of the individual limbs and torso can bias our internal representation of gait, the presence of form cues such as body configuration will override this bias.

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53.422 The perceived depth affects biological motion perception

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We explored the effect of depth perception in biological motion (BM) perception. The stimuli were the point-light walkers comprised of dynamic random dot stereogram (dot density was 50 %). Joints of the walker were either in front (front-walker condition) or behind (behind-walker condition) of the background with the binocular disparity (Disparity-defined Biological motion, DB). In the control condition, joints were defined by the dot density or mean luminance (25 % density, Luminance- defined Biological motion, LB). As another control condition, we examined the performance to detect the movement of a single joint defined by the binocular disparity (Disparity-defined Single motion, DS). Subjects were asked to judge the direction of walker's articular movement (forward or backward walking). In DB, the performance was significantly higher (67 %) than chance level when the walker was in front, but that was chance level when the walker was behind of the background. The performances for two control conditions (LB and DS) were about 100 %. In the next experiment, we investigated the perception of BM when the LB and DB were superimposed while their directions of articular movements were opposite. The luminance contrast of walker was 5, 10, 15, or 20 %. Subjects were asked to judge the direction of LB, but they were unaware that the articular movement of DB was opposite to the LB. They correctly perceived the direction of LB when the luminance contrast was strong. However, when the luminance contrast was weak, they perceived the direction of DB as LB direction in the front-walker condition. In the behind-walker condition, the perception of LB persisted. These results indicate that there is a common process of BM perception independent of whether luminance or disparity defines walker, and it processes only the objects perceived as in front.

53.423 Biological motion perception: Walker distance does not matter

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Human ability to perceive biological motion pattern is well established. Furthermore, it has been shown that observers' performances for detecting biological motion patterns in noise are worse when the walker pattern is inverted. The purpose of the present study was to determine if there is a difference between performances when biological motion patterns, in an upright and inverted orientation, are disposed at different distances in virtual space. To create our setup, we used a full immersive virtual reality environment (CAVE), giving the observers the experience of stereoscopic vision. We used a biological motion pattern composed of 13 dots, walking left or right on a treadmill. The size of the walker was 1.80 meters disposed at a virtual distance from the observer of 4, 8 and 16 meters subtending 24, 12 and 6 degrees of visual angle respectively. Using a staircase procedure, the observer's task was to identify the walker's direction (left or right) in upright and inverted conditions. The walker was presented in a scrambled mask, where the noise dot density was increased with two successive correct answers. The scrambled mask was generated by randomly selecting dots with biological motion patterns and repositioning them in 3D space. The results showed that distance does not influence performance. In other words, biological motion detection in noise, in upright and inverted conditions, does not depend on how far the walker is positioned in 3D space.

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53.424 Perceptions of an Animated Figure as a Function of Movement Naturalness: No Sign of the Uncanny Valley

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Much energy has been invested in the development of human-like robots and animated figures capable of socially interacting with humans. Mori (1971) suggested that as a robot becomes more human-like, observers will rate it with increasing familiarity until it reaches a point at which subtle differences from human-like appearance and movement produce a feeling of profound discomfort in the observer, an effect known as the Uncanny Valley. An alternative idea, based on theory of motor resonance, suggests that as the movements of a robot become more human-like, they resonate with our own motor representations and we will be more likely to consider them familiar. Here we used a computer generated figure animated with a walking movement captured from a human actor. Movement was varied in its naturalness across 10 levels by manipulating a) the joint articulation of the arms and legs; b) the phase relationship between opposing arms and legs; or c) increasing the magnitude of a short, physiologically implausible "jerk" at a random point in the walk cycle. Two groups of participants viewed either a mannequin (N=22) or a human-like figure (N=18) walking for 4s, then rated the walker according to humanness, familiarity, and eeriness. Ratings across all three movement manipulations and for both figure types increased (or decreased for eeriness) linearly as the movement became more natural, inconsistent with the Uncanny Valley hypothesis. Plots of familiarity and eeriness ratings as a function of humanness also showed a linear increase (or decrease) with no valley, even as humanness ratings approached the maximum possible rating. These findings are more consistent with the proposal that as a computer-generated figure's movements become more like the movement of a human, they produce increasingly greater feelings of familiarity. Resonance of the figures movements within the motor system of the observer may underlie such feelings.

53.425 **Critical temporal windows for natural point-light gender discrimination**

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There is a growing body of literature investigating point-light biological motion perception. Based solely on the kinematics of a handful of dots representing the body and major joints of a human actor, observers can extract complex information such as gender from point-light displays. Many previous studies have used artificially generated point-light animations to investigate critical features for gender discrimination (Cutting, 1978; Mather & Murdoch, 1994). Here we investigate the diagnostic cues for gender discrimination of natural point-light walkers using a technique similar to temporal "bubbles" (Thurman & Grossman, 2007), an adaptation of the "bubbles" technique (Gosselin & Schyns, 2001). We presented three full cycles of a point-light walker, randomly chosen from a set of 25 male and 25 female actors (Troje, 2002), while observers made forced-choice gender discriminations. On each trial, we removed a randomly chosen subset of frames from the animation and assessed performance as a function of frames present and absent. We reason that performance is best when a non-critical interval is removed, but declines when a critical interval is removed. Hence, our experiment identifies the temporal windows and diagnostic features that most often lead to a correct gender discrimination. Preliminary results suggest that hip sway, as reflected by the distance between the hip dots over time in the profile view, is a primary critical feature for discriminating gender in natural point-light displays. This result is consistent with previous studies using artificially generated point-light animations (Barclay et al., 1978; Cutting 1978). This interpretation is supported by the observation that male walkers in our data set with high levels of hip movement are consistently misclassified as female, and that females with low hip movement are typically misclassified as male.

53.426 **Action Invariance: An fMRI investigation of biological motion specificity in the STSp**

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Functional neuroimaging studies of the human superior temporal sulcus (STS) have established this brain region to be involved in the perception of biological motion (Grossman et al., 2000; Thompson et al., 2005), suggesting that this area is the human homologue of macaque STPa, a region with neurons tuned to specific body actions (Oram & Perrett, 1994). Integrated within these action-tuned neurons in monkey STS are individual cells that generalize across multiple viewpoints for the same action, forming a class of viewpoint-invariant, or 'action-invariant' neurons (e.g. Jellema & Perrett, 2006). In this study, we use the rapid fMR-adaptation paradigm to probe the tuning specificity of the human STS, specifically measuring the viewpoint-dependence of neural populations within this region. Methods. Subjects viewed pairs of point-light animations of human actors depicting the identical action, two different actions, or the same action mirror-reversed. Tuning for specific actions should be reflected by a reduced peak response for the repeated animations relative to the different actions (adaptation), while viewpoint invariance would be revealed by a reduced response to the left-right reversed animations compared to the different actions pairs. Results. Whole-brain general linear model analysis in individual subjects reveals clusters of action tuned responses (i.e. adaptation to repeated) and viewpoint-invariant responses (adaptation to left-right reversed pairs) on the STS, in and adjacent to the STS brain region localized with point-light animations. Conclusions. Regions of the human STS contain clusters of neurons that are viewpoint-invariant, much like those identified on monkey STS. These results are consistent with models of STS function as building abstracted representations of actions, which likely form the basis of some higher social functions such as perceived animacy and social understanding (e.g. Saxe et al., 2001; Martin & Weisberg, 2003).

53.427 **Biological Motion and Social Interaction Activate Distinct Regions of the STS**

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Neuroimaging studies have identified the posterior superior temporal sulcus (STSp) as the brain area active during perception of biological motion (i.e. Grossman & Blake, 2002; Beauchamp et al., 2002). The STSp has also been identified in tasks that require understanding of social interaction and animacy through interactive dynamics (Martin & Weisberg, 2003). The current study measures brain activity associated with these two types of tasks to determine whether the biological motion responses are associated with the same or a distinct brain area as social understanding. Method: The visual STSp was identified as the brain area that responds more during blocks of point-light animations of human actions as compared to blocks of motion-matched 'scrambled' animations (Grossman et. al, 2000). The social STSp was identified as the brain area more activated by simple geometric shapes interacting in a social manner (e.g. chasing, dancing, or playing) as compared to mechanical type animations (Martin & Weisberg, 2003). Results: As reported in the literature, both localizers identified regions on the STS. Within-subject analysis revealed these brain areas to be adjacent with distinct foci, with some partial, peripheral overlap in some subjects. In all cases the point-light localized STSp was more anterior than the social selective area. Functional patterns of neural activity in the visual STS area dissociated the social and mechanical animations, similar to the social region. The reverse was not true, however: neural activity in the social STS area did not discriminate between biological and scrambled animations. Conclusions: These results suggest that the cortical areas optimally driven by observing human actions are not the same as those driven by observation of social interaction. A more sophisticated understanding of STS cortical organization is required to parse out the complex patterns in this brain area.

Acknowledgement: We thank Alex Martin for the social interaction stimuli.

53.428 **Distinctive postural and dynamic features for bodily emotion expression**

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The visual system is able to extract from human movements subtle style information such as the expressed emotional state. There has been much interest in identifying the actual physical features supporting this perceptual ability. General level of movement activation is an important cue, but it does not support the distinction between, e.g., anger and happiness, two emotions sharing a similar level of activation.

We motion-captured the gait of 25 individuals who walked neutrally at different velocities, and who expressed different affects (anger, happiness, fear, sadness). By fitting kinematic models the average flexion angles were computed as a measure of body posture. Dynamic information was extracted from the joint-angle trajectories using a blind source separation algorithm that results in highly compact representations of the trajectories (Omlor & Giese, NIPS 2006). Movements were presented by animating 3-D avatar stimuli, used in a classification and an expressiveness-rating experiment.

The expressed emotion was recognised at rates between 70 and 90%. Anger and happiness, with high activation (fast and large movements), tended to be confused with each other, as did the less activated affects fear and sadness. These findings were in accordance with differences between these styles observed on the dynamic measures. In terms of body posture, arm flexion was a very expressive cue for both fear and anger, whereas happiness and sadness were associated with little mean limb flexion. Sadness and happiness could further be distinguished on the basis of head and spine inclination.

Our findings show that the perception of emotional body expression is driven by quantifiable characteristics of the movement trajectories. Whereas activation is a basic feature distinguishing body expressions of happiness and anger from those of fear and sadness, postural tension could be an additional feature that is suitable for discriminating between emotions falling at the same end of the activation dimension.

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53.429 **The local inversion effect in biological motion perception is acceleration-based**

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The ability to discriminate direction from spatially scrambled point-light displays relies on the orientation of the foot dot motions (Troje & Westhoff, 2006). We present two experiments that investigated this local motion-based inversion effect by testing direction discrimination from novel biological motion displays that exaggerate and display solely foot-specific information. In Experiment 1, we isolated the foot motion of a treadmill human walker, human runner, cat, and pigeon and presented observers (n = 20) with 1000 ms displays consisting of 10 copies of two foot dots that traced 150 ms segments at counterphase positions of the gait cycle. For each foot type, we derived left and right signalling displays from five such segment pairs that collectively sampled the entire gait cycle and presented them at both upright and inverted orientations. Direction discrimination accuracies varied with foot type, orientation, and segment pair. Significantly, the decrease in accuracies due to inversion was most substantial for the runner stimuli which exhibit the most pronounced vertical velocity changes and smallest for the cat stimuli which carry little vertical motion. In Experiment 2, a new group of observers (n = 20) were presented with the natural human walker stimuli of Experiment 1 and with stimuli that were spatiotemporally-matched to the natural stimuli but moved with constant velocities. Here, overall discrimination accuracies did not differ per foot type, decreased with inversion, and varied with segment pair. Critically, performances were higher for upright than for inverted displays for the natural stimuli only. Upright and inverted versions of the constant velocity stimuli did not differ. The results suggest that the local inversion effect in biological motion perception is carried by the velocity gradients of the foot motions. We conjecture that the visual system is sensitive to characteristic velocity changes exhibited by biological movements in a gravity-driven environment.

53.430 **Person identification across actions from biological motion**

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A significant amount of past research has studied person identification from point light displays of walking humans, investigating parameters such as viewing angle and the differential contributions of structural and kinematic information. However, little is known about the ability of human observers to generalize identity across different activities. In this study we use a same/different paradigm to compare observers' ability to identify point light displays within and across activities. We drew from a database of 100 motion-captured humans, each of which encompassed both walking and running activities. Subjects were shown successive paired stimuli and had to indicate whether the stimuli represented the same or different person. In either case, the two displays were at slightly different viewpoints. Two independent factors were examined: stimulus pairing (walker/walker, runner/runner, walker/runner) and information content (structural only, kinematic only, full information). For all information contents for stimulus pairing of matching activities (walker/walker, runner/runner) subjects performed significantly better than chance ($t(5)=2.71$, $p<0.05$ at worst). For different activities (walker/runner) subjects performed significantly better than chance for full information ($t(5)=3.85$, $p<0.02$), but not for kinematic only or structural only information ($p>0.05$). The main effect of Pairing was significant ($F(2, 30)=35.7$, $p<0.001$), with the walker/runner pairing being the most difficult. Information was not a significant factor. However, there was a significant interaction between Pairing and Information ($F(4, 30)=4.03$, $p<0.01$) that manifested in performance on the runner/runner task in particular being better for full information than for structural or kinematic only. Results are discussed in light of a principal components-based linear model that estimates a runner time series from a given walker time series by equating principal component coordinates.

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53.431 **A right-facing bias in the processing of biological motion?**

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Recently, Troje (2008; Troje & Westhoff, 2006) has suggested that the local motion contained in upright, scrambled biological motion displays can trigger a simple "life detection" mechanism. The goal of the present study was to further characterize this mechanism. In two experiments, we assessed participants' ability to make accurate direction-facing judgments about point-light displays presented very briefly in central vision. In both experiments, the walkers varied in terms of the amount of the configural information that was available in the displays, and with regard to their orientation (upright or inverted) and facing direction. In the first experiment (in which stimuli were unmasked) we found that heading could be discerned from upright, scrambled displays even with brief (170 ms) exposure durations. In the second experiment, we showed that local motion cues could support accurate heading judgments, regardless of the species depicted (human, cat or pigeon). In contrast, when viewers had to rely solely on global cues to make their heading judgments, their performance was disproportionately better with upright human displays. Exposure times in this experiment were 500 ms, and all stimuli were masked. Whether they had to rely on local or global cues to make their heading judgments, viewers in Experiment 2 (unlike those in Experiment 1) tended to show a bias to report seeing a right-facing walker. We speculate that the right-facing bias may be more apparent when longer exposure durations are used, or in situations where greater attentional resources are required (as is the case when a target must be disembedded from a mask). The right-facing bias is discussed in relation to the literature on attentional biases and specialized scanning habits associated with reading.

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53.432 **Perceptual biases expressed during observation of human movement**

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Perceptual biases in distance and length perception are influenced by the Horizontal-Vertical llusion, angles (Wolfe et al., 2004), and context (Proffitt, 2006). Of interest is the expression of these biases in human movement. In human movement, hand/arm movements provide a spatial context/referent for distance perception. Examined here are hand movement patterns that form angles, traverse different distances, and movement directions going towards or away from the body. Participants viewed two sets of bodies with hand/arm movements and indicated which set moved the greatest distance. Direction of hand movement was evaluated to determine the influence the body context on distance perception. Movement sets were either towards or away from the body, or a mixture of both. Movement distances varied from 0 (equal distances) to 40% differences to evaluate the sensitivity level for detecting differences in human movement distances. Distance perception was influenced by angles up to 180^o and horizontal-vertical movements. Movement direction was significantly modulated distance perception. Movement sets where both patterns were towards the body yielded the most accurate judgments. The least accurate judgments included a mixture of movement direction (towards the body vs away from the body, away from the body vs towards the body). A non-linear increase in accuracy was observed as percent movement distances increased. Most notable were the selective influence of movement angles, direction, and percent difference on distance perception. In sum, direction and pattern of movement modulates distance perception. The body's contextual information reduced distance perception errors when the two sets of movements were matched for direction.

53.433 Recognizing emotional states from biological motion within noise

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Perceiving the activities of other people is an important social skill of obvious survival value. Human vision has highly sensitive mechanisms for recognizing activities performed by others (Johansson, 1973). We previously showed that foveal and peripheral performance of biological motion detection within noise could not be equated by any magnitude of size scaling (Ikeda et al., 2005), suggesting that the resources for keen biological motion perception are concentrated on the central region of the visual field. Biological motion provides information not only for recognizing others' activities but also for inferring others' emotional states (Dittrich et al., 1996). In the present study, we examined whether a similar central limitation would be observed for the recognition of emotion from biological motion. Neutral and emotional (sad, angry, or happy) biological motion sequences were embedded in motion noise and presented successively (2AFC). Participants indicated which of the two intervals contained emotional biological motion. A staircase procedure varied the number of noise dots to produce a criterion level of performance. The poorer spatial resolution within the periphery was compensated by spatially magnified the entire stimulus. As in the previous detection task, foveal performance regularly increased with stimulus size until it reached the saturation level. Performance at the far most periphery (more than 8 deg) could not be equated by size scaling. The saturation level and the saturation size appeared to differ among different emotions. In addition, performance in the moderate eccentricity (e.g., 4 deg) showed inconsistent tendencies; for example, performance with some of emotional biological motion increased steadily with stimulus size, and in some cases, performance increased irregularly. These results indicate that the eccentricity dependency (and underlying processes) may differ, at least partially, between biological motion detection and emotion inferences from biological motion.

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Tuesday, May 13, 8:30 am - 12:30 pm Poster Session, Orchid Ballroom

Saccadic Eye Movements
Spatial Vision: Mechanisms 2

Saccadic Eye Movements

53.501 Saccadic Reaction Times and Speed of Information Processing Development

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Infants' speed of information processing (SIP) has typically been assessed by habituation and preferential looking paradigms (see Bornstein, 1998; Orlain & Rose, 1997). These kinds of tasks, however, are incongruent with how SIP is assessed with adult populations and differ from adult theories of SIP (Jensen, 2005; Smith, 1968). With adults, the manual reaction time (RT) to press a button (among several choice buttons) is usually taken as an index of SIP (Hick, 1952; Jensen, 1987). Consistently it has been found that manual RTs increase with the log2 of the number of choices, or bits of information, (Jensen, 1987) which has become known as Hick's law (Hick, 1952). Although infants cannot perform manual button responses, they can provide us with saccadic RTs. In the present study we measured 5- and 9-month-old infants' saccadic RTs to increasing bits of information in a visual choice RT task. Five-month-old infants' saccadic RTs increased with more bits of information in accordance with Hick's law. Nine-month-old infants' saccadic eye RTs did increase with more bits but not to the extent as the younger infants. Adults showed no increase in saccadic RTs with increased bits of information, which is consistent with past studies (e.g. Kverega, Boucher, & Hughes; Saslow, 1967). These data indicate that as infants age, and presumably as their SIP becomes faster, they are able to process more information per unit of time. Thus, there appears to be a developmental trend that occurs with measuring SIP through saccadic eye movements. By using this method of measuring SIP in infancy we are better able to make direct comparisons to the adult literature.

53.502 Saccadic gain adaptation follows perceived position

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The saccadic system maintains high accuracy by adaptation. In the laboratory, the amplitudes of saccades can be adapted by changing the position of the saccadic target during the saccade, using the double-step paradigm. Previous studies have shown that saccadic adaptation is mainly driven by the retinal position error and not by corrective saccades. Here we investigate if the physical position or the perceived position influences adaptation.

It is known that the position of a drifting sine-wave grating within a stationary Gaussian envelope is misperceived in the direction of motion. We made use of this visual illusion and a modified double-step paradigm to manipulate the perceived position of a saccade target without affecting its physical position. In each trial, subjects initially fixated the center of a stationary Gabor patch. The Gabor was composed by a 1 cpd, vertically oriented sine wave grating and a Gaussian envelope with a standard deviation of 0.5 deg. After a randomized delay, the Gabor patch stepped 5 deg rightwards. At the same time the sinusoid began to drift rightwards at a rate of 4 Hz. As soon as the subjects initiated a saccade to the new position of the Gabor, the sinusoid changed its motion direction and began to drift leftwards. This procedure corresponds to a backward step in a double-step paradigm, but influences solely the perceived position.

The results show a significant decrease of saccadic gain. This indicates that not only physical position errors but also perceived position errors can trigger saccadic adaptation. Furthermore it emphasizes that the perceptual illusion of misperceived position does affect the motor system.

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53.503 Optimality of saccadic decisions under risk

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It has been shown that humans have the ability to take into account the consequences of hand movements in an optimal fashion. Here we studied saccadic eye movements in a rapid fixation task that provided explicit rewards and penalties for the saccade endpoint. Subjects were instructed to make a saccade towards a color coded target region as quickly as possible while trying to avoid a nearby penalty region. Saccades into the target won points; saccades into the penalty could yield a loss. Subjects' task was to win as high a score as possible. Subjects' scores were compared to optimal scores which were calculated taking into account each observer's movement endpoint variability, similar to a recent model of optimal movement planning under risk. 3 paradigms ('gap', 'no gap' and 'overlap') which lead to different saccadic latencies were used. Results show that scores in the 'gap' experiment are poor in trials with the shortest latencies (120 ms – 140 ms) but improve significantly with longer latencies. In the 'no gap' experiment, latencies were on average 20 ms longer, in the 'overlap' experiment on average 55 ms longer than in the 'gap' experiment. However, scores at a given latency level remained largely unaffected by the experimental paradigm. This shows that planning of the saccade does not interfere with other processes that occur before the eye starts moving, e.g. disengaging fixation. We conclude that, with additional time of about 40 ms - 100 ms for processing, saccades can be planned and executed optimally in some conditions. This is in line with the idea that processing of reward related information - which is believed to be encoded in area LIP - takes additional time. This time does not seem to be available in trials with very short latencies.

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53.504 Saccadic adaptation: reinforcement can drive motor adaptation

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Does saccadic gain adaptation, often described as a simple form of learning, have much in common with other forms of learning, in particular those guided by reinforcement? We investigated whether

saccade adaptation could be guided by reinforcement if no retinal error existed. To eliminate retinal error, we either had the target vanish when the saccade started, or we placed the target on the fovea at the end of the saccade. To reinforce small saccades, we had subjects make saccades to targets 14 deg away, with an auditory signal after those saccades with amplitudes in the lower 35% of the previous 50 saccades. This auditory reinforcement caused a progressive decrease in saccade amplitude, much as in conventional saccade gain adaptation in which we displaced the target during saccades so that the fovea landed beyond the target. Alternatively, we used the reappearance of the target at the fovea after the saccade as the reinforcement, providing it only on the smaller saccades, as above. This too caused a progressive decrease in saccade amplitude. When we discontinued the auditory reinforcement of small saccades and instead reinforced those saccades with amplitudes in the highest 35% of the past 50 saccades, saccade gain returned to normal in most subjects, although in one subject the gain remained low, until we restored the retinal error by having the target reappear at its original location.

We interpret the altering of saccade gain by differential reinforcement as suggesting that normal saccade adaptation may also be driven by reinforcement rather than only by average retinal error. More specifically, our finding that presenting the target on the fovea can act as a reinforcement suggests that normal saccade adaptation might be driven simply by the reinforcing value of those saccades that fall closer to the target.

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53.505 Adaptation of saccadic eye movements: behavioural evidence for different mechanisms controlling saccade amplitude lengthening and shortening

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Ocular saccades are fast and accurate movements of both eyes. Saccade accuracy can be maintained throughout life by adaptation mechanisms despite physiological or pathological alterations of the sensorimotor system. This study was aimed at testing whether these saccadic adaptation mechanisms involve changes in the sensory and/or motor stages of sensorimotor transformation. We used the double-step target paradigm to adapt reactive saccades directed to the right. Leftward (backward condition) and rightward (forward condition) intrasaccadic target steps were used to, respectively, decrease and increase saccade amplitude in different subjects groups. In each condition, we measured the effects of these adaptive changes of pro-saccades amplitude on anti-saccades (saccades directed to the opposite direction of a target). In the backward condition, all 8 tested subjects showed a statistically significant decrease of the amplitude of their rightward pro-saccades (-17.3 ±1.9% on average). A group analysis showed a significant transfer of adaptation to rightward ("motor") anti-saccades (average gain change = -18.4 ±2.8%), but not to leftward ("sensory") anti-saccades (+3.6 ±4.8%). In the forward condition, only 8 of the 12 tested subjects showed a significant adaptive increase of the amplitude of their rightward pro-saccades (+11.5 ±2.1% on average). Moreover, the group analysis performed in these 8 adapted subjects did not reveal any transfer of adaptation to "motor" and "sensory" anti-saccades (+4.7 ±4% and +2.3 ±4.8%). Control experiments achieved in two further groups of 15 and 10 subjects rejected the contribution of unspecific factors (e.g. fatigue …) in this pattern of results, and duplicated these results for the other direction (leftward) of trained saccades. These findings suggest that, whereas the level of involvement of forward adaptation cannot be resolved, the mechanisms involved in the backward adaptation of reactive saccades 1) take place at a motor level, and 2) clearly differ from those involved in the forward adaptation.

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53.506 Adaptation of saccadic eye movements: neurological evidence for different mechanisms controlling the amplitude of reactive and voluntary saccades

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How the central nervous system generates accurate motor behaviour across the life span is a fundamental issue in Neuroscience. Sensory-motor adaptation processes play a central role, and yet their underlying neural substrates and task-specificity bases are still poorly understood. We addressed these issues here by studying adaptation of saccadic eye movements, a well-established model of sensorimotor plasticity. The cerebellum plays a major role in saccadic adaptation but it has not yet been investigated whether this role can account for the known specificity of adaptation to the saccade type (e.g. reactive versus voluntary). In this study, we used the double-step target paradigm to measure the adaptive abilities in 9 neurological patients at a chronic stage after a stroke affecting different cerebellar and/or pre-cerebellar areas. Each patient was tested during two separate sessions, for reactive saccades (RS) triggered by the sudden appearance of a visual target, and scanning voluntary saccades (VS) performed when exploring a more complex scene. The results revealed that 6 out of 9 patients showed a deficit in saccadic adaptation: 2 patients for RS, 3 for VS and one patient for both RS and VS. Thus, a dissociation of adaptive abilities between reactive and voluntary saccades was seen in 5 subjects, suggesting the involvement of separate cerebellar modules for the two saccade types. The deficit mostly concerned ipsilesional saccades rather than controlesional saccades. These findings extend for the first time the demonstrated role of the cerebellum in RS adaptation to adaptation of VS and hence suggest a cerebellar involvement in task-switching processes for oculomotor plasticity. They are consistent with our recent proposal that the adaptive update of saccadic commands involves both a brainstem site common for RS and VS and partially separated areas in the cerebellum specific to the reactive or voluntary task (Alahyane et al., Brain Res., 2007).

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53.507 Saccadic gain adaptation can depend on the visual context

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When the brain is led to believe that the saccades it is generating are too large (by having a target step back while the eye is in flight), saccade amplitude gradually decreases, an adaptation widely seen as a simple form of motor learning, possibly driven by an effort to correct motor error. Not surprisingly according to this view, Deubel (1994) found that if only one of two alternately presented targets (distinct in both color and form) stepped back, adaptation was identical for both targets. Using a somewhat amended paradigm, we find differential adaptation to two visually distinct targets.

Subjects were presented with a target that either blinked at 5 Hz or was continuously illuminated; after 0.7-1.2 sec, it stepped horizontally by 9-11 deg. Throughout each experiment, only one target-type (blinking or steady) stepped back by 30% during the subject's saccade. The two targets were presented in blocks of 3-10 trials for 425 trials, and were subsequently interleaved randomly for 80 trials.

Saccades to whichever target stepped back (the adapting target) had smaller amplitudes than those made to the other target, both during the alternating blocks (0.85 vs 0.92 gain) and during the interleaved target presentation (0.82 vs. 0.91 gain). When the target type switched, the gain of the first saccade was 0.1 lower to the adapting target and 0.085 higher to the non-adapting target. The difference in gain between the targets did not exist when only one target was present during an adaptation session, except for occasional probe-trials in which the other target was present but vanished upon saccade onset.

We conclude that saccade adaptation, like many other forms of learning, can be associated with a visual context. This implies that the learning is not restricted to the motoric domain.

53.508 **Previous saccades to other locations affect the programming of current antisaccade coordinates, but not those of prosaccades**

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Studies of the contextual effects of prior probability on saccades show latency changes when subjects make saccades to one of only two high-probability locations, compared to blocks with many locations. However, in this study we asked, does a second target location in the same block influence saccadic accuracy?

We had subjects perform antisaccades in blocks containing two equally probable target locations, all at 8.5° eccentricity. In all blocks one target location was on the horizontal meridian. In half of the blocks, this was paired with a target above the meridian, while in the other half it was paired with a target below the meridian. We explored the effects of proximity by varying the directional angle of the second target from the horizontal meridian (20°, 40°, 60° or 80°) in different blocks. Last, we included two blocks of prosaccades, one with above- and one with below-meridian second targets with a directional angle of 20°.

We analyzed the vertical and horizontal coordinates of saccadic endpoints to the horizontal-meridian target as a function of 1) the location (above or below the meridian) of the second target, and 2) the directional angle of the second saccadic goal.

While prosaccades were not influenced by the location of the second target, antisaccades were significantly displaced towards the second target. This effect on antisaccades was greater the closer the second target was to the first target.

These findings show that targets at other locations in prior trials can cause antisaccade goal coordinates to shift in the current trial. This new context effect can be modeled as the effects of summation between neural activity at current goal coordinates and reduced but persistent activity at the second location.

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53.509 **Reactive Saccades Dynamics: Visual Integration and Visual Context**

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To foveate a visual target, subjects usually execute a primary hypometric saccade (S1) bringing the target in perifoveal vision followed by a corrective saccade (S2). However, in some subjects, saccade behaviour is characterized by the execution of more than one S2. Are these S2 pre-programmed or do they only depend on post-saccadic retinal error? To answer this question, we examined the saccade behaviour of 6 subjects by varying the timing of visual target presentation and by modifying the visual background.

Subjects were instructed to perform saccades towards one out of three visual targets. In 20% of the trials, the target was slightly displaced at S1 onset (so-called double step paradigm, used to force the saccadic system to unconsciously integrate a new target position) and was maintained until the end of S1 ('Brief'), until the start of the first S2 ('Medium'), or until the last S2 completion ('Long'). In the remaining 80% trials, the target location was unchanged ('Fixed'). Experiments took place either in a complete dark room (Dark condition) or in a dimly lit room with an added random dots background (Background condition). Detailed saccadic parameters of S1 and S2 were analysed offline.

Results showed that S2 performance was less accurate for Brief and Medium targets conditions, suggesting that the duration of visual integration is a main factor responsible for corrective saccade accuracy. Surprisingly, although S2 accuracy decreased in the Background condition compared to the Dark condition, S1 accuracy had an opposite effect. Finally, the Fixed target condition showed a remarkable effect: as compared to the Dark condition, the Background condition decreased saccade latencies but kept the same accuracy, and the number of S2 decreased in hypometric subjects. The role of attention and the post-saccadic processing of visual information are discussed.

53.510 **Visuomotor set can suppress the inhibitory influence of distractors on express saccades**

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Express saccades are movements of extremely short-latency (80-110ms). Despite their reflexive nature, recent work in our lab has shown that express "averaging" saccades elicited by two closely-spaced stimuli can be influenced by an instruction issued prior to stimulus appearance (Edelman et al, 2007). Previous work has also shown that when two stimuli are presented with a large directional difference, the production of express saccades decreases (Chou et al, 1999). Here we examine whether a high-level instruction (visuomotor set) can rapidly resolve the competition of two far-apart stimuli, allowing an express saccade to proceed. Subjects performed a 150-200 ms gap task in which two bright squares (1° x 1°) appeared, one 8° eccentric and positioned at a random direction 0, or +/- 60° away from the right horizontal meridian, and the other at equivalent positions to the left. Subjects were instructed to make a saccade to the stimulus ("target") in the hemifield indicated by a central fixation arrow and to ignore the contralateral "distractor." Subjects also performed a task in which no distractor appeared. EMs were recorded (Eyelink II) in two subjects at 500 Hz. Both subjects were "express saccade makers." Surprisingly, the presence of the distractor increased reaction times by only 11 ms. Saccades virtually always landed on the desired target. We also found that: 1) narrowing the focus of the visuomotor set by positioning stimuli closer to the horizontal meridian reduced the distractor effect, 2) express saccades could occur with high frequency even without a visuomotor set, and 3) the distractor effect was large only when two stimuli were presented unexpectedly in the uncued hemifield. This evidence suggests that high-level processes are sufficient, but not always necessary, to suppress distractor-related transient visual activity to an extent sufficient for express saccade generation.

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53.511 **Luminance And Saccadic Supression On Perisaccadic Spatial Distortions**

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Visual direction of foveal targets flashed just prior to the onset of a saccade is misperceived as shifted in the direction of the eye movement. We examined the effects of luminance level and temporal interactions on the amplitude of these perisaccadic spatial distortions (PSDs). PSDs for single-flashed stimuli were larger with low than high luminance levels, and there was a reduction of PSDs for low luminance targets flashed immediately before the saccade. PSDs for two sequential pre-saccadic flashes (ISI = 50 ms) differed from predictions based on a single-flash: PSD was increased for the first flash and reduced for the second.Paradoxically, when the two pre-saccadic flashes were presented near the saccade onset, the earlier flash was distorted more than the later flash, even though the later flash occurred closer in time to the saccade.

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53.512 **Spatio-temporal topography of saccadic suppression**

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Visual perception is modulated during saccadic eye movements. Contrast thresholds for the detection of luminant visual stimuli are significantly increased briefly before, during and after saccades. Previous studies measured the temporal evolution of this suppression but did not investigate any position dependency. Accordingly, in our current study we explored the contrast threshold for visual stimuli presented during saccades at different positions in the visual field.

Eye movements were recorded in human subjects with an infrared eye tracker (EyeLink 2, SR-Research) running at 500 Hz. Visual stimuli were presented on a CRT monitor or on a large tangent screen in front of the subjects who initially fixated a target left from the center on the horizontal meridian. 500 to 1000 ms after trial onset, the fixation target was switched off and a saccade target appeared right from the vertical meridian. Visual stimuli were presented perisaccadically for 10ms at different positions in the visual field.

The detection rate of stimuli was reduced during saccades as compared to steady fixation. However, this reduction was not constant across space but increased with retinal eccentricity. Also the time of peak saccadic suppression turned out to be a function of stimulus position within the visual field. Maximum suppression occurred earlier at and near the saccade target as compared to regions at and around the initial fixation target.

We developed a numerical model to get a better insight into the underlying neural processes. In essence, our model combines previously described psychophysical data on retinal contrast sensitivity and perisaccadic shifts of attention. Based on our model data we conclude that visual perception is perisaccadically suppressed at a global scale. The observed spatio-temporal topography of saccadic suppression most likely results from the eye movement dependent stimulus eccentricity and additional attentional effects.

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53.513 **Perisaccadic visual compression shown by target-flash mislocalization may be affected by flash visual persistence interacting with background stimuli**

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Perisaccadic target-flash mislocalization can vary according to where the flash is presented, e.g., a flash occurring near the saccade starting point tends to be mislocalized in the direction of the saccade, whereas a flash occurring beyond the saccade end point tends to be mislocalized in the opposite direction. Such findings have been interpreted as reflecting a compression of visual space. Different studies, however, show differences in the time course of the compression. For example, the studies by Honda (1993) and Atwater & Lappe (2006) show maximum compression just after the saccade, whereas the study by Morrone, Ross & Burr (1997) shows maximum compression around the onset of the saccade. Recently, I proposed a model suggesting that some of the main characteristics of compression arise from an extraretinal signal whose onset time varies systematically across the retina (Pola, VSS 2007). One feature of the model is that the perceived location of a flash comes from flash retinal signal persistence interacting with the extraretinal signal (Pola, 2004). Another is that the perceived location of one flash can be influenced by the perceived location of a second flash by way of persistence, especially if the time interval between the two flashes is less than the duration of the persistence (Pola, 2007). In the present work, this model is used to provide an account of differences in compression from one study to another: The main features of compression may come from the way in which the extraretinal signal varies across the retina (see above). However, some of the differences in compression may be a consequence of different background stimuli, where perceived flash location is affected by persistence interacting with these stimuli. Taking into account background stimuli and re-plotting data, a number of differences between the studies are markedly reduced.

53.514 **A visual target in the blind hemifield of hemidecorticate patients reduces latency and improves accuracy of antisaccades**

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It is thought that the phenomenon of blindsight in hemidecorticate patients requires the superior colliculus (SC), which appears viable after a hemispherectomy. Using a task that maximally solicits the SC, we investigated whether an unseen target in the blind hemifield can alter the timing/ amplitude of an ongoing antisaccade in a hemidecorticate patient. Each trial began with a central fixation point that was extinguished, followed by a brief (86ms) light spot (cue) in the seeing hemifield. The patient was required to make a saccade away from the cue to its mirror location (antisaccade). The cue was presented either alone, or was accompanied by a flashed probe (86ms) at the cue's mirror location in the blind hemifield. The probe was presented simultaneously with the cue, or after random delays of 86ms, 136ms, or 186ms. We found that for delays of 86ms and greater there was a significant reduction in the latencies of antisaccades. A reduction in the error of the antisaccade was found, which was most pronounced at delays of 136ms and 186ms. At these delays the error was reduced by half relative to the no-probe condition. A recent study showed a correlation between behavioral choice and an ipsi-lesional neural activity in the SC of monkeys' with V1 lesions (Yoshida et al., 2007). Thus, our findings suggest that the presentation of a light stimulus at the goal position, after a cue has already been presented, increases neuronal activity in the ipsi-lesional SC which adds to preparatory motor activity and drives the firing frequency over the threshold necessary for saccade generation to the probe position.

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53.515 **Cortical Contributions to Saccadic Suppression**

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Saccadic suppression is the perceptual suppression of visual stimuli during or just before rapid eye movements. How, or even where in the brain this perceptual suppression takes place is not clear. One common viewpoint, however, is that that saccadic suppression originates in the Lateral Geniculate Nucleus (LGN). This study uses behavioral methods to show that at least part of the mechanism must be of cortical origin.

We flashed sinusoidal gratings just before an eye movement and compared their 80% detection thresholds to those obtained during fixation. The critical manipulation was to change the background luminance in the visual hemifield opposite to that where the stimulus appeared. It has been shown before that background luminance affects the amount of saccadic suppression. Our data, however, showed that increasing the background luminance in the left hemifield increased the suppression of the target in the right hemifield.

Since each LGN receives information exclusively from one of the visual fields, this change in suppression can only be due to cortical processing. We conclude that at least part of the processing that takes place to suppress peri-saccadic stimuli must take place in the cortex.

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53.516 **Objective characterization of square-wave jerks in progressive supranuclear palsy patients and healthy volunteers**

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The eyes do not stay perfectly still during visual fixation. Fixational eye movements and saccadic intrusions continuously change the position of the gaze. Here we focus on the most common type of saccadic intrusion: square-wave jerks (SWJs). SWJs are characterized by one small horizontal saccadic movement that moves the eye away from the fixation target, followed by a corrective saccade towards the target shortly thereafter. SWJs are prevalent in some neurological diseases such as progressive supranuclear palsy (PSP). However, they are also common in normal subjects. We developed an objective algorithm to automatically identify SWJs in PSP patients and normal subjects, during visual fixation of a small target. Our results show that SWJs are common in both PSP patients and normals. However, SWJ rates and magnitudes are larger in the PSP group. Thus the objective characterization of SWJs may provide a powerful new tool in the differential diagnosis of oculomotor disease.

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URL: http://smc.neuralcorrelate.com/

53.517 **Older adults just can't look away: Age-related changes in saccadic trajectory curvature**

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There is considerable evidence that the ability to inhibit irrelevant information declines as people grow older. In the present research we investigated whether such an inhibitory deficit extends to the systems responsible for the control of saccadic eye movements. Participants made saccades to a visual target that appeared concurrently with a distractor, and saccadic latencies and trajectories were recorded. Consistent with earlier findings, younger adult's early-onset saccades curved towards the distractor (as the distractor competed with the target for response selection) while late-onset saccades curved away from the distractor (as the distractor location became inhibited over time). In contrast, older adults' saccades always curved towards the distractor, indicating they were unable to inhibit the distractor in the same manner as the younger adults. This demonstrates that, as people age, they lose the ability to prevent their eyes from being drawn to irrelevant visual distractors. As the location of gaze plays a dominant role in determining what information in the visual field is processed, this finding has important implications for changes in the efficiency of visual processing with age.

53.518 **Influence of Relative Saccade Direction on Detection of Transsaccadic Natural Scene Transitions**

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Saccadic eye movements are rapid shifts of gaze that direct the fovea, from one point of interest to another. On each saccade, the entire scene streams across the retina at hundreds of degrees per second. However, this streaming is not apparent, due to a reduced visual sensitivity toward motion during saccades.

We have observed that when scenes translate transsaccadically (during saccades) they are perceived as moving slower than equivalent sized intersaccadic transitions. We confirmed these findings using a magnitude estimation technique (Sadr, Allison & Vinnikov, ECVP 2007).

We further explored the dependence of transsaccadic motion perception on the direction of shift in a 4AFC experiment. We examined the effect of different scene transitions relative to saccade directions both horizontally and vertically, and subjects had to indicate direction of the scene transitions if detected. Subjects sequentially fixated blinking fixation points (20o apart) indicated on each image based on horizontal or vertical saccade direction conditions.

We conclude that during saccades, the magnitude of the velocity signal is attenuated as well as its detectability. Furthermore, the extent of saccadic suppression depends on the relative saccade direction and the direction of scene transition.

53.519 **Fitts's Law and the optimal planning of sequences of saccades**

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Speed/accuracy tradeoffs in motor tasks obey Fitts's Law, which states that movement time depends on distance and the required level of precision. We investigated whether Fitts's Law applies to sequences of saccades.

Saccades were made in sequence to 4 target circles (diameter 15′-180′) located at the corners of an imaginary square (corner separation 90′-360′). Following convention, Fitts's "index of difficulty" (ID) was defined as Log2 (2S/D), where S=separation; D=diameter.

The time to complete the sequences increased with ID, showing that Fitts's Law can apply to sequences of saccades. For small targets and large separations, the latency of the primary saccade was short and corrective saccades were frequent. For larger targets and smaller separations, the latency of the primary saccade increased, and corrective saccades were rare.

These patterns suggest that saccadic planning takes the expected variability of landing positions into account. When landing variability is large relative to required precision (small targets; large eccentricities), short-latency primary saccades are followed by secondary saccades to correct errors. When variability is small relative to required precision (large targets; small eccentricities), a single, longer latency primary saccade is sufficient. Meyer et al. (1988) observed comparable results for a manual task and proposed that planning reflects a compromise between latency and precision to achieve optimal performance.

Conclusions: (1) The applicability of Fitts's Law shows that transformations to visual arrays that do not alter the ID (such as changes in viewing distance) will not affect the time to perform the saccadic sequence. This ties scanning time to the properties of the scene itself. (2) Saccadic reaction time and the occurrence of corrective saccades are typically attributed to structural aspects of the stimulus or task. Our results suggest that saccadic timing and corrections are the result of strategies designed to achieve required accuracy in the shortest time.

53.520 **The Which and the Where of eye movement control**

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We have previously shown that, when deciding which of two target locations to fixate, the only visual information used is the initial 60-100ms after the stimulus is presented (Ludwig et al., 2005). This is true despite the optimal strategy being to continue accumulating evidence until the target has been chosen. In this study, using fixations to Gaussian blobs that are spatially rather than luminance jittered, we instead investigate the temporal properties of the system that decides where to fixate. Here instead of finding a single, stimulus onset locked system, we find strong evidence for two separate systems being involved in the decision over where to fixate. The first has essentially identical properties to the system that decide which location to look at: it is locked to the stimulus onset, and has an impulse response of about 65ms. The second and more important system, integrates, not relative to the stimulus onset, but to information around 135msec before the saccade is made. Using a second Posner type pre-cuing experiment, we found an effect of the pre-cue on the stimulus onset based system, but not on the saccade locked system. We interpret this pattern of results in terms of a two stage process of eye movement control: firstly, a high level system decides which the general region of interest is. Only after this decision is made, is a fast, low level system used to choose exactly where within this region to fixate. We identify the first mechanism with information passing through the Basal ganglia, and the second with more direct information coming to the superior colliculus via V1 and MT.

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Spatial Vision: Mechanisms 2

53.521 **Size and shape-frequency after-effects: same or different mechanism?**

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Aim. The size, or luminance spatial frequency after-effect (LFAE) is the phenomenon in which adaptation to a luminance grating of given spatial frequency causes a shift in the perceived spatial frequency of a grating away from that of the adapting grating (Blakemore & Sutton, 1969, Science, 166, 245-7).The analogous shape-frequency after-effect (or SFAE) is the phenomenon in which adaptation to a sine-wave-shaped contour causes a shift in the apparent shape-frequency of a test contour away from that of the adapting stimulus (Gheorghiu & Kingdom, 2007, Vis.Res., 47, 834-44). It is widely believed that the LFAE is mediated by luminance-spatial-frequency-selective channels, while it has been suggested that the SFAE is mediated by curvature-selective channels. However it is possible that the SFAE is mediated by the same mechanism as underlies the LFAE, in spite of the fact that the stimuli involved have little Fourier energy in common. Methods. We measured both SFAEs and LFAEs using a conventional staircase procedure. The contour-shape stimuli were sine-wave-shaped contours and edges; luminance stimuli were sine-wave, square-wave and line luminance gratings. The rationale was that if the after-effects were reduced when adaptor and test stimuli were of a different class (shape versus luminance), this suggested that the SFAE and LFAE were mediated by different mechanisms. Results. While similar-sized after-effects were found for same-class adaptor-and-test stimuli (either shape or luminance), the after-effects were greatly reduced for different-class adaptor-and-test stimuli (shape adaptors and luminance tests, or vice-versa). Conclusion. SFAEs are mediated by different mechanisms to the LFAE.

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53.522 **An after-effect of perceived length**

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Aim. Both single-unit recording studies in V1 and psychophysical studies have revealed orientation-selective mechanisms whose length selectivity is partially separable from their width or spatial frequency selectivity. This suggests that length might be a spatial dimension coded early in vision. If so, one would expect line length to be adaptable, with adaptation producing shifts in the perceived length of subsequently presented lines. Method.

Subjects adapted to horizontal d.c.-balanced lines of various lengths, presented either singly or in grids. After adaptation, the perceived length of horizontal test lines that were either shorter or longer than the adaptors was measured using a conventional staircase procedure. To test whether any after-effect of perceived length was a manifestation of the well-known size or spatial-frequency after-effect, we also used vertically-oriented square-wave grating adaptors whose bars were equal in width to the length of the adaptor lines. Results. Adaptation to line length made shorter lines appear shorter and longer lines appear longer, analogous to the repulsion effects found with other spatial dimensions such as orientation and spatial frequency. With square-wave grating adaptors however, the after-effect was much smaller. Conclusion. Line length is an adaptable dimension and the resulting line-length after-effect is not simply a manifestation of the size or spatial-frequency after-effect. Line length appears to be a spatial dimension that is likely coded through the population response of neurons tuned to similar widths but different lengths.

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53.523 **Asymmetrical Adaptation to Highpass versus Lowpass Filtered Images**

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After adapting to high-pass filtered (sharpened) images, subsequent images appear to be blurred. Similarly, after looking to low-pass filtered (blurred) images, subsequent images appear sharpened. Until now these two effects were assumed to reflect a response change in the same underlying mechanism. We investigated the characteristics of the adaptation curves as a function of adapting stimuli. Methods: The procedures were modified from Webster et al (2002). Observers adapted (initial 30s, top-up 3sec) to images that were digitally blurred or sharpened by varying the slope of the spatial spectrum up to ±0.50 relative to the natural slope. Observers were asked to decide whether a briefly presented (500ms) test image was perceived "too blurred or too sharp compared to what you think is normal". Twenty seven observers were tested to determine the point of subjective neutrality (PSN – the spectral slope of the image that appears normal). Observers adapted to at least one scene at a minimum of 7 adaptation levels. The PSN for each adaptation level was used to compute individual adaptation curves. Results: Adaptation curves were characterized by the slope of the sigmoid fitted curves (representing the gain of adaptation) and the asymptotes (saturation levels). All observers showed repeatable adaptation effects. Inter-observer variability in the gain of adaptation was found. In addition, within-observer differences were found in the saturation levels to low-pass and high-pass filtered images; some observers showed less adaptation (or even none) to blur than to sharp or vice versa. Conclusions: Adaptation to blurred and sharpened images varies among individuals. Asymmetry between adaptation to blurred and sharpened images suggest a different process for each of these phenomena previously considered parallel.

53.524 **Efficient Adaptive Measurement and Classification of Contrast Sensitivity Functions**

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Purpose. The contrast sensitivity function (CSF), describing observer's grating sensitivity as a function of spatial frequency1, is a canonical measure of spatial vision. Clinically, a number of visual neuro-pathologies exhibit characteristic CSF deficits2. The cards/charts currently used for clinical testing, though easy to use, limit the sampling range and grain of grating contrast and spatial frequency, and therefore limit test precision.We sought to develop adaptive testing methods that (1) estimate CSFs with the precision of psychophysical testing and short testing time of cards/charts, and (2) classify CSFs into pathological categories based on candidate CSFs with very short testing time. Method. Describing the CSF with a simple functional form5, the quick CSF (qCSF) method searches one-step-ahead for the stimulus contrast and spatial frequency minimizing the expected entropy3-5 of the posterior jointly defined over four parameters: (1) peak sensitivity, (2) peak spatial frequency, (3) bandwidth at half-peak sensitivity, and (4) low spatial frequency truncation. In an orientation discrimination task, observers ran the qCSF concurrently with an adaptive method3 estimating thresholds independently at 6 spatial frequencies. Each of four sessions provided two qCSF estimates and one conventional CSF estimate. For adaptive classification4, candidates included one normal CSF, one CSF with general-deficit, and three CSFs with low, middle and high frequency-specific deficits. Stimulus placement minimized the expected entropy for the probability of class membership. Results. In agreement with simulations, psychophysical results validated that CSFs obtained with 30, 50, and 100 qCSF trials agree with conventional CSF estimates: (mean r=.944, .960, and .976). Classification simulations showed that detecting abnormal CSFs typically took less than 10 trials and classifying specific abnormal CSFs took 20-30 trials. These adaptive Bayesian methods, generating efficient and precise CSF estimates, have clear implications for laboratory and clinical applications.

1.Campbell & Robson(1968)
2.Regan(1993)
3.Kontsevich, and Tyler (1999)
4.Cobo-Lewis(1996).
5.Lesmes et-al(2006)
6.Watson and Ahumada(2005)

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URL: lobes.usc.edu/qMethods

53.525 **Diverse Long Range Configural Judgments Use a Single Map of Object Locations**

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Purpose. To test whether configural judgments across large distances in visual space share a common, abstract representation of object locations. Method. Let T be a perceptual task with dependent variable v (e.g., percent correct in a 2AFC judgment) in which performance is limited by the salience of targets on a background, and let S1, S2,…, SN be stimulus properties (e.g., brightness, darkness, greenness, etc.) that can be used to define targets and adjusted in intensity to control performance in task T. Then for any level pof performance in T let QT(p) be the N-dimensional vector whose kth component is the intensity of Pk that yields performance p in task T. The range of QT (i.e., the locus of N-dimensional vectors visited by QT) is called the task T equisalience curve for S1, S2,…, SN. If two tasks share the same equisalience curve for a set of properties, this supports the hypothesis that they are informed by a single, shared representation. We used stimuli comprising widely separated (all by at least 10 deg.) texture-defined discs on a textured background. Discs were defined by being either brighter, darker, greener, higher in contrast variance or lower in contrast variance than the background. Equisalience curves were measured for (1) three different configural tasks, requiring judgments about the relative locations of three discs, and (2) a task in which the observer judged which of three (widely separated) discs was different in size from the other two. Results. The equisalience curves for the three configural tasks were identical (within measurement error) but differed significantly from that for the size-judgment task. Conclusion. These results support the idea that long range judgments of spatial configuration make use of a shared, abstract map of object locations.

53.526 **Non-Euclidean Visual Traveling Salesman Problem**

Yll Haxhimusa[1] (yll@psych.purdue.edu), Zygmunt Pizlo[1], Joseph Catrambone[1]; [1]Psychological Sciences, Purdue University

Traveling Salesman Problem (TSP) is defined as the task of finding the shortest tour of N cities given intercity costs. Usually the intercity costs are 2D Euclidean distances. In the presence of obstacles or in the case of 3D surfaces, the intercity distances are in general not Euclidean. The TSP with obstacles and on 3D surfaces approximates our everyday visual navigation. There are three questions related to the mechanisms involved in solving TSP: (i) how do subjects find the intercity distances, (ii) how do they determine clusters of cities, and (ii) how do they produce the TSP tour. In our model, the non-Euclidean distances (geodesics) are found by using a non-linear Eikonal equation, i.e. the evolution of interfaces (Sethian, 1999). The geodesic distances are then used as intercity costs in an MST graph pyramid (Haxhimusa et. al., 2007). The original TSP problem is represented by a sequence of problems involving clusters of cities. The hierarchical clustering is performed by using a Boruvka's minimum spanning tree. Close to the top of the pyramid, the original TSP problem is represented at a very coarse level and involves very small number of "cities". This coarse representation is solved optimally. Expanding this coarse tour in a top-down manner leads to a solution of the original TSP. The new model has an adaptive spatial structure and it simulates visual acuity and visual attention. The model solves the TSP problem sequentially, by moving its attention from city to city. The model's performance will be compared to the performance of human subjects.

Acknowledgement: AFOSR

53.527 **Visual sensitivity to achromatic gradients with different luminance profiles**

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Gradients (smooth spatial variations in luminance and/or chromaticity) are all around us as shading or other illumination phenomena. They provide cues to light-source positions, object shape and the spatial layout of scenes. However, not much is known about how the visual system processes gradients. We measured detection and discrimination thresholds for horizontal achromatic gradients.

The gradient stimuli had a fixed size (4°). Its horizontal luminance profile was either linear or sinusoidal and was generated such that its mean luminance was constant and equiluminous with the surround (56 cd/m2). Only its contrast varied from trial to trial. We used a temporal 2-AFC with a QUEST procedure to determine contrast thresholds for four observers in detection and discrimination experiments.

In the detection experiment, the background was either uniform (UB) or non-uniform (NUB; mosaic-squares of different luminance). Detection thresholds for gradients against UB and those for a step stimulus of a control study (against UB or NUB) were all identical. However, detection thresholds for gradients against NUB were on average 4 times higher, indicating that NUB effectively disrupts the edge cue at the boundaries of the gradients. Thresholds for sinusoidal gradients were significantly lower than for linear gradients.

In the discrimination experiment, two conditions were tested using only NUB; observers indicated which interval contained a gradient that was stronger (or weaker) than a reference gradient of fixed contrast. Observers performed better in the stronger condition by an average factor of 2. For this condition, thresholds for sinusoidal compared to linear gradients were lower by a factor of 2.

The differences in thresholds found between sinusoidal and linear gradients suggest that the visual system uses the information within the gradient for detecting or discriminating it. The asymmetry found between discrimination conditions implies that increments and decrements might be processed differently.

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53.528 **Psychophysically defined gain control pool and summing circuit bandwidths for orientation selective pathways**

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The Olzak-Thomas (1999) model of spatial vision proposes an initial stage of weighted linear filters followed by a stage of nonlinearities and then a stage of specialized higher-level summing circuits. Among the nonlinearities is a contrast gain control mechanism that pools the output of the first stage over different orientations and/or spatial frequencies. One of the summing circuits is specialized to signal orientation information. It is broadband with respect to spatial frequency but more narrowly tuned to orientation. We measured the orientation bandwidth of the contrast gain control pool and summing circuits associated with orientation judgments. To determine the bandwidth of the contrast gain control pool, orientation discrimination performance for vertical 3 (or 15) cpd luminance gratings was measured for the grating alone and in the presence of a 15 (or 3) cpd mask, as a function of mask orientation. Two-cue stimuli were used to measure the bandwidth of higher-order orientation summing circuit. Two-cue stimuli were initially composed of two near-vertical gratings of widely different spatial frequency, each presenting a cue to discrimination. They could vary together in one condition (i.e., both left vs. both right), or could vary in opposition. Superiority in performance in the varying-together condition (configural effect) indicates the operation of a summing circuit. The presence of a configural effect was measured as a function of the base orientation of the second component (the first was always varied around vertical). Our results show that for nearly all observers, the masking effect slowly decreases until the orientation of mask reaches 80 degrees, where it disappears. The configural effect disappears abruptly when the orientation of the second cue reaches 4 degrees off vertical.. These results indicate that the gain control pool is widely tuned with respect to orientation, while the higher level summing circuit is quite narrowly tuned.

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53.529 **Representation of Mean Spatial Frequency**

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Statistical properties of visual arrays can be used as summary representation of a complex scene. Current study investigated how we summarized various spatial frequencies (SF) and whether the visual system could be adapted to this summary. In Experiment 1, we investigated how we perceived different SFs using the magnitude estimation procedure. The magnitude of perceived SF followed a power function with an exponent of 1.13. In Experiment 2, participants were asked to estimate the mean SF of two different gratings. For the two different gratings, five pairs of different spatial frequencies were used (1-4, 1.5-6, 2-8, 2.5-10, 3-12 cpd). The estimated mean SFs based on the psychometric function found in Experiment 1 were a good approximation of participants' estimates of mean SF. These results suggest that mean SF is calculated on psychological scale. In Experiment 3, we first measured the contrast threshold for each participant using QUEST. We then had participants adapt to either two gratings with different SFs (separated by 2 octaves) or one of the two gratings. When participants were adapted to the two gratings, the two adaptors were intermittently presented for 4 minutes and they took turns in every 2 seconds. The adaptor was presented for 2 minutes when they were adapted to one of the two gratings. To maintain adaptation, we used 4-second top-up. The contrast threshold of mean SF was significantly elevated when the participants were adapted to the two gratings, whereas it was not elevated when they were adapted to only one of the two gratings. When we measured the contrast threshold using the same gratings as the adaptors rather than mean-SF grating, the contrast threshold was significantly elevated. Our findings suggest that the visual system represents mean SF as well as individual SFs.

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53.530 **Mega surround suppression: a synergy between target pedestal and surround mask**

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When a target in the periphery is displayed next to a matching mask, contrast sensitivity is suppressed, producing elevated contrast increment thresholds. This surround suppression is strong only when the mask is located close to the target and, literally, surrounds it (Petrov & McKee, 2006). For example, a mask of the same size as the target produces negligible suppression unless juxtaposed with the target, even in this case the suppression is weak (Petrov, Popple, & McKee, 2007). The target in the present study was a uniform luminance disk displayed on a gray background 10 deg to the left and right of fixation. From trial-to trial, observers were asked to identify which location contained an incremental change in contrast. A mask (50 % contrast disk of the same size as the target) was presented in both locations 5 deg inward of the target; it was displayed for the same duration as the contrast increment (8 - 150 msec). We found that for brief durations (<30 msec) surround suppression was amplified five-fold if the contrast increment lagged the target pedestal onset by 100 - 1000 msec. For latencies shorter than 100 msec the increment fused perceptually with the pedestal onset, and the suppression amplification effect promptly disappeared. For longer latencies the effect became less pronounced. The effect grew with the pedestal contrast, but saturated above 20%. We found similar results for Gabor targets and masks. Surprisingly, we found no significant effect of mask orientation on suppression strength. Conventional surround suppression disappears if mask and target orientations differ by more than 45 deg (Petrov, Carandini, & McKee, 2006). To summarize, we observed a new powerful type of surround suppression arising, apparently due to some form of synergy between pedestal masking and surround masking.

53.531 **Comparison of pupil responses to the first and second order gratings**

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Background: Small, transient constrictions of the pupil are elicited by the onset of basic visual attributes such as colour, motion and luminance-defined gratings, as well as more complex stimuli such as faces. Evidence for cortical origins of such responses rely on attenuated responses measured after focal cortical lesions. We aimed to (a) establish whether similar responses are elicited by the onset of second order gratings; (b) in view of similarities/differences in psychophysical properties and neuronal processing of first and second order gratings, establish the similarities/differences in pupil responses as a function of spatial frequency, contrast and retinal eccentricity.

Method: Gabor patches (spatial standard deviation, SSD = 2.5°; limited to ±2xSSD) with temporal smoothing (temporal standard deviation, TSD= 250ms; duration 4xTSD) were presented at a range of carrier frequencies, contrasts and eccentricities. Each block of testing contained randomly interleaved first and second order carriers. Pupil responses were measured in normal observers (n=6) using a modified ASL pupillometer and were analysed using P_trace software.

Results/conclusions: We have demonstrated the existence of significant transient pupil constrictions elicited by the onset of second order gratings. The response amplitude to foveally presented first and second order gratings (2 cycles/°) varied monotonically with increasing grating contrast. Similar to previous reports, we showed that the pupil response amplitude to first order gratings varied systematically with spatial frequency within the range of frequencies tested (0.5-4.0 cycles/°). However, the second order gratings lacked similar frequency tuning properties. The shift to lower spatial frequencies for the peak pupil response to first order gratings as a function of retinal eccentricity mirrors that of the contrast sensitivity function. On the other hand, for second order gratings, there was only a general attenuation of response amplitude without a relative eccentricity dependent shift in peak sensitivity.

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53.532 **Time course of motion-induced shifts in perceived position**

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The perceived position of briefly presented visual stimuli can be markedly affected by nearby motion signals. Here we investigate the effective temporal window of this interaction by measuring shifts in the perceived position of stimuli presented at various times before, during and after a fixed period of motion. Observers were required to judge the vertical alignment of two target patches (1-dimensional Gaussian blobs; width= 1 deg; $\sigma_{vertical}$ = 0.33 deg; horizontal separation = 5 deg; duration = 20ms) presented adjacent to two vertical strips of sinusoidal grating (1 cycle/deg, width = 1 deg, height = 25.6 deg, separation = 1 deg) that drifted in opposing directions (up/down) at 5 deg/s. Results reveal a consistent and distinctive time course for periods of inducing motion ranging from 2 to 8 seconds. Perceived position begins to be pulled in the direction of motion for target onsets 100-200ms prior to the commencement of motion. This positional shift increases in magnitude as a function of temporal proximity, reaching maximum where target and motion onset are synchronous. Thereafter, the effect reduces by ~50% over the next 800ms, then remains constant for the majority of target onsets spanning the period of motion. Near the offset of motion, the magnitude of positional shifts dissipates to zero over a period of ~500ms and positional shifts in the opposite (aftereffect) direction are observed. This pattern of results is incompatible with existing accounts, which posit that shifts in perceived position reflect the simple accrual of motion signals over a fixed temporal interval.

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53.533 **Are Shifting, Splitting, and Scaling of Attention Similar Processes?**

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Background: The focus of visual attention can be distributed in at least three different ways:

(1) shifting to one location (Posner, Snyder, & Davidson, 1980), (2) splitting between non-contiguous locations (Kramer & Hahn, 1995), or (3) scaling attention over a large or small area (Eriksen & St James, 1986). While some evidence suggests that the type of distribution influences task performance (McMains & Somers, 2005), it is unknown how performance changes as a function of (a) time required for cue effectiveness (i.e. SOA) or (b) type of distribution. Based on previous research, we hypothesized that the optimal cue facilitation time is similar for shifting and splitting attention (Kramer & Hahn, 1995), but slower for scaling (Greenwood & Parasuraman, 2004). The hypothesis was tested by varying cue-target SOAs. Method: A modified Awh & Pashler (2000) paradigm was used: a location precue to a target digit in a search array of distractor letters. Conditions were: no-cue (control), one cue (shifting), two non-contiguous cues (splitting), three contiguous cues (scaling) with a range of SOAs from 50 to 200 ms. All cues were valid in predicting target location. Following the presentation of the cue(s) a target array was displayed. Following array offset, participants made unspeeded responses about the presence of the target digit. Accuracy of target response was analyzed as a function of SOA and cue type. Results and Conclusions: For all distribution conditions (except control) accuracy increased with time. In addition, splitting and shifting developed faster (and in a time course consistent with the shifting literature) than scaling. Although splitting may not occur if distractors are absent (Awh & Pashler, 2000), this finding suggests that in the presence of distractors there may be more processing overlap between splitting and shifting than between either and scaling.

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53.534 **Visual Performance and Glare: Spatial properties of visual obscuration**

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Purpose: The aim of this study was to investigate the relationship between the size of a glare image on the retina and the ability to detect a visual stimulus in and around the glare field. For this, we measured the ability to detect a Gabor patch stimulus through glare from 532 nm laser illumination.

Methods: A three-channel standard Maxwellian-view optical system was employed. One channel projected the extended-source laser images; a second channel projected the standard laser image; and the third channel projected the background and Gabor patch, which were presented on a LCD monitor. The laser glare stimulus size ranged from a standard point source to an 8^{o} extended-source field, and the angle between the laser glare and Gabor patch stimuli was from central, or 0^{o} aspect, to 5^{o} off-aspect angle. The mean luminance of the monitor was 100 cd·m^{-2}, and the contrast of the Gabor patch stimuli was 60%.

Results: The extended-source images proved to be much more effective at obscuring the Gabor targets than the standard, point-source laser. In cases where the extended-source laser covered the Gabor patch, at least 1.5 log units less retinal irradiance was necessary to obscure the target, compared to the point-source laser. Additionally, as the extended-source laser stimulus size increased, progressively less retinal irradiance was needed to obscure targets "under" the laser. This suggests a spatial summation effect for obscuration by glare.

Conclusions: Glare effectiveness increases with the size of the glare image, and, for large sources, spatial summation effects contribute to this increased effectiveness.

53.535 **Precorrecting visual objects destined for defocus**

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Spectacles correct visual defocus by altering the light coming from an object to the eye. Another approach is to alter the object O itself, replacing it with an object O´ whose defocused image is a perfect copy of O. This is sometimes physically possible, but not always. E.g., suppose a defocused eye converts objects of the form 1 + m cos fx into images of the form 1 – .1 m cos fx (i.e., defocus reduces contrast at frequency f by the factor 0.1 and also causes a phase reversal.) To create a perfect image of the object 1 + .1 cos fx (m = .1), substitute the precorrected object 1 - 1.0 cos fx. Then the defocused image is 1 - .1(-1.0) cos fx = 1 + .1 cos fx, so precorrection works. But if m = .2, the necessary precorrected object 1 - .2/.1 cos fx cannot be physically constructed because it is not nonnegative. A general theory of precorrecting objects for defocus can be developed using the tools of Fourier optics. Its main conclusion is that spectral precorrection can greatly improve the recognizability of severely defocused images (by eliminating shape-distorting phase reversals), but post-defocus contrast is inevitably low: no precorrection operation can make the total contrast energy of a defocused image exceed the contrast energy of the defocusing pointspread function. Put another way, precorrecting for defocus can only preserve the contrast of objects that are already low-contrast to begin with—objects whose Fourier spectrum is the product of the optical transfer function of the out-of-focus eye times the spectrum of some other object. Such objects have, in effect, already been defocused once, and precorrection can only save them from being defocused twice.

53.536 **Resolving inconsistencies between parametric estimates of psychometric functions by nonparametric fitting**

Kamila Żychaluk[1] (kamila.zychaluk@manchester.ac.uk), David H. Foster[1]; [1]School of Electrical and Electronic Engineering, University of Manchester

Traditionally, experimentalists assume that the psychometric function underlying a given set of stimulus-response data has a standard shape, i.e. that it belongs to a class of so-called parametric model functions such as Gaussian or Weibull functions. Once the model is chosen, its parameters are adjusted for best fit to the data. In practice, however, the correct model is rarely known. A consequence of this uncertainty is that the fit may be biased, leading to incorrect inferences such as the estimated threshold stimulus level for a particular criterion probability of response. Goodness-of-fit measures can be used to identify badly fitting psychometric functions but these measures are not always helpful in deciding which parametric model should be used. The problems of parametric models are illustrated by an experiment in which a subject had to detect a sinusoidal grating of varying orientation and contrast in a two-alternative forced-choice task. Different parametric models were fitted, including the logistic, Gaussian, Weibull, and reverse Weibull functions, and all gave acceptable fits as measured by the deviance. But the estimated thresholds for 75%-correct performance for each model were very different, sometimes exceeding 10% of the stimulus range tested. With closely similar deviances, fit itself could not be used to decide which curve, and therefore which threshold, should be taken as the final estimate. Instead, it is argued here that a nonparametric method offers a more consistent and neutral approach. The model curve is estimated by adjusting for best fit locally over neighbourhoods defined along the stimulus range. The results are much less dependent on the chosen model, freeing the analysis, and estimated thresholds, from arbitrary model choices.

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53.537 **The neural correlates of the 3-dot vernier task: visuospatial extrapolation examined within the framework of a duplex model of vision**

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Since the discovery of orientation-specific receptive fields in the occipital cortex some 40 years ago, much progress has been made in elucidating the mechanisms of contour processing. However, many of the studies to date have focused on the role of relatively short-range local interactions between orientation-tuned filters. In contrast, little is known about how information is integrated across spatially disparate regions of the visual field in the absence of explicit local orientation cues. To examine this process, referred to here as visuospatial extrapolation, a block functional magnetic resonance imaging (fMRI) design was employed in which observers performed a version of the three-dot vernier task using Gabor patches. The replacement of the dots with Gabor patches meant that an identical stimulus set could be used to perform a simultaneous orientation discrimination: a suitable control task that involves visuospatial processing without the need for extrapolation across space. The data were consistent with ventral stream activity during the extrapolation task, with task-specific activations being largely restricted to foci within the lateral occipital complex (LOC), an area implicated in the process of form perception and object recognition. In contrast, the orientation discrimination task led to activations in caudal regions of the intraparietal sulcus (IPS), an area characterised by sensitivity to surface orientation and object rotations. Viewed within the framework of the duplex model of vision, these results do not support a simple dissociation of the ventral and dorsal streams for perception and action respectively. Instead, they contribute to a growing body of evidence that suggests a subset of purely perceptual tasks activate a network of cortical foci that incorporate both dorsal and ventral stream regions.

53.538 **Effects of reference frame on the perception of human-body orientation in infancy**

Aki Tsuruhara[1] (aki.tsuruhara@gmail.com), So Kanazawa[2], Masami Yamaguchi[1,3]; [1]Chuo University, [2]Shukutoku University, [3]PRESTO, JST

We investigated the effects of reference frame on the perception of stimulus orientation in infancy. The human-body figure was used as the stimulus, because the human-body is an ecologically important stimulus. This result was compared with the results of previous studies using a grating as the stimulus (Jouen, 1985; Tsuruhara et al. 2007).

We used the preferential looking technique. The stimuli were vertical and oblique human-body silhouette. The infants' looking times for each stimulus were measured. In Experiment 1, only human-body figures were presented. In Experiment 2, each human-body figure was surrounded by a vertical square, and in Experiment 3, the surrounding square was oblique. Additionally, control experiments were conducted. In the control experiments, the stimuli in each experiments were inverted. These inverted human-body figures didn't seem to be human-bodies.

The results showed that, in Experiment 2 and 3, the results using the human-body figure were similar to the previous results using a grating stimulus. Vertical surrounding squares induced the preference to the oblique human-body figure and the grating over the vertical human-body figure and the grating. Oblique surrounding squares induced no preference. In the control experiments, the inverted human-body figure produced the same results.

On the other hand, in Experiment 1, the results using the human-body figure differed from the previous results using a grating stimulus. Previous studies showed that infants preferred the vertical grating over the oblique grating. By contrast, in our experiment, infants preferred the oblique human-body figure over the vertical human-body figure. In the control experiments, the inverted human-body figure produced no preference.

The results of this study suggest that, in infancy, the perception of human-body orientation differs from the perception of grating orientation, although the reference frame have the similar effects on these two stimuli.

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53.539 **Percept dependent acitivity in the occipitotemporal cortex for Ebbinghaus illusion**

Ansgar Koene[1] (arkoene@ntu.edu.tw), Yu-Chin Huang[1], Chien-Chung Chen[1]; [1]Psychology Department, National Taiwan University

Early visual areas encode visual information in retinotopic coordinates, signaling retinotopic size and orientation properties. Distance and orientation invariant object recognition however requires stimulus processing based on relative stimulus dimensions (e.g. relative lengths and orientation of edges with respect to each other) independent of absolute retinotopic size or orientation.

Here we used event-related fMRI to measure BOLD response to a variant of the Ebbinghaus illusion to test where visual information processing starts to encode relative, opposed to retinotopic, sizes. The stimulus consisted of a white test disk superimposed on a background texture of overlapping disks whose size was smaller, equal or larger than the test disk. Visibility of the individual inducer disks was achieved through the use of different gray levels. We chose this variant of the Ebbinghaus illusion to avoid BOLD response differences due to changes in the retinotopic area stimulated by the inducers.

Perceived size was determined using a 2-interval-forced-choice design. A comparison disk of variable size was presented for 400ms in one hemi-field then after a 100ms blank period the Ebbinghaus stimulus was presented for 600ms with the test disk in the other hemi-field. Psychophysical comparison with the traditional Ebbinghaus illusion showed that the strength of the illusion in our variant was comparable.

Comparison of BOLD response across conditions (equal sized vs. small inducers; equal sized vs. large inducers; small vs. large inducers) revealed illusion related activity in the intraoccipital sulcus (IOS), the middle temporal gyrus and the temporal pole. The IOS and the posterior middle temporal activation may relate to depth judgment suggesting that the Ebbinghaus illusion is related to textural depth cues. The temporal pole activation may relate to categorical object processing. Our result is consistent with the notion that the Ebbinghaus illusion results from depth judgment.

Tuesday, May 13, 2:30 - 4:00 pm
Talk Session, Vista Ballroom

Visual Pathways: Receptors to Cortex

Moderator: Adam Reeves

2:30 pm

54.11 Early scotopic dark adaptation; change in noise alone?

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Just after turning off a steady adaptation field, the log threshold for a large, 1.3 deg, rod-mediated test flashes abruptly drops from the Weberian increment threshold curve half-way down to absolute threshold, before the leisurely process of dark adaptation begins (Reeves & Grayhem, VSS 2007). The abrupt drop parallels that seen in photopic vision and is due, we argued, to the removal of photon-driven (square-root) noise consequent on shutting off the adaptation field (Krauskopf & Reeves, Vision Research 20, 193-196). Method We now test the same idea with a tiny, 5 min arc, 200 ms rod-detected test seen in Maxwellian view, for which the increment threshold curve follows the Rose-DeVries square-root law. Result: Thresholds dropped abruptly from the square-root law right to the absolute threshold, as predicted by the removal of photon-driven noise from the field. Conclusions: photon noise from the field always drives up threshold following the square-root law. Light adaptation additionally reduces sensitivity by saturating responses to large scotopic tests in a manner also proportional to the square-root of field intensity, the combined effect giving rise to Weberian behavior. Tiny rod tests escape saturation and reveal the photon-driven noise effect alone.

URL: http://www.atsweb.neu.edu/psychology/a.reeves/WEBSITE

2:45 pm

54.12 The S-cone luminance input depends on the level of M-cone adaptation

Caterina Ripamonti[1] (c.ripamonti@ucl.ac.uk), Elizabeth Crowther[1], Andrew Stockman[1]; [1]Institute of Ophthalmology, University College London

When the S-cone signal is enhanced by intense long-wavelength chromatic adaptation, the S-cones can make a small, but significant contribution to luminance, as defined by heterochromatic flicker photometry or motion detection. Here, we investigate how the S-cone contribution to flicker photometry depends on changes either in the chromaticity or in the intensity of the adapting background. We use alternating luminance-equated tritanopic metamers in order to maintain S-cone isolation as the intensity of the adapting background is decreased (or when no background is present), and try to measure flicker photometric nulls between S-cone and L- or M-cone flickering lights by adjusting both the relative modulation and the relative phase of the two stimuli. Our results are surprising. First, we find that the same S-cone stimulus that makes a clear contribution to flicker photometry in the presence of a long-wavelength adapting background makes no measureable contribution to luminance when the background is removed. Second, we find that flicker-photometric nulls are possible between S-cone and M- and L-cone signals on backgrounds longer and equal in wavelength to 543 nm, but only if the backgrounds exceed a criterion radiance. Remarkably, these criterion radiances closely follow an M-cone spectral sensitivity. Thus, the S-cone luminance input is apparently silent unless the M-cones are also excited above a certain level. Our results suggest that the S-cone luminance signal is somehow gated by M-cone signals, a finding that is reminiscent of the silent chromatic surrounds suggested by Ingling and his co-workers.

Acknowledgement: Fight for Sight, BBSRC

3:00 pm

54.13 LGN abnormalities in human amblyopes revealed by high-field fMRI

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Aims. To compare the responsiveness of the LGN (lateral geniculate nucleus) when driven by the fixing and fellow amblyopic eye in a group of adult amblyopes. Methods. MR images were acquired on a 4T Bruker MedSpec scanner using a TR of 1.5sec. A binocular localizer was used to establish an ROI for the left and right LGN for each of 5 amblyopic observers. Stimuli were flickering (8Hz) coloured checkerboards that were presented in a block design alternating between the stimulus and a blank of zero luminance. LGN activation driven by fixing and fellow amblyopic eyes was compared. Results. Clear interocular response differences were observed in all five amblyopic subjects with stronger responses (peak and integrated response activity) coming from the fixing eye. Across our sample of amblyopes there was a significantly weaker response from the amblyopic eye for 9 out of the 10 LGNs. Conclusions. There is an amblyopic eye processing deficit at the level of the LGN. A previous VBM study (Barnes et al, HBM 2006 abst.) suggested a significant correlation between the functional deficit in the cortex and LGN structure in human amblyopes. Here we show that LGN function, when driven by the amblyopic eye, is anomalous.

Acknowledgement: CIHR grant to RFH (#MOP-53346) and a Welsey Research Institute Grant.

3:15 pm

54.14 Identification of optic radiation in-vivo using diffusion tensor imaging and fiber tractography

Anthony Sherbondy[1] (sherbond@stanford.edu), Robert Dougherty[2], Brian Wandell[2]; [1]Electrical Engineering, Stanford University, [2]Psychology, Stanford University

Purpose. Measuring the properties of the white matter pathways from retina to cortex in the living human brain will have many uses for understanding visual performance and disabilities. We use diffusion-weighted magnetic resonance imaging (DWI) and a novel fiber tractography method, ConTrack, to identify the optic radiation (OR) in the living human brain. We illustrate the use of this method for an important clinical application: identifying the Meyer's loop portion of the optic radiation prior to temporal lobe resection for intractable epilepsy.

Methods. DWI data was acquired using a single-shot echo-planar sequence and two b-values, b = 0 and b = 800 s/mm2 along 6 diffusion weighted directions, in a 1.5T GE Signa LX scanner. In eight subjects ConTrack was used to identify the most likely pathway between a sub-volume covering the entire lateral geniculate nucleus (LGN) and a sagittal plane lateral and adjacent to V1.

Results. The most anterior position of the OR pathways was located with respect to multiple landmarks (Figure 1). The location of the anterior tip of the OR and other parameters match the range estimated from dissection results (Table 1); these dissections are used as the gold-standard (Ebeling, 1988).

Discussion. The incidence of visual field defects caused by anterior temporal lobectomies is reported to be from 50% to 100% of those postoperatively assessed with kinetic perimetry (Krolak-Salmon, 2000). The high percentage of vision loss in these procedures is attributed to large individual variability in the course of the anterior projections or Meyer's loop. Previous DTI-FT estimates of the OR miss major portions of the Meyer's loop and underestimate the most anterior position of this visual pathway (Yamamoto, 2005; Miller, 2005). The ConTrack DTI-FT algorithm locates the OR at a distribution of positions that match the estimates obtained using dissection method.

URL: http://graphics.stanford.edu/~sherbond/vss/vss08_487_figures.htm

3:30 pm

54.15 **Topography of responses to colour and luminance in human subcortical visual pathways as revealed by high-resolution fMRI at 7T**

Marcus Grueschow[1,2,3] (m.grueschow@gmx.net), Jochem Rieger[3], Jörg Stadler[4], Claus Tempelmann[3], Hans-Jochen Heinze[3], Oliver Speck[5], John-Dylan Haynes[1,2]; [1]Max Planck Institute for Cognitive and Brain Sciences, Leipzig, Germany, [2]Bernstein Center for Computational Neuroscience, Berlin, Germany, [3]Dept. of Neurology II, Otto-von-Guericke University, Magdeburg, Germany, [4]Non-Invasive Imaging Lab, Leibniz-Institut for Neurobiology, Magdeburg, Germany, [5] Dept. of Biomedical Magnetic Resonance, Institute for Experimental Physics, Magdeburg, Germany

Chromatic signals, are transmitted to cortex via the lateral geniculate nucleus (LGN) and potentially also via the superior colliculus. The latter has not been studied to date in humans using cone-contrast controlled stimuli. Here we investigated the BOLD-responses in these sub-cortical regions using various cone-contrast levels. We measured sixteen axial slices covering cortical, tegmental, and thalamic regions on a Siemens 7T MR-scanner (inplane-resolution 1.38x1.38mm, slice-thickness 1.5mm, TR=1s). Visual stimuli were hemifield-checkerboards (18deg) containing a central fixation marker. Two directions in cone contrast space were used with four contrast levels each (L-M: 1.75%,3.5%,7%, and 14%; L+M: 7%,14%,28% and 56%). Although hemodynamic response amplitudes were substantially lower in subcortical regions than in V1 it was possible to record reliable signals from SC and LGN. Responses to colour and luminance stimuli in V1, LGN and also the superior colliculus increased monotonically with cone contrast. Luminance contrast sensitivity was highest in the SC. At 7% cone contrast V1 and LGN responded stronger to color-opponent stimuli while the SC preferred luminance stimuli. At 14% cone-contrast, we measured approximately equal BOLD-responses to colour and luminance in all three regions, also in SC. This provides evidence for color-opponent properties in the SC. The shape of the BOLD response differed substantially across the ROIs, possibly indicating different adaptation properties of the underlying neurons. In addition, the gain of luminance responses was sufficient to separate magno- and parvo-cellular subdivisions of the LGN. Thus, ultra-high-field fMRI may serve as a valuable tool to study fine-grained topographies of subcortical visual processing non-invasively in the human brain.

3:45 pm

54.16 **Time course of cortical responses to illusory and real lightness changes**

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Using fMRI with short repetition times (TR = 227 ms), we measured the time course of BOLD signals in response to illusory and real lightness changes in human early visual cortex.

The illusory stimulus was composed of a background and foreground region. The background consisted of four horizontally arranged, contiguous, gray rectangular bands. The rightmost and leftmost bands (the “flanks”) had the same luminance. One of the central bands was lighter and the other darker than the flanks. The foreground consisted of two narrow vertical bars positioned to hide the two vertical luminance edges, one between each central band and its bordering flank. In this configuration the background is seen as a planar surface with the flank closer to the lighter central band appearing lighter, and the flank closer to the darker central band appearing darker. When the contrast of the two central bands is reversed, the apparent lightness of the flanks reverses. We constructed a “real stimulus” identical to the illusory stimulus except that the two flanks differed in luminance, psychophysically matched to the illusory difference. In the fMRI experiment attention was controlled through a demanding fixation task.

We analyzed the BOLD signal within independently determined ROIs corresponding to small regions within the flanks of the stimuli far from any edges (1.6 x 1.6 deg at ±8 deg from the central fixation mark). We found that the peak cortical activity to illusory lightness change in V1 was significantly delayed by as much as 1 second compared to that of a real change. We psychophysically compared the critical flicker rate at which the illusory and real flanks no longer appeared to change in lightness. The rate for the illusory stimulus was significantly longer than that for the real stimulus, consistent with the lag found in the V1 BOLD signal.

Acknowledgement: his work was supported by NIH grant EY015261. The 3T scanner at the University of Minnesota, Center for Magnetic Resonance Research is supported by BTRR P41 008079 and by the MIND Institute. Partial support has been provided by the Center for Cognitive Sciences, University of Minnesota.

Tuesday, May 13, 2:30 - 4:00 pm
Talk Session, Royal Palm Ballroom 4-5

Face Perception: Emotion and Experience

Moderator: Frederic Gosselin

2:30 pm

54.21 **What does the activity in the amygdala and the insula correlate with in fearful and disgusted faces**

Zakia Hammal[1] (zakia_hammal@yahoo.fr), Nao Tsuchiya[2], Ralph Adolphs[2], Martin Arguin[1], Philippe Schyns[3], Frédéric Gosselin[1]; [1]Département de Psychologie, Université de Montréal, [2]Division of Humanities and Social Sciences and Division of Biology, California Institute of Technology, [3]Department of Psychology, University of Glasgow

It has already been demonstrated that the amygdala plays an important role in the processing of fear (Adolphs et al., 1994, 1995; Broks et al., 1998; Calder et al., 1996) and the insula, in the processing of disgust (Hennenlotter et al., 2004, Sprengelmeyer et al., 1998, Calder et al., 2000, Wicker et al., 2003).

There is some-temporally sluggish-evidence that the amygdala is involved in the processing of high-spatial frequency eye information (Whalen et al., 2005; Adolphs et al. 2005). However, little is known about what the insula might respond to in disgusted faces. Here, we used the Bubbles technique (Gosselin & Schyns, 2001) with intracranial electroencephalography (EEG) to shed new light on these issues.

Patient DA, who was undergoing intracranial clinical monitoring for epilepsy, was shown 21,600 stimuli that varied in their emotional content while EEG was being recorded from chronic depth electrodes (four contacts in the right amygdala and four in the right insula). On each trial, one of four faces (fearful and disgusted man and woman from Eckman & Friesen, 1976, set) was sampled by randomly located Gaussian apertures (Gosselin & Schyns, 2001). We performed multiple linear regression on the location of the information samples and wavelet coefficients of the electroencephalographic activity for every electrode contact and emotion category (Chauvin et al., 2005; Smith et al., 2006).

Fear classification images show the eyes region, especially the eye on the ipsilateral side of the image as early as 200 ms after stimulus onset in some of the amygdala contacts. Disgust classification images show the nose region, especially the nasolabial ferrows as early as 60 ms after stimulus onset in some of the insula contacts. This confirms the hypothesis that the amygdalas and the insula participate to the processing of the facial expression of fear and disgust (Smith et al., 2005).

2:45 pm

54.22 **Decoding Frequency and Timing of Emotion Perception from Direct Intracranial Recordings in the Human Brain**

Naotsugu Tsuchiya[1] (naotsu@klab.caltech.edu), Hiroto Kawasaki[2], Matthew Howard[2], Ralph Adolphs[1]; [1]Humanities and Social Sciences, California Institute of Technology, [2]Department of Neurosurgery, University of Iowa

How do regions of higher-order visual cortex represent information about emotions in facial expressions? This question has received considerable interest from fMRI, lesion, and electrophysiological studies. The most influential model of face processing argues that static aspects of a face, such as its identity, are encoded primarily in ventral temporal regions while dynamic information, such as emotional expression, depends on lateral and superior temporal sulcus and gyrus. However, supporting evidence comes mainly from clinical observation and fMRI, both of which lack temporal resolution for information flow. Recently, an alternative theory has been proposed which suggests that common initial processing for both aspects occurs in the ventral temporal cortex. To test these competing hypotheses, we studied electrophysiological responses in 9 awake human patients undergoing epilepsy monitoring, in whom over 120 sub-dural electrode contacts were implanted in ventral temporal (including fusiform face area, FFA) and lateral temporal (including superior temporal sulcus, STS) cortex. The patients viewed static and dynamic facial expressions of emotion while they performed either a gender discrimination or an emotion discrimination task.

We used a novel decoding method that quantified the information about the facial stimulus that is available from the time-varying neuronal oscillation in the field potential. We estimated the stimulus-induced oscillation from a time-frequency spectral analysis using a multi-taper method. This time-frequency representation of the response was then subjected to a multivariate decoding analysis.

Our analysis revealed that ventral temporal cortex rapidly categorizes faces from non-face objects within 100ms. We found that ventral temporal cortex represents emotion in dynamic morphing faces more quickly and accurately than lateral temporal cortex. Finally we found that the quality of represented information in ventral temporal cortex is substantially modulated by task-relevant attention.

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3:00 pm

54.23 **Classification Maps: An information-theoretic technique for relating cortical activity to stimulus information in a facial expression categorization task**

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The categorization of facial expressions has been shown to be associated with a lateral-occipital negativity in the ERP record at around 170 ms following stimulus onset (N170). It has been suggested that this negativity reflects processing in a region of the lateral-occipital cortex known as the Fusiform Face Area (FFA). Using both source reconstruction and classification image techniques, in combination with an information-theoretic framework, we propose a new method to relate the cortical electrical activity over the FFA region to the stimulus information that is used to solve the classification problem, where the stimuli on each trial are corrupted by random noise in the form of Gaussian apertures or “Bubbles”.

For each voxel in our source reconstructed cortical region of interest we produce a classification image, correlating the uncertainty in our noisy stimulus to the uncertainty in our cortical signal. For each stimulus pixel we then have a distribution of correlations over voxels at each time point following stimulus onset. The entropy of this distribution then tells us, for that pixel and that time, how “spatially informative” the cortical signal is. Furthermore, the mutual information between these distributions at different times tells us the extent to which they correspond to temporally stable “classification maps”.

We first found that the pixels with the highest spatial information at the time of the N170 correspond to the regions of the stimulus involved in correct classification performance (e.g. the mouth for “happy”, the eye for “fear”). Furthermore, we found that the classification maps associated with these pixels formed clear clusters of high and low correlation whose mutual information was stable over time. We therefore propose that the spatio-temporal activity pattern over the FFA reflects a task-oriented classification process which can only be found by examining the information-theoretic properties of its distribution.

3:15 pm

54.24 **The Effect of Homeomorphic Image Transformations on Face Matching Performance**

Danelle A. Wilbraham[1] (wilbraham.1@osu.edu), James C. Christensen[1], James T. Todd[1], Aleix M. Martinez[2]; [1]Department of Psychology, Ohio State University, [2]Department of Electrical and Computer Engineering, Ohio State University

Many researchers agree that faces are represented in a multidimensional face space with the “mean face” at the origin [Valentine, Q. J. Exp. Psych. 43(2), 1991]. It is often assumed that the component dimensions of this space involve appearance based features, but there is relatively little empirical data to support that view. The research described here was designed to address this issue by systematically manipulating images of human faces using a variety of homeomorphic transformations, some of which resembled craniofacial changes that can occur in nature (e.g., growth), whereas others did not. Each type of transformation was applied with several different magnitudes, and the differences in image structure they produced were measured using several possible metrics involving either pixel intensities or wavelet outputs.

Observers performed a sequential face matching task in which they viewed an image of a standard face, followed by a transformed version of either the same face or a different face, and they were required to judge whether the two successive images depicted the same individual. The results revealed that performance deteriorates with the magnitude of image change for each possible transformation type. However, there were also clear differences among the different types of transformations that cannot be explained by simple differences in low level image structure. These findings suggest that observers’ judgments may have been based on configural relations among facial features that can remain relatively invariant over some types of transformations, but not others.

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3:30 pm

54.25 **Local gender biases in face appearance across the visual field**

Seyed-Reza Afraz[1] (afraz@fas.harvard.edu), Maryam Vaziri-Pashkam[1], Patrick Cavanagh[1,2]; [1]Psychology department, Harvard University, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes

While testing stimuli in another experiment, we had noticed that the perceived gender of a neutral face could change from male to female at different locations in the visual field. To investigate this effect systematically, we asked subjects to discriminate face gender for briefly presented faces at 8 different loci around the fixation. The stimuli were faces morphed at various levels between the female prototype to the male prototype. The faces were about 2 degrees in diameter, presented at 3 degrees eccentricity for 50 milliseconds. The point of subjective equality (PSE) for male/female discrimination was determined from the psychometric curves for tested locations. Results from all individual subjects showed hot spots in which faces look significantly more masculine or feminine (in comparison to the average PSE of the individual). The configuration of these hot spots was distinctive for each individual. To investigate stability of this hot spot configuration, subjects were tested again after about three weeks (19 to 24 days) from the initial test. All subjects showed the same pattern and the PSE values for the tested locations were highly and significantly correlated for each individual across the three weeks interval. Using the same paradigm in a separate experiment, we asked subjects to discriminate slightly horizontally vs. vertically elongated ellipses at different loci. There again we found some degree of heterogeneity across space, although the effect magnitude was smaller and the pattern was less stable in time. Our results suggest localized, independent biases in the tuning of face selective units, at least in the gender dimension, that support recent findings of crude retinotopy in face analysis areas in the brain.

3:45 pm

54.26 **Perception of Chinese characters in novices’ and experts’ eyes: Similarities and differences between face and Chinese character recognition**

Janet Hui-wen Hsiao[1] (jhsiao@cs.ucsd.edu), Garrison Cottrell[1]; [1]Computer Science & Engineering, UC San Diego

We use the logographic characteristic of Chinese orthography to examine whether face-specific effects, such as holistic processing and the left side bias effect (Bruce & Young, 1998), can also be observed in expertise-level Chinese character processing by comparing novices’ and experts’ perception of Chinese characters. We first examine holistic processing with the complete composite paradigm (Gauthier & Bukach, 2007). We show that non-Chinese readers (novices) perceive characters more holistically (i.e. stronger composite effect) than Chinese readers (experts). Chinese readers have a better awareness of the components of characters, which are not clearly separable to novices. This result suggests that holistic processing is neither face-specific nor expertise-specific; it depends on the features of the stimuli and the tasks typically performed on the stimuli. We then use mirror-symmetric Chinese characters to examine the left side bias effect. We create “chimeric characters” from the symmetric characters in the most common fonts (Ming and Kai, which are slightly asymmetric). A right chimeric character consists of two right-halves of the original character, whereas a left chimeric character consists of two left-halves of the original character. We show that, similar to face perception, when asked to judge whether the left or the right chimeric character looks more similar to the original one, Chinese readers have a preference over the left chimeric character, whereas non-Chinese readers do not have a preference; this effect is also reflected in the eye movement data: a leftward shift in the preferred landing position when viewing the characters among Chinese readers compared with non-Chinese readers. This result suggests that the left side bias effect may be a real visual expertise marker.

Tuesday, May 13, 4:30 - 6:15 pm
Talk Session, Vista Ballroom

Spatial Vision: Crowding and Eccentricity 2

Moderator: Susana Chung

4:30 pm

55.11 Drastically different percepts of five illusions in foveal and peripheral vision reveal their differences in representing visual phase

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One important theoretical hypothesis on visual crowding suggests that peripheral visual processing may contain less precise spatial and temporal phase information than foveal processing. To test this hypothesis, we created displays for which the percept depends critically on the internal representations of the spatial or temporal phase in the input stimuli. Five illusions were created and viewed in both foveal and peripheral vision:

1. The peripheral escalator. A column of ovals drifts in front of a grating tilted at 20 deg; in the fovea, the ovals are perceived to drift horizontally; in the periphery, the ovals appear to move obliquely.

2. The giddy-up illusion. Six ovals move slowly across the screen. Each oval is filled with a grating that drifts at a higher velocity. Foveally, the ovals appear to move slowly; peripherally, the ovals appear to move quickly.

3. The moving column illusion. A column of black/white diamonds shifts back and forth. Flanking columns (up to 5 degrees away) make the center column appear to drift up and down in synchrony with the direction of movement.

4. The P.D.Q. Kanizsa illusion. A 16x12 array of Kanizsa pacmen rotate in opposite directions so as to continually reassemble arrays of Kanizsa squares. As the rotation rate increases, the peripheral range over which the squares can be seen decreases.

5. Foveal-winks/peripheral-blinks illusion. Identical 3 Hz modulating fields are surrounded by white and black rings. In the fovea, the lights appear to modulate asynchronously (i.e., wink); in the periphery, the lights appear to modulate synchronously (i.e., blink).

The drastically different percepts in foveal and peripheral vision cannot be explained by simple differences in their spatial resolution because blurring did not alter the percept in foveal vision. Rather, they support the hypothesis that visual processing in the periphery may contain less precise phase information.

Acknowledgement: Supported by NEI
URL: shapirolab.net

4:45 pm

55.12 What role does contour integration play in crowding?

Ramakrishna Chakravarthi[1] (rama@nyu.edu), Denis Pelli[1]; [1]Department of Psychology, New York University

Linking features together is called 'contour integration' when it helps object recognition and 'crowding' when it hurts it. But, so far, the two processes have been studied independently. Good continuation, usually assessed by contour integration tasks, is considered an essential property that forges strong links between features. As a consequence, one might expect that closely placed elements with aligned orientations might crowd each other to a greater degree than non-aligned elements. To test this prediction, we measured orientation discrimination thresholds for a target bar as a function of the goodness of continuation between it and two flankers. Targets and flankers were oriented bars 1 deg in length, 1.5 deg apart, presented at 10 deg eccentricity in the lower visual field. In experiment 1, in accordance with the above hypothesis, collinear flankers raised threshold 4.5 times more (on average) than orthogonal flankers. However, this result can also be explained by flanker similarity in orientation. Experiment 2 tested this latter possibility by presenting flankers with similar or dissimilar orientations as the target but which did not form a contour with it. Despite absence of good continuation, parallel flankers raised threshold 4x more than flankers with different orientations (that is, the target was crowded as much as with collinear flankers). Finally, experiment 3 directly pitted the two hypotheses against each other by presenting a single flanker that either shared orientation with the target or had good continuation with it but not both. Results indicate that crowding is most effective with a parallel (and hence similar) flanker and is weak or non-existent with a flanker that forms a contour. We conclude that elements bound together by contour integration do not crowd each other any more than unbound elements (beyond the effect of flanker similarity). Thus contour integration processes are transparent to crowding processes.

5:00 pm

55.13 The origin of crowding zones

Anirvan S. Nandy[1] (nandy@usc.edu), Bosco S. Tjan[1,2]; [1]Dept. of Psychology, Univ. of Southern California, [2]Neuroscience Graduate Program, Univ. of Southern California

Crowding, the marked inability to identify shapes in peripheral vision when targets are flanked by other objects, has been widely studied; however, the mechanism of crowding remains unsettled. Here, we attempt to provide the rudiments of a model that accounts for several widely accepted characteristics of crowding: (a) the spatial extent of crowding scales to half the target eccentricity (Bouma, 1970); (b) the zone of crowding exhibits a marked radial-tangential anisotropy (Toet & Levi, 1992), and (c) crowding is asymmetric in that an outward flanker (away from the fovea) is more effective at crowding a target than is an inward flanker (Bouma, 1973). Our model assumes a columnar architecture of the cortex, with columns packed hexagonally in cortical space. We assume that the receptive field sizes of V1 columns increase with eccentricity with a slope of 0.1 (Motter, 2002). We further assume that the initial receptive fields of higher cortical areas (V2, V3, V4) are constructed by recursive isotropic axonal projections in the cortical space, and that such connections can be both integrative and competitive (Reynolds et. al., 1999). A Hebbian learning scheme, assumed to be active during development, modifies and sharpens the initially homogeneous synaptic weights. We noticed that attention-mediated saccades, which bring a peripheral target to the fovea with a radial eye movement, can lead to anisotropy in the weight adjustments. Our simulations showed that connection weights are more sharply pruned along the tangential direction than the radial direction. The end result is that the zone of feature competition for a V4 neuron has the size and shape that agree with Bouma's Law and exhibit the radial-tangential anisotropy. Considerations of V1 receptive field layout (denser sampling toward the fovea) and the resulting precision in position coding (more precise toward the fovea) reveal the inward-outward asymmetry.

Support: NIH EY016391

5:15 pm

55.14 Feature Maps for Letters

Susana Chung[1] (schung@optometry.uh.edu), Bosco Tjan[2], Yiji Lin[1]; [1]College of Optometry, University of Houston, [2]Department of Psychology, University of Southern California

Object recognition involves the detection and integration of valid features to form a coherent percept. Previous studies hinted that different parts of letters are used for identification in the fovea and the periphery; and that more valid features in the stimulus are required for identifying crowded than for single letters. However, the specific features used for identifying individual letters are unknown. Are these features different between the fovea and periphery, and between crowded and uncrowded conditions? To answer these questions, we used a set of 26 lowercase letters that were constructed of Gaussian patches, with each patch having the chance to be individually turned on or off. We tracked observers' response (letter identity) to each stimulus letter presented singly, or when flanked by two nearby letters, at the fovea and 10° lower field. Letter size was twice the acuity-threshold separately determined for each condition. On each trial, a random subset of the patches that constituted the target and its flanking letters (if present) was shown. The probability of a patch being shown was adjusted such that each observer's overall performance accuracy was close to 52% correct. We performed a reverse-correlation analysis to identify the patch locations that significantly correlated with each observer's response for a given letter, resulting in a "feature map" for identifying that letter. Contrary to the expectations based on previous studies, the feature maps are very similar between the fovea and 10° lower field, and between the crowded and single-letter conditions. For some letters, there are subtle differences across conditions in how much observers rely on a given patch location. Our findings suggest that when letter size is scaled to equate for overall performance, the critical features for letter identification are largely invariant between the fovea and periphery, and between the crowded and uncrowded conditions.

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5:30 pm

55.15 Supercrowding: Weakly masking a target greatly enhances crowding

Timothy Vickery[1] (tim.vickery@gmail.com), Won Mok Shim[2], Yuhong Jiang[3], Ramakrishna Chakravarthi[4], Robert Luedeman[1]; [1]Department of Psychology, Harvard University, [2]Department of Brain and Cognitive Sciences, Massachussetts Institute of Technology, [3]Department of Psychology, University of Minnesota, [4]Department of Psychology, New York University

Crowding describes the impairment in identifying targets in the periphery that are flanked by similar distracters, which typically occurs when the target-distracter distance is less than half the target's eccentricity. Here we report a surprising finding, whereby the range of crowding is dramatically enhanced by weak masks surrounding or trailing a target. Observers identified the orientation of a T-shaped target placed 12° in the periphery. The T was either unflanked or flanked by distracter Ts appearing at target-distracter distances equal to 30%, 50%, or 70% of the target's eccentricity. The target was also either not masked, or enclosed by a white square contour, or followed by a weak backwards pattern mask. When no flankers were presented, performance was near ceiling, and there was only a small effect of adding the mask: with a surrounding contour performance dropped from 100% to 87% and with a backwards pattern mask performance reduced from 99% to 93% on average. Flankers at a target-distracter distance of 50% and 70% of the target's eccentricity did not produce crowding when the target was not masked, as expected, but dramatically impaired target identification when the target was weakly masked. The effects of crowding and masking were super-additive, and thus could not be explained by their simple combination. Further experiments showed that these flanker effects obeyed some basic properties of crowding: the outermost flanker was most effective and decreased target-distracter similarity reduced crowding. Critically, "weakening" the target by reducing its contrast did not have this dramatic effect. Although the identification of the target in isolation was impaired by reduced contrast, distracter-target distances of 50% and 70% of target eccentricity did not induce crowding for a low-contrast target. Weakly masking a target reveals "supercrowding," suggesting that feature integration in the periphery occurs over much larger distances than previously observed.

5:45 pm

55.16 Nasotemporal asymmetry of acuity and crowding

Sarah Rosen[1] (sarahbr2@gmail.com), Ramakrishna Chakravarthi[1], Denis G. Pelli[1]; [1]Psychology and Neuroscience, New York University

Peripheral acuity is thought to reflect ganglion cell density. The critical spacing of crowding is thought to reflect the (reciprocal of) cortical magnification factor. At large eccentricities, beyond 20 degrees, nasal retina has a much higher acuity than temporal retina (Anderson and Mullen, 1991). With binocular viewing, left and right visual fields are symmetric but we wondered whether the critical spacing of crowding, tested monocularly, would show an asymmetry. An asymmetry would be surprising because dichoptic crowding experiments have indicated that eye of origin doesn't matter. We measured the critical spacing at an eccentricity of 25 degrees for 5 deg target and flanker letters (black, uppercase Courier) on the horizontal meridian. The flanker was displaced from the target either inward (toward the fovea) or outward (away from the fovea). We also measured acuity for identifying an isolated target letter and found both subjects to have an acuity ratio of 1.5. The mean ± standard error of the ratio of critical spacings for both conditions for two observers is 1.5 ± 0.2 deg. Thus crowding tracks acuity and eye of origin does matter. Critical spacing for crowding at a given location in the visual field depends on which eye is used.

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6:00 pm

55.17 Reduction of the crowding effect in spatially adjacent but cortically remote visual stimuli

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When embedded in adjacent flanking distractors, a target becomes more difficult to perceive. The neural mechanism for this crowding effect remains unclear. Here we addressed the issue of whether cortical distance between target and distractor, independent of their distance in visual space, contributes to the strength of the crowding effect. Two spatially adjacent visual stimuli presented on either side of the vertical meridian are projected to contralateral cortical hemispheres. Thus, these two stimuli are initially processed in different hemispheres and are cortically distant from each other, at least in early visual areas, compared to two stimuli with the same spatial distance but presented to the same visual hemifield. In one experiment, we presented a peripheral target just next to the vertical meridian (left or right side) in the lower visual field. In an orientation discrimination task, observers performed significantly worse (more crowding) when more distractors were presented to the ipsilateral than to the contralateral visual field as the target stimulus. In another experiment, three texture patches were placed in a tangential configuration relative to the fixation point at the same eccentricity, and observers were asked to discriminate a small contrast difference inside the middle patch (target). Observers showed an abrupt increase in performance when one of the flankers crossed the vertical meridian. Together these results indicate that cortical distance between target and distractors, independent of their separation in visual space, is an important factor in determining crowding strength.

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Tuesday, May 13, 4:30 - 6:15 pm
Talk Session, Royal Palm Ballroom 4-5

Perceptual Learning 1

Moderator: Zoe Kourtzi

4:30 pm

55.21 Practice little, gain much: short training enables long-term resistance to perceptual deterioration

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Intensive training or testing reduces performance on perceptual tasks. These effects are specific to basic image features, implicating early stages of the visual stream rather than general fatigue (Mednick, Nakayama, et al., 2002; Ofen, Moran & Sagi, 2007). Here we show, for the texture discrimination task, that such adaptation-like performance decrements are practically eliminated following practice with a small number of trials and sleep. Texture stimuli were presented for 40 ms and backward masked (Censor, Karni & Sagi, 2006). Observers decided whether an array of 3 diagonal bars embedded in an array of horizontal bars (19×19) was horizontal or vertical. In each session the SOA (target-mask asynchrony) decreased gradually to obtain a psychometric curve. One group of observers practiced the texture discrimination task with 12 trials/block of SOA (~450 trials/session), showing low thresholds (112.3±3.5 ms, mean±SE). A second group practiced the task with 50 trials/block (~1600 trials/session), showing higher thresholds (174.8±7.2 ms). Both groups returned for intense test-sessions with 50 trials/block. Results showed that the average threshold in the 50 trials/block test-sessions was significantly lower for the observers trained with short 12 trials/block sessions (117.8±5.0 ms), as compared to those trained with 50 trials/block (158.3±6.3 ms). This learning effect was long-term, observed even when training and test were separated by nine months, and was not found when training and test were not separated by sleep. Thus, short training produces consolidation of an effective memory within the visual neural network, resistant to the performance decrements that are induced by intensive testing. We suggest a link between perceptual deterioration and learning: best performance is achieved with short training while further training leads to decrements due to connectivity saturation. Resistance is achieved by sleep dependent consolidation of unsaturated connectivity. This link may have an important role in the underlying mechanisms of perceptual learning.

4:45 pm

55.22 Learning confidence in a visual task

Simon Barthelmé[1] (simon.barthelme@gmail.com), Pascal Mamassian[1]; [1]Laboratoire Psychologie de la Perception, CNRS, Université Paris Descartes

Life's most crucial decisions must often be made in the face of severe uncertainty. One ecologically relevant form of uncertainty comes from the intrinsic limits in the accuracy and reliability of biological visual systems. A moving shadow can be that of a cloud or that of a hawk: a wise hare will take its visual uncertainty into account when choosing to flee or stay. For the evaluation of visual uncertainty to be maximally useful, it must show both sensitivity and calibration. Variations in uncertainty must be detectable, and the subjective probabilities assigned to hypotheses must match relative frequencies in the environment. The traditional way of approaching this problem in psychophysics is by way of confidence ratings: sensitivity and calibration require that observer0's confidence ratings match observed probability correct. However, it is hard to draw definite conclusions from confidence ratings, notably because of large interindividual differences. Here we introduce a task which limits the impact of observer differences in strategy. We induced uncertainty by having observers make orientation judgments in white noise. On every trial, observers had the option to either make a judgment on a stimulus, or to skip it in favour of an as-yet-unseen stimulus. If the observer chose to respond to the first, the trial was ended. If they chose to skip the first, another stimulus was presented, which they had to respond to. Maximisation of performance in this task requires both sensitivity and calibration, and no symbolic probability judgment is required. Results show that observers can make use of the "skip" response to improve performance. Furthermore, observers learned to calibrate their expected probability of success in this task in the absence of trial-by-trial feedback, indicating that the evaluation of uncertainty can benefit from unsupervised learning.

5:00 pm

55.23 Neural mechanisms of multisensory perceptual learning

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

Studies of perceptual learning have traditionally focused on unisensory stimuli. However, multisensory interactions can occur at early stages of visual processing (Watkins et al, 2006, 2007), and therefore might play a role in low-level perceptual learning. Indeed, we recently demonstrated that training on a multisensory motion coherence detection task facilitates visual perceptual learning (Seitz, Kim, & Shams 2006). Furthermore, this facilitation is not due to a general effect of attention, but rather involves processes sensitive to featural relations between the visual and auditory stimuli (Kim et al, 2007). In the current study, we investigate neural mechanisms underlying multisensory learning effects. We scanned the brains of six subjects using functional MRI before and after 10 days of training on the congruent visual-audio motion coherence detection task. In the scanner, subjects performed a motion discrimination task involving congruent and incongruent motion-stimuli for both the trained and the opposite of the trained motion-direction. Comparing multisensory effects pre- and post-training, we observe robust changes in activation that are specific to the trained motion-direction in an impressive variety of brain areas, including subcortical (cerebellum) and "amodal" association cortices (frontal, anterior temporal, superior parietal, anterior cingulate), as well as areas traditionally known as sites of multisensory integration (inferior parietal lobe, superior temporal sulcus). Of particular interest, multisensory learning effects were also observed in visual and auditory cortices, which are typically considered to be "unisensory". While many of these brain areas have previously been implicated in multisensory processing, this study demonstrates a substantial degree of plasticity in multisensory processing systems. Furthermore, these changes at multiple processing levels may underlie the enhancement in visual learning experienced with multisensory training.

5:15 pm

55.24 Category and Perceptual Learning in Subjects with Treated Wilson's Disease

Zhong-Lin Lu[1] (zhonglin@usc.edu), Pengjing Xu[2], Xiaoping Wang[2], Barbara Dosher[3], Jiangning Zhou[2], Daren Zhang[2], Yifeng Zhou[2]; [1]Laboratory of Brain Processes (LOBES), Department of Psychology, University of Southern California, [2]Department of Neurobiology and Biophysics, School of Life Sciences, University of Science and Technology of China, Hefei, Anhui 230027, P.R.China, [3]Department of Cognitive Sciences, University of California, Irvine

In category learning, observers improve their performance in classifying novel stimuli into discrete categories through trial-and-error with feedback. In perceptual learning, observers improve their discrimination or detection performance in perceptual tasks through repeated practice or training. Converging evidence from cognitive psychology, neuropsychology, and brain imaging has identified separate brain systems for rule-based explicit category learning and non-verbalizable implicit category learning. The neural circuitry for perceptual learning is however less clear. We investigated whether some brain structures important for category learning might also be important for perceptual learning. Specifically, we evaluated the speed and accuracy of explicit and implicit category learning, and the magnitudes of perceptual learning in low and high external noise environments for subjects with treated Wilson's disease and compared their performance with that of normal controls. Wilson's disease (WD), hepatolenticular degeneration, is an autosomal, recessively inherited disorder of copper metabolism with the greatest brain damage in the basal ganglia, a structure that is important in both explicit and implicit category learning. The WD subjects exhibited deficits in both forms of category learning as well as perceptual learning in high external noise. However, their perceptual learning in low external noise was relatively spared. Furthermore, there were significant correlations between the magnitude of perceptual learning in high external noise and both forms of category learning, but the magnitude of perceptual learning in low external noise was not significantly correlated with either form of category learning. The results imply that damage to brain structures in Wilson's disease, especially the basal ganglia, compromises both category learning and the development of templates in perceptual learning in high external noise, but may spare perceptual learning in low external noise, which may be served predominantly by other brain structures. Supported by NIMH, NEI, and the Chinese NSF.

5:30 pm

55.25 Simultaneous training of two high precision tasks is largely independent even when orientation or position is shared

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Specificity is a key property of perceptual learning. Improvements in one task after extensive training may not transfer to different stimuli or tasks. We argued that specificity or transfer depend critically on the precision of the tasks. Jeter et al. (2006) used the simultaneous training paradigms of Liu et al. (1998) and found full specificity for a high precision task that differed in both orientation and position. The current experiment extended this investigation to test tasks in simultaneous training that differed only in orientation, only in position, or in both position and orientation in a 2AFC high precision (+/-5^o from a reference angle) orientation discrimination task using Gabor patches in external noise at a fixed contrast. Trials were interleaved in uneven proportions in A-A-B-A-A-B... order. 'A' trials appeared on one position diagonal (e.g., NW/SE) with one orientation reference, while 'B' trials shared positions, reference orientations, or neither. Accuracy on the 'B' trials should equal the first half of all 'A' trials for independent training; if transfer occurs, the 'B' accuracy should be better. We generally found independence of learning 'A' and 'B' tasks, whether they differ in one or both features. Training the same orientations in different positions yielded slight positive transfer, while different orientations in the same locations yielded slight negative transfer for certain layout configurations. Overall, these results support the previous claims of Jeter et al. of independence of high precision tasks in simultaneous learning protocols.

5:45 pm

55.26 **Learning against the natural statistics: experience-dependent plasticity for contour detection in the human visual cortex**

D. Samuel Schwarzkopf[1] (D.S.Schwarzkopf@bham.ac.uk), Zoe Kourtzi[1]; [1]Cognitive Neuroimaging Lab, Birmingham University, United Kingdom

Perceptual integration and detection of coherent form in cluttered scenes is a fundamental skill for survival in the complex environments we inhabit. Recent work proposes that the visual system is optimized through evolution and development to solve this challenge by exploiting statistical regularities in natural scenes, e.g. collinear alignment of edges. We investigated the potential role of shorter term plasticity mechanisms (i.e. learning) in shaping perceptual integration processes using contours that violate collinearity. We compared the ability of observers to detect contours embedded in noise when the Gabor elements defining the contours were a) aligned along the contour path (collinear contours), or b) oriented orthogonally to the contour path (orthogonal contours). Observers' detection performance was higher for collinear contours that are more frequently encountered in natural scenes than orthogonal contours. Importantly, training to detect orthogonal contours (2200-4000 trials, over 3-5 daily sessions) resulted in improved performance similar to that for the detection of collinear contours. fMRI measurements prior to training showed significant activations in extrastriate ventral and dorsal visual areas for collinear, but not orthogonal contours, when compared to stimuli in which the orientation of contour elements was randomly jittered by up to 45°. However, fMRI measurements on the same observers after training showed similar activation patterns for orthogonal and collinear contours in accordance with the behavioural learning effects. Critically, multivariate analysis revealed that classification of fMRI responses for orthogonal vs. collinear contours decreased after training, suggesting that learning shapes selectivity for global contours irrespective of the alignment of local elements (along vs. orthogonal to the path). Our findings provide novel evidence for experience-dependent plasticity in the human visual cortex that mediates our ability to detect contours in cluttered scenes and may contribute to the learning of statistical regularities in natural environments.

6:00 pm

55.27 **Boosting perceptual learning by feedback manipulation**

Kazuhisa Shibata[1,2] (kazuhi-s@atr.jp), Shin Ishii[1], Noriko Yamagishi[3,2], Mitsuo Kawato[1,2]; [1]Nara Institute of Science and Technology, [2]ATR Computational Neuroscience Laboratories, [3]National Institutes of Information and Communication Technology

Perceptual learning is a long-lasting perceptual sensitization after extensive training. Because the learning is specific for a trained eye, feature or position, greater plastic changes may occur in lower visual cortex. However, how an external performance feedback during the training is utilized for this sensory learning remains unclear. If it works as a supervised signal, its information quality is most important. By contrast, if it is used for a plasticity control, a feedback that boots perceptual learning can be made even when it does not reflect subjects' actual performance. Here, using the feedback manipulation procedure, we show that subjects implicitly evaluate the statistical characteristics of the performance feedback and utilize it for the plasticity control. Subjects performed a grating discrimination task 40 times within each block. After each block, the feedback was presented to subjects. Subjects showed a significant sensitivity increase during 30 blocks when the block feedback reflected actual subjects' accuracy (control condition). This learning tendency was well-explained by a linear regression (basic learning tendency). In the feedback manipulation condition, the block feedback followed the basic learning tendency with Gaussian noise and did not reflect subjects' actual performance. When we made the gradient of the feedback larger than that of the basic learning tendency, subjects' sensitivity increase was significantly greater compare to the control condition. Surprisingly, when we made the variance of the Gaussian noise of the feedback smaller, the learning was boosted more. We confirmed that subjects were not aware of the feedback manipulation. We further showed that these behavioral results can be interpreted by the optimal statistical framework using Kalman filter estimation. We argue that, if subjects' learning dynamics is identified, we can make the feedback that maximizes the perceptual learning even when it does not reflect subjects' actual performance.

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Tuesday, May 13, 2:30 - 6:30 pm
Poster Session, Royal Palm Ballroom 1-3

Attention: Costs of Divided Attention

Attention: Neural Mechanisms

Perceptual Organization: Grouping and Segmentation

Attention: Costs of Divided Attention

56.301 **Distinguishing serial and parallel models using variations of the simultaneous-sequential paradigm**

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The simultaneous-sequential paradigm employs a visual search task to distinguish alternative models of visual attention. It has been successful at distinguishing unlimited-capacity, parallel models from other alternatives. Here, this paradigm is expanded to also distinguish between serial and limited-capacity, parallel models. The simultaneous-sequential paradigm compares accuracy performance between simultaneous and sequential presentations of otherwise equivalent stimuli. When processing capacity is unlimited, accuracy performance is equivalent for simultaneous and sequential presentations. When capacity is limited, performance improves in sequential presentations. We developed variations on the simultaneous-sequential method to distinguish between other alternative models. One comparison tests for fixed capacity models and another comparison distinguishes serial from limited-capacity, parallel models. In this study, these methods are applied to two test cases: (a) simple feature detection and (b) semantic word categorization. The results provide evidence that contrast increment detection is an unlimited capacity process. The semantic word categorization experiment is in progress.

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56.302 **Attentional Resources and the Parvocellular and Magnocellular Pathways**

Satomi Maeda[1] (amster.2@wright.edu), Allen Nagy[1]; [1]Department of Psychology, Wright State University

The parvocellular and magnocellular pathways are thought to be largely independent visual processing streams, which process different aspects of visual information. The magnocellular pathway is thought to process information about the location and movement of objects, while the parvocellular pathway is thought to process information that is useful for recognition and identification of objects. This study used a dual task methodology to test the hypothesis that the two pathways draw from independent pools of attentional resources. We predicted that engaging in two search tasks that were processed by different pathways would result in less dual task performance decrement than two tasks that were processed by the same pathway. Two groups of eight small disks were simultaneously presented for 200 milliseconds. Each group contained a single target. Observers were asked to identify the location of the target in each group. Magnocellular targets were defined by brief luminance transients and parvocellular targets were defined by color. Targets that yielded approximately 75% correct in single task conditions were used in the dual task condition. Results showed little or no dual task interference when two transient targets or a color target and a transient target were paired. A small dual task performance decrement was observed when the two groups of stimuli contained identical target and distractor colors. A larger decrement was observed when the targets in the two groups differed in color. An even larger decrement was observed when the roles of target and distractor colors were reversed in the two tasks. Two search tasks that were mediated by different pathways or by the magnocellular pathway showed little dual task performance decrement. However two search tasks that were mediated by the parvocellular pathway resulted in varying degrees of dual task interference, depending on the target and the distractor colors in the two tasks.

56.303 **Cross-Hemifield Attention Benefits for Visual Enumeration**

David Somers[1,2] *(somers@bu.edu), Summer Sheremata*[1]*;* [1]*Psychology Department, Boston University,* [2]*Program in Neuroscience, Boston University*

Visual enumeration, the ability to determine the number of objects presented visually, has been shown to consist of a subitizing range (~3 or fewer objects) and a counting or estimating range (>~3). Subitizing occurs rapidly, accurately with minimal attentional demands, while counting or estimating is slower, more prone to errors and strongly dependent on spatial attentional effects. The Zoom Lens theory of spatial attention (Erikson & St. James, 1986) predicts that performance in an attentionally demanding task should decline as the spatial extent of visual attention is broadened. However, recent evidence has suggested performance benefits from splitting the spotlight of attention and in deploying attention to both visual hemifields (e.g., Awh & Pashler, 2000; McMains & Somers, 2004; Alvarez & Cavanagh, 2005). Previously Green & Bavelier (2006) investigated the effects of increased spatial spread of targets on enumeration ability. Consistent with the Zoom Lens model, performance declined as spatial extent increased. Here we have re-investigated this issue, specifically investigating the influence of spreading targets across single or multiple visual hemifields and/or quadrants. Contrary to the predictions of the zoom lens model, enumeration performance was better when targets were placed in opposing quadrants in the right and left hemifields than when targets were restricted to a single quadrant. Performance in the “split quadrant” condition closely matched the predictions of a simple model of hemispheric independence that was derived from the single quadrant performance data. Performance was further enhanced when targets were distributed across all four visual quadrants. These results demonstrate that enumeration benefits from recruiting attentional resources in both hemifields. One possible explanation is that subitizing might occur in parallel across multiple attentional foci.

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56.304 **Testing a theory of visual attention**

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One claim of the recent Boolean map theory of visual attention (Huang & Pashler, 2007) is that visual information that can be consciously accessed at one moment is limited to one feature, linked to possibly multiple locations (i.e., a map). We report new tests of the predictions. First, it should be efficient to detect a missing location, but not a missing feature, because multiple locations but not multiple features can be simultaneously represented (thus allowing a missing location, but not a missing color to be spotted). Second, the claim of “single feature access” should hold for a wide range of features including orientation, spatial frequency, motion direction, etc. Third, we should be unable not only to access multiple features in newly appeared objects but also to continuously monitor multiple features after they have been seen (i.e. instantly report a change on any of them), because the claim of “single feature access” implies only one single feature can be included in the content of visual access at one time, not one single feature can be added into the content of visual access at one time. Fourth, we should have greater difficulty judging the simultaneity of two features (appearing in objects) than judging the simultaneity of two locations (filled by objects), because the serial nature of feature access disrupts the direct verification of simultaneous presence. Fifth, it should take longer to retrieve objects of different colors from working memory than to retrieve objects of the same color from working memory, because retrieving objects of different colors has to be done sequentially whereas retrieving objects of the same color can be done simultaneously. These predictions were tested and generally confirmed. Their implications will be discussed.

56.305 **Trading off visual acuity? Transient attention increases acuity at cued locations and decreases it at uncued locations**

Barbara Montagna[1] *(barbara.montagna@nyu.edu), Franco Pestilli*[1]*, Marisa Carrasco*[1,2]*;* [1]*Department of Psychology, New York University,* [2]*Center for Neural Science, New York University*

Goal: Attention trades off processing resources between attended and unattended locations. This trade-off has been shown for early visual dimensions, i.e., contrast sensitivity increases at the attended locations while decreasing at unattended locations (Pestilli & Carrasco, 2005). How general is this trade-off mechanism? Does it generalize to other basic visual dimensions? Specifically, is increased acuity at attended locations (e.g., Carrasco, Williams, & Yeshurun, 2002) accompanied by a decrease in acuity at unattended locations? Here we measured the effects of attention on acuity at cued and uncued locations relative to a neutral (baseline) condition.

Methods: Transient (exogenous) attention was manipulated via non-informative peripheral cues preceding stimulus presentation. On each trial, a precue appeared either at fixation or adjacent to one of two upcoming Landolt squares. After a 60-ms SOA, the two squares (side length=1°; eccentricity=9.4°) appeared for 30-ms to the right and left of fixation. Next, a response cue indicated to the observer the target stimulus (left or right). Observers localized a gap (top or bottom) in the target Landolt square. To assess acuity, we measured 75% gap-size thresholds using an adaptive staircase procedure (Quest).

When precue- and response cue-locations matched (valid trial), acuity was measured at cued locations (attended); when they mismatched (invalid trial), acuity was measured at uncued locations (unattended). On neutral trials, two precues appeared 0.5° off fixation indicating stimulus onset without drawing attention to the stimulus.

Results: Acuity increased at valid-cued locations, and decreased at uncued locations, as compared to the neutral condition. This result indicates a trade-off for acuity with transient attention, even when only two stimuli are present. This finding, analogous to that of transient attention on contrast sensitivity, suggests that visual processing trade-offs are a general mechanism of attentional allocation.

Acknowledgments: NIH R01 EY016200-01A2

56.306 **Coactivation occurs within objects, not between dimensions**

J. Toby Mordkoff[1] *(jonathan-mordkoff@uiowa.edu), Rose Halterman*[1]*;* [1]*Dept of Psychology, University of Iowa*

Previous work has suggested that targets from separable dimensions, such as color and shape, can coactivate responses. This contrasts with the “race” that occurs between targets from the same dimension. Assuming, for example, that the targets are red and X, a red O and green X would coactivate the response, whereas two red Os or two green Xs would participate in a race to activate the response. However, instead of focusing on the number of dimensions that contain targets (two vs one), it could alternatively be argued that the critical difference concerns the number of objects (one vs two). When multiple targets are from the same dimension, they must be processed as distinct objects. When targets are from different dimensions, they may be combined into a single object. Under this view, for which we have found some very strong evidence, coactivation occurs within objects and not between dimensions.

56.307 **Neural basis of feature cueing in the perception of object contours**

Bobby Stojanoski[1] *(stojanoski@utsc.utoronto.ca), Matthias Niemeier*[1,2]*;* [1]*University of Toronto at Scarborough,* [2]*Centre for Vision Research, York University*

Cueing attention to a particular location is space leads to enhanced processing of objects in that circumscribed area. However, attention can also be cued to non-spatial properties of objects (e.g. colour) resulting in preferential processing of that feature throughout the visual field. We have previously shown that this principle of feature-based attention contributes to higher-level processing, such as during the perception of objects. When attending to contour defined loops, perception of similar object contours is better relative to the perception of other incongruent features. In the current experiment we investigated the influence of feature cues. Participants viewed a rapid serial visual presentation of random arrays of gabors that sometimes formed a loop that was either contour- or motion-defined and that should be detected as quickly as possible. To cue feature-based attention, in separate blocks of trials there was an 80% chance that the target was a contour or motion, respectively. We found valid cues to contour-defined loops produced faster reaction times compared to invalid cues. This demonstrates the impact of a feature cue in perceiving object contours. To investigate the neural mechanism responsible for this feature cue effect, we recorded ERP’s while performing this task. We observed cue-related positivity at about 300ms after stimulus onset. Our data argue for a contribution of later, possibly top-down mechanisms to feature-based attention, perhaps reflecting an attentional set for feature dimensions.

Acknowledgement: NSERC

56.308 **Testing Lavie's (1995) perceptual load theory**

Michael Wenger[1] (mjw19@psu.edu), Daniel Fitousi[1]; [1]Department of Psychology, The Pennsylvania State University

Lavie's perceptual load theory (1995; Lavie & DeFockert, 2001; Lavie & Tsal, 1994) holds that observers can efficiently filter out task-irrelevant distractors when performing under high levels of

perceptual load (e.g., large display size), but fail to do so under low levels of perceptual load (e.g., small display size). On this account, perceptual load modulates selectivity by way of limiting or

freeing processing capacity. When load is high, capacity is exhausted and there are no available resources left to process irrelevant distractors; while the reverse holds true for low load. Central to

load theory (Lavie, 1995) are critical hypotheses regarding the construct of capacity and its dissociation from sensory and perceptual processes (Lavie & DeFockert, 2001). Inferences on capacity changes under different levels of load have been made only at the level of mean RTs. The present work subjected this theory and its core assumptions to rigorous scrutiny in three ways: (a) By testing hypotheses regarding changes in processing capacity using the hazard function of the RT distributions, allowing a very fine-grained assessment of processing capacity (Townsend & Wenger, 2004; Townsend & Ashby, 1978; Wenger & Gibson, 2004). (b) By testing assumptions

regarding sensory mechanisms using signal detection theory (Green & Swets, 1966). (c) By applying these analyses at the level of the individual observer approach in order to assess the extent to which individual differences in critical characteristics of processing may vary (e.g., Estes & Maddox, 2005). Our results indicate that (a) there are considerable individual differences in capacity as a function of varying perceptual load, and (b) there are significant violations of some of the foundational assumptions of perceptual load theory, such as the assumption that capacity limitations are independent of sensory limitations.

56.309 **Effects of selective attention on the chromatic VEP: Task-relevant stimuli**

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Introduction: When viewing spatially separated visual stimuli, performance is often compromised for unattended stimuli. This has been reported for both behavioral and electrophysiological measurements. Performance is further compromised when the unattended stimulus is similar to the attended stimulus (task-relevant). In electrophysiological studies attentional effects are not typically seen in early responses, and are particularly absent in the pattern-onset VEP. However studies have reported larger attentional effects under conditions of selective attention when the attended and unattended stimuli are similar. The present study used chromatic pattern on-set VEP stimuli to measure attentional modulations at early visual stages with similar attended and unattended stimuli.

Methods: 8 subjects fixated on a central location with chromatic pattern on-set stimuli presented to either visual field. Target and non-target stimuli were chromatic 1cycle/degree horizontal sine wave gratings presented in an on/off manner. In one condition subjects directed attention to the left visual field where various chromatic stimuli were displayed (100ms on/400ms off) and VEPs recorded while a temporally unsynchronized pattern was displayed (100ms on/ 500ms off) in the right visual field. In another condition the stimulus presentation remained the same, however subjects directed attention to the right visual field. Attention was monitored by having subjects press a button whenever a predetermined chromatic stimulus appeared.

Results: No significant change in waveform amplitude or latency was found between conditions. Waveform characteristics of chromatic pattern on-set VEP do not appear to be effected by attentional shifts even when using task-relevant distracter stimuli. These data are consistent with our previous data employing other attentional shift paradigms.

Conclusion: Combined with our previous results, the data suggest that monitoring attentional state is not necessary when recording chromatic onset VEPs as the waveforms will be unaffected by attentional shifts as long as gaze is directed toward the stimulus.

Attention: Neural Mechanisms

56.310 **The effect of a top-down cue on spread attention in the macaque**

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Attention can be allocated to different regions of the visual scene according to the attentional priority of the objects in the scene. These priorities are represented by activity in the priority map in the lateral intraparietal area (LIP). In this study, we are interested in understanding how the brain focuses or spreads attention. To examine this, we trained two monkeys to perform a change blindness task. A trial started when the monkey fixated a central white spot during a delay of 1100 ms. Then, a combination of 1, 2, 4 or 8 oriented bars was flashed for 500 ms at equal eccentricities. After a gap of 50-150 ms, the bars reappeared for 1000 ms. In some trials, one of the bars was rotated 90 deg when it reappeared. The monkey had to saccade to this bar within 600 ms to be rewarded. In the remaining trials, no bar was rotated and the monkey was rewarded for maintaining fixation. The behavioral performance was recorded in term of the percentage of correct responses. Both monkeys showed a decrease in performance according to the number of distractors, suggesting that attention was spread and that the amount of attention at a location decreased as the number of bars increased. In another block of trials, to implement top-down attention, only 1 of the 8 stimulus locations could have the rotating stimulus – the stimuli in the 7 remaining locations will not rotate for the entire block. The addition of top-down attention increased performances indicating that attention is focused to this location. However, performance with top-down attention was worse than performance when only 1 stimulus was presented, suggesting that the presence of distractors limits the amount of attention and that the distractors are not completely suppressed on the priority map.

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56.311 **Dynamics of the priority map in LIP during visual search**

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When searching for an object in a scene we tend not to look at the same location over and over again. Modelers have suggested that after we have looked at a location, it is inhibited on the saliency map. We, and others, have proposed that activity in the lateral intraparietal area (LIP) acts as such a map, in which features or locations are represented by levels of activity related to the attentional priority at that location. Although, the neural activity of LIP area describes the attentional priority across the visual field, it is unclear how this priority map is updated during ongoing visual search. To investigate this, two monkeys were trained to perform a task in which they searched for a reward-loaded target among 5 targets and 5 distractors. After the stimuli appeared, the monkeys were free to move their eyes to find the reward-loaded target. Stimuli were spaced such that when looking at one stimulus, another was in the LIP neuron's receptive field. Although LIP neurons responded to both the targets that had and had not been already looked at, the responses were stronger to the targets that had not been seen. This difference could be the result of an eye movement to the target in the receptive field just before or after the analyzed epoch. This possibility was ruled out by showing that the responses to targets that had not been seen were still higher than targets that had been seen when the monkey had just made a saccade from that stimulus or was about to make a saccade directly to that stimulus. We suggest that the activity in LIP provides a priority map that encodes the location of interesting objects in the environment and dynamically keeps track of locations we have already looked at.

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56.312 Saliency-based guidance of gaze in monkeys with unilateral lesion of primary visual cortex

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We investigate residual visually-guided behavior in monkeys after unilateral ablation of primary visual cortex (area V1), to unravel the specific contributions of V1 to salience computation in the primate brain. We analyze eye movements (108,458 saccades) of six macaque monkeys (three normals, three with unilateral V1 ablation) watching ~54 minutes of television and other natural video stimuli (97,051 video frames). A computational model of saliency-based, bottom-up attention quantifies the monkeys' propensity to attend to salient targets in their normal vs. lesioned hemifields. To eliminate stimulus biases, we randomly presented all video clips twice, original and horizontally flipped. All monkeys are attracted towards salient stimuli, significantly above chance (assessed by simulating random saccades), for saccades directed both into normal and lesioned hemifields (t-tests, $p<0.0001$ or better). We compute a saliency deficit score (SDS) comparing the extent to which saccades directed into one hemifield may be more or less saliency-guided than saccades directed into the other hemifield (SDS=0% would indicate no asymmetry, SDS=100% would indicate complete blindness in the lesioned hemifield). For the lesioned monkeys, SDS is significantly different from 0% (t-tests, $p<0.00001$ or better) but surprisingly low (range 9% - 28%; average for normal monkeys: 4%), indicating a significant residual attraction towards salient targets even in the lesioned hemifields. Further, the recent history (up to 500ms before saccade onset) of saliency values around saccade targets reveals significantly increased salience just before saccades into the normal, but not the lesioned, hemifield (Bonferroni-corrected t-tests, $p<0.05$ or better). Taken together, our results suggest that unilateral ablation of V1 does not abolish the natural tendency of monkeys to gaze towards salient targets during natural vision, although it significantly decreases the monkeys' ability to rapidly select targets in the lesioned hemifield that have recently become salient.

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56.313 Perceptual load-induced selection as a consequence of spatial interactions in visual cortex

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Perceptual load has been proposed as a determining factor in the degree to which unattended information is processed. Although there is considerable support for this theory, there is currently no a priori definition of what constitutes high or low perceptual load. Last year, we suggested that local competitive interactions in visual cortex underlie perceptual load: stimuli that induce strong competitive interactions among items should require a strong top-down bias in order to overcome the competition and select the target, and can thus be characterized as high perceptual load. Accordingly, we showed that increasing display density, which should also increase competitive interactions in visual cortex, resulted in reduced distractor processing. This year we test an even more surprising prediction of our theory. If perceptual load is determined by local interactions in early or intermediate visual areas (in which the representation of a hemifield is confined to a hemisphere), then placing multiple items within the same hemifield should result in greater perceptual load and reduced distractor processing than when the target item appears alone within a hemifield. In half of the trials the search array was positioned such that target appeared alone in the hemifield (with the non-targets in the opposite hemifield). In the other half of the trials, the target shared a hemifield with the two non-target items. The distractor was located at fixation. As predicted, we found that trials in which the target appeared in a different hemifield than the non-targets produced greater distractor effects than trials in which the target appeared in the same hemifield as the non-targets. These results not only support the hypothesis that local suppressive interactions among the target set dictate the extent to which a distractor can be ignored, but they also suggest that the attentional bias is determined independently in the two hemispheres.

56.314 Attention improves decoding of stimulus orientation in early visual areas

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Previous neuroimaging studies have shown that attending to a spatial location leads to enhanced BOLD responses in corresponding regions of the human visual cortex. However, it is unclear whether these enhanced cortical responses simply reflect the top-down selection of a spatial region or whether they might convey additional information about the attended features at that location. To address this issue, we used functional MRI in combination with multivariate pattern analyses to investigate the effects of attention on orientation-selective responses in early human visual areas. Subjects performed a near-threshold orientation discrimination task involving one of two laterally presented gratings. Gratings of independent orientation (base orientation of either 55 or 145 deg) were simultaneously presented to the left and right of a fixation point, twice in each trial. Attention was directed to either the left or right grating by a central cue. Small orientation changes were introduced between successive presentations of the gratings using an adaptive staircase procedure, and subjects had to report whether the second grating was rotated clockwise or counterclockwise relative to the first. Analyses of the amplitude of the BOLD response revealed much stronger responses for attended than unattended locations in early visual areas. To test whether this also resulted in additional information about the attended features at these locations, we used a pattern-based approach to decode the presented stimulus orientation from cortical activity found in these regions (Kamitani & Tong, Nat Neurosci, 2005). We found significantly better classification performance of the decoder in the attended condition as compared to the unattended condition in areas V1, V2 and V3. We conclude that attention not only enhances the strength of cortical responses in early visual areas, but also improves the feature selectivity of these responses when analyzed at a population level.

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56.315 Contrast-specific neural responses underlying the perceptual bias

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Visuo-spatial and attentional functions are assumed to be predominantly represented in the right hemisphere because right-hemisphere lesions cause severe deficits such as spatial neglect. However, there is much debate about which neural mechanisms are affected, partially because in healthy people functional and behavioural right-dominant asymmetries are subtle and across participants inconsistent; e.g., most (though not all) people show a slight leftward bias in tasks that require perceptual comparisons of line length, numerosity, and luminance. Here we used a gratingscales task at different levels of pixel noise and event-related potentials to study biases in spatial frequency judgments. We found that leftward bias increased as contrast decreased with increasing pixel noise and that participants with reduced task sensitivity showed a stronger bias than sensitive participants. Also, task sensitivity was correlated with a more pronounced stimulus contrast-related negativity at posterior electrodes 100 ms after stimulus onset, and we observed a task-related component at about 200-300 ms that was modulated by sensitivity as well as contrast. While our data are consistent with a cognitive, possibly attentional account of perceptual bias, future research is required to unravel the complex interactions between attentional and 'preattentional' mechanisms of the right hemisphere.

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56.316 Estimating the shape of the feature-based attentional gain function

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Single-unit recording studies suggest that when making a coarse-discrimination (e.g., find a 90° target among 180° distractors), attention enhances the gain of neurons that are tuned to the target feature. However, when making a fine-discrimination (e.g. find a 90° target among 85° distractors), boosting the gain of neurons tuned to the target feature is suboptimal because these neurons respond about equally well to the target and to distractors. Gain should instead be applied to neurons that are tuned to an 'exaggerated' target feature (e.g. 95°) because these neurons will undergo a larger firing rate modulation in response to the small difference between the target and distractors (Navalpakkam & Itti, Neuron, 2007). Thus, the distribution of attentional gain across feature space – or the attentional gain function – should critically depend on the nature of the behavioral task.

Here, we estimated the shape of the attentional gain function during a fine-discrimination task. On every trial, a central precue indicated the distractor orientation as well as the directional offset of the target from the distractors (±5°). On 70% of the trials, four oriented Gabors were presented simultaneously, one in each quadrant; subjects indicated the spatial position of the target with a button press response. Given the high frequency of these trials, subjects should always anticipate a fine-discrimination trial. However, we occasionally (30% of trials) probed the distribution of attentional gain by measuring contrast detection thresholds for one oriented Gabor offset by 0°, ±5°, ±10°, ±20°, or ±40° from the anticipated target orientation. Contrast thresholds were lowest either at the target orientation or at the 'exaggerated' target orientation (+5° from target), suggesting that attentional gain was generally applied to the most informative sensory neurons. Moreover, the shape of the attentional gain function reveals the accuracy and precision of feature-based attention on a subject-by-subject basis.

56.317 **Strong exogenous attraction to attention by unique eye of origin --- evidence for a bottom-up saliency map in the primary visual cortex**

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Human observers searched a background texture of 639 uniformly tilted bars, spanning 34ox46o in visual angle, for a bar with a unique tilt located at one of 28 locations, 15o from the display's centre. There were three critical, randomly interleaved, trial conditions: monocular, with all bars presented to the same single eye; and dichoptic congruent (DC) or incongruent (DI), involving an ocular singleton that was either the target bar (DC) or a background bar on the opposite lateral side from the target (DI). When the target bar was tilted 50o from the background bars, reaction times to report whether it was in the left or right half of the display were shorter in the DC condition, longer in the DI condition, than that in the monocular condition, whether or not subjects were aware or informed of the different dichoptic conditions. In another experiment, when the target bar was tilted 20o from the horizontal background bars, and with all bars having the same (uniform) or different (non-uniform) luminance values and being masked after 200 milliseconds, observers' reports of the target's tilt direction from horizontal were more accurate in DC than the other conditions, irrespective of the luminance condition. With the same stimuli, but without a tilt singleton, the same observers were at chance reporting the existence of an ocular singleton when the bars had non-uniform luminances. These findings suggest that the ocular singleton acted as a valid or invalid exogenous cue to the target. Further experiments showed that set size effects in a difficult visual search under monocular presentation can be dramatically diminished in the DC presentation. Since primary visual cortex (V1) has substantially more monocular cells (for eye origin information) than other visual areas, and is least associated with awareness, our findings support the hypothesis that V1 acts as a bottom-up saliency map (Li 2002, Trends Cognitive Sciences, 6(1):9-16).

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URL: http://www.cs.ucl.ac.uk/staff/Zhaoping.Li/

56.318 **Do gamma-band oscillations bind features when attention is focused on multiple-feature objects during visual search?**

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Many theories propose that activity in the gamma band is responsible for solving the binding problem when viewing arrays of multi-feature objects. For example, synchronized firing of cells coding for the features of an attended object are thought to underlie our perception of bound object representations during visual search. However, the evidence for such an oscillatory binding mechanism is sparse. In the present study we analyzed EEG data collected during a demanding visual search task requiring serial shifts of attention. Event-related potentials (ERPs) time-locked to the onset of the search array allowed us to measure when attention was focused on possible target items. We predicted that if gamma activity binds the features of these objects, then we should be able to measure a burst of gamma-band power accompanying the focusing of attention on the complex objects in the search arrays. Using a Morlet's wavelet time-frequency analysis we measured the power in the gamma band across each trial. We did not observe any clear modulation of gamma-band power following the onset of the search array despite the indication of ERP components showing when attention was deployed to the objects in the search arrays. These findings are inconsistent with the hypothesis that gamma-band oscillations bind together the features of an object embedded in a cluttered visual scene.

56.319 **Retinotopically independent processing of saliency signals in the near-absence of attention**

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It has been proposed that salient locations in a visual scene are represented in a spatial saliency map. For the calculation of such a saliency map different feature contrast maps for luminance, orientation, motion, color, etc. are combined. Brain regions that are candidates for encoding such a saliency map are the pulvinar, superior colliculus, the frontal eye fields and the posterior parietal cortex. But there is also evidence for a saliency map within the ventral visual pathway. In the experiment presented here we investigated the neural correlates of orientation pop-out in humans. Two types of stimuli were used: (a) Homogenous stimuli consisting of an array of bars all of which had the same orientation (randomly chosen to be 0°, 45°, 90° or 135°), and (b) pop-out stimuli consisting of homogenous arrays but with one bar in each quadrant orientated differently (0°, 30°, 60° or 90°) relative to the background. We used an event-related stimulation protocol and stimulated with pop-out stimuli for 4 sec after which the homogenous background stimuli were presented for 7, 10 or 13 sec. During stimulation attention was directed to the fixation using a task that demanded attending the center. This way no overt attention was directed to the salient positions at the two quadrants. BOLD activity in striate and extrastriate cortex showed a significant signal increase for salient positions in V1, V4 and intraparietal sulcus. Furthermore BOLD signals in V4 monotonically increased with the relative orientation of bars in the corresponding region of the visual field. However the encoding of relative orientation was not modulated by the presence of pop-out signals in other regions of the visual field. The results point to a retinotopically independent processing of pop-out signals in the absence of attention.

56.320 **N200 latency predicts behaviorally measured attentional shift time**

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It has been suggested that the N200 event-related potential (ERP) component is involved in focusing spatial attention onto a target location (Luck & Hillyard (1994), Psychophysiology 31: 291-308). Here, we demonstrate that the latency of this component correlates with behaviorally measured attentional shift time.

We measured attentional shift time on individual trials using our previously developed method (Carlson et al. (2007). Journal of Vision 6 (12):6). We recorded scalp ERPs while observers monitored an array of running clocks; one of these clocks was exogenously cued after a variable delay. After each trial, observers reported what the time on that clock was when it was cued. The difference between the reported and veridical time was taken as a measure of attentional shift time for that trial.

Critically, there was no a priori difference between trials: aside from varying when and which clock was cued, all trials were identical. ERP recordings were sorted a posteriori by the measured attentional shift time on each trial. The data showed a significant positive linear correlation between the latency of the N200 ERP component, recorded at POz, and the behavioral measure of attentional shift time.

Our results corroborate previous evidence that the N200 ERP component is involved in shifting visual attention, and also demonstrate a direct link between variability in a neuronal measure (N200 latency) and behavior.

56.321 **Phase-encoded attention tasks reveal topographic maps in posterior parahippocampal cortex**

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Recent studies have demonstrated two retinotopically organized areas, VO-1 and VO-2, in human ventral occipital cortex adjacent to hV4 (see Wandell et. al., Neuron, 2007 for review). In the present study, we extend these findings by examining topographic organization in the areas adjacent to the VO complex in human posterior parahippocampal cortex using a cognitive mapping approach.

Data were collected using a phased array coil with a functional in-plane resolution of 2x2 mm2. While maintaining fixation, subjects were required to allocate attention towards a rotating wedge of moving dots. Subjects detected changes in the direction of motion for the majority of dots. In a second scan session, subjects attended an expanding/contracting ring filled with bouncing balls while maintaining fixation. Subjects detected when one of the balls dimmed. Subjects performed both tasks around 75% accuracy. In a third scan session, responses evoked by object, scene, face, and color stimuli were probed.

We identified two topographic areas that have not previously been described in the human. The new regions are located along the collateral sulcus in the posterior portion of parahippocampal cortex with the first new region being adjacent to VO-2. Both regions contain a complete representation of the contralateral visual field with boundaries defined by a phase reversal. Eccentricity mapping revealed a representation of the fovea and periphery organized perpendicular to the polar angle maps. These two additional topographic areas show selectivity for scenes as compared to objects and faces. We are currently comparing this topographic organization to that obtained with typical retinotopic mapping methods.

Using an attention-demanding task, we revealed topographic organization not previously reported with typical retinotopic mapping methods. These new topographically organized regions overlap with the functionally defined place area, PPA, and show strong preference for scenes in both the foveal and peripheral representations.

56.322 **Selective lateralization of steady state visual evoked potentials at the second harmonic**

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We previously reported that the steady-state visual evoked potentials (SSVEPs) elicited by lateralized flickering stimuli were topographically fractionated into bilateral 1st-harmonic (1f) responses and contralateral 2nd-harmonic (2f) responses (VSS 2007). The current study investigated whether this harmonic-based topographic segregation generalized to a broader range of frequencies. We used flicker frequencies of 6.25 Hz, 8.33 Hz, 12.5 Hz, 16.7 Hz, and 25 Hz, inducing 1f and 2f responses ranging from theta to gamma frequencies. The bilateral topography of 1f responses generalized to all frequencies. We confirmed that the bilateral-contralateral topographic segregation of 1f and 2f responses was harmonic (rather than frequency) dependent. Specifically, the 1f elicited by the 16.67 Hz flicker and the 2f elicited by the 8.33 Hz flicker both had the same response frequency of 16.67 Hz; similarly, the 1f elicited by the 25 Hz flicker and the 2f elicited by the 12.5 Hz flicker had the same response frequency of 25 Hz. In both cases, we demonstrated a bilateral 1f and contralateral 2f, confirming the harmonic dependence of SSVEP lateralization. Interestingly, the degree of lateralization (contralateral minus ipsilateral) of 2f responses exhibited an inverted-U-shaped frequency dependence, broadly peaking around 25 Hz (12.5 Hz stimulus flicker), showing no lateralization at the lowest, 12.5 Hz (6.25 Hz stimulus flicker), and highest, 50 Hz (25 Hz stimulus flicker), frequencies. This frequency dependence of lateralization cannot be attributed to the frequency dependence of 2f responses which monotonically decreased with increasing flicker frequency. Combined with our previous finding that only the contralateral 2f responses were substantially modulated by visual spatial attention, the obtained frequency dependence of lateralized 2f responses suggests that top-down feedback for visual spatial attention may selectively utilize an ~8-34 Hz range of frequencies.

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56.323 **MEG responses in the human brain during the selection of visual targets**

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It has been previously demonstrated that magnetoencephalography (MEG) is a valuable tool to measure electromagnetic responses in the human brain during a variety of tasks. Here we combine MEG and magnetic resonance imaging (MRI) on healthy humans to study the brain electromagnetic responses during a task that involves selecting a target among different stimuli, sustaining attention on that target and finally the detection of a change in one of the target's attributes. We recorded MEG-evoked responses while subjects were presented with two differently colored moving random dot patterns (RDPs) left and right of a central fixation spot (the target and distractor). Subjects were required to: first, select the target RDP and then identify a transient change either in the direction OR color of this target. Target selection was based on the rule 'red>blue>green' being the target the stimulus with the highest color rank. Preliminary results (n=5) revealed that selection based on this rule was accompanied by contralateral activation of the inferior parietal lobe (IPL) at about 170 ms after target/distractor onset followed about 40 ms later by a lateralized peak of activation in the right IPL. On the other hand, detection of direction changes in the target resulted in contralateral activation of area MT/V5 while color changes activated contralateral extrastriate area V4. The activation latencies were about 190 ms after change onset in both cases. Our findings suggest that target selection in the human brain involves high level areas such as the IPL while change detection mainly involve extrastriate visual areas encoding the changing visual attribute.

56.324 **Pre-stimulus activity predicts subsequent target detection in meta-contrast masking**

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We used event-related potentials (ERPs) to study the neural electrical activity associated with conscious perception of targets in a meta-contrast masking paradigm in which the detection of a target is inhibited by a subsequent mask with adjacent but non-overlapping contours. It has been proposed that early visual activity elicited by these stimuli is fed forward to higher brain areas, and that in order for the perception to reach consciousness, these higher brain areas must then feed this information back to the early visual areas. This theory further proposes that when these feedback signals from higher areas encounter the new activity elicited by the mask instead of the original target activity, the conscious perception of the target is inhibited. In the current experiment, after a fixation cue, target and mask pairs were presented using an SOA chosen so that observers reported perceiving roughly half of the masked targets. ERPs for trials where observers reported seeing the target were compared with those for unseen targets. We examined not only the differential activity elicited by detected and undetected targets, but also differential preparatory activity prior to the target onset that might predict subsequent target detection. For target locked ERPs, there was a difference in visual ERP components between detected and undetected targets starting with the N2 component, but no difference was evident in the earlier P1 and N1 components measured at occipital sites, consistent with the reentrant theory. Interestingly, preliminary analyses suggest that the ERPs elicited by the fixation cross preceding the targets were different for detected and undetected targets, implying that brain states preceding the target appearance influenced the likelihood of its detection. These results further support the assertion that attention modulation and feedback activity play a role in the efficacy of meta-contrast masking.

56.325 **Decoding cognitive control in the parietal cortex**

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We have previously reported evidence for a transient reconfiguration signal in the medial superior parietal lobule (mSPL/precuneus) that is time-locked to the initiation of shifts of attention within several perceptual domains, (e.g., attention shifts between spatial locations, features, objects or sensory modalities; Yantis et al., 2002; Liu et al., 2004; Serences et al., 2004, Shomstein & Yantis, 2004). Independently, studies of task-switching have revealed a frontoparietal cortical network exhibiting transient activity during switches between two categorization tasks (e.g., Braver et al., 2003). Here we investigated the neural basis of cognitive control during task-switching and spatial attention shifting within the same paradigm. Subjects directed covert attention to one of two rapid serial visual presentation (RSVP) streams displayed to the left and right of fixation, and were prepared to perform one of two digit categorization tasks (high/low or even/odd). Each stream contained mostly filler distractor items along with occasional cues and digit targets. Four types of cues instructed subjects to shift or hold spatial attention or to switch or hold their categorization task. Using the standard univariate GLM, we observed a transient reconfiguration signal evoked by both attention shift and task switch cues in a common region of mSPL/precuneus. We then applied multivoxel pattern classification (linear support vector machine) to determine whether this apparently domain-independent signal differs for the two domains of cognitive control. The multivoxel patterns of activity within this region did predict which type of shift was being executed on an individual trial basis. The multivariate analysis reveals that although this region is recruited for shifts in multiple domains, domain-specific spatial patterns of activity are associated with different acts of control.

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56.326 **Neglected Sight: Preserved Visual Functions Within A Neglected Hemifield**

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In human subjects, damage of posterior parietal cortex in the right hemisphere often produces a neglect of visual stimuli in the left (contralateral) visual field. Unilateral removal or reversible cooling deactivation of the equivalent region in cats also results in an equally severe, if not greater, contralateral neglect and the cats cannot report the position of visual stimuli. In the current study, we tested for residual visual functions in four cats when they were forced to use the neglected field. To force use of the neglected hemifield, we divided the optic chiasm and forebrain commissures and placed a contact occluder over the left eye during cooling deactivation of right posterior parietal cortex lining the posterior middle suprasylvian sulcus. Under these forced conditions, all four cats could: 1) localize moving stimuli within the previously neglected hemifield; 2) perform direction of movement discriminations with differences greater, but not less than or equal to 30°; and 3) perform 3-D object and 2-D pattern discriminations. We conclude that, under free viewing conditions, the unimpaired hemisphere (and hemifield) dominates visual processing and control of visually-guided behavior. However, when visual input to that unimpaired hemisphere is blocked, the considerable visual processing within the neglecting hemisphere is revealed, and visual localization, some aspects of movement direction discrimination, and many aspects of form discrimination are all possible. In these regards, the split-brain preparation is a highly valuable experimental animal model system for investigating neglect of visual stimuli, and residual visual functions within the neglected hemifield.

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Perceptual Organization: Grouping and Segmentation

56.327 **Context effects in figure-ground perception: The role of biased competition, suppression and long-range connections**

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Does context affect figure-ground perception? And do the conditions under which context effects occur elucidate the underlying mechanisms? Salvagio, Peterson & Kim (VSS 2007) reported that context modulated the strength of the figural cue of convexity: Convex regions were increasingly likely to be seen as figure as the number of alternating convex and concave regions increased from 2 to 8 (57%-89%). Context effects were found when concave regions were homogeneous but not heterogeneous in color; homogeneity of the convex regions was irrelevant. On a biased competition model, convex and concave regions compete for figural status; concave regions are overpowered and suppressed. Our previous results suggested that context effects require long-range connections between neurons responding to homogeneous features of suppressed regions. We investigate whether the same pattern holds for more global figural cues, e.g., small area and symmetry. We found small area-context effects: As the number of alternating small and large regions increased, smaller regions were increasingly likely to be seen as figures. Like convexity-context effects, small area-context effects were observed when larger regions were homogeneous, $p < 0.01$, but not heterogeneous in color, ps > 0.05; homogeneity of the smaller regions was irrelevant. Again, biased competition (a bias toward small regions) and homogeneity of the suppressed regions (the larger regions) were necessary for context effects. In contrast, we did not obtain symmetry-context effects, $p > 0.10$, perhaps because display width increased with region number. Symmetry resolution is impaired in the periphery relative to the fovea. Consequently, the symmetry bias is ineffective in the periphery and asymmetric regions are not suppressed. Without suppression, long-range connections linking homogeneous regions do not mediate context effects. Thus our tests of both small area and symmetry implicate long-range connections between neurons responding to homogeneous features of suppressed regions as the mechanism for context effects.

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

56.328 **Ventral extra-striate visual regions, feedback and texture perception**

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We investigated the role of feedback in texture segmentation. We tested the texture perception of a patient (HJA) with visual agnosia who has a large bilateral lesion of the ventral cortex, likely to include V2, V3 and V4. Previously he has been found to have difficultly segmenting overlapping figures and grouping object parts. Models of texture segmentation (e.g. Theilscher & Neuman (2003) Neuroscience 122 p921-939) propose that simple segmentation can be done by early visual areas but feedback from higher visual areas (such as V4) is required for more difficult tasks.

Method: Participants viewed a 12x12 grid of lines and detected the presence of a 7x2 shape defined by a difference in orientation between these lines and the vertical background lines. The orientation contrast (difference) between the lines in the shape and background lines was measured at different levels of background orientation noise.

Results: Control participants easily detected the shape in aligned background element but needed more orientation contrast with there was orientation noise in the background. HJA was poor with all backgrounds, particularly so with aligned background elements. Adding additional random jitter to the background elements improved HJA's performance, but not significantly. Changing the orientation of the background elements to -45° and halving the density of the line elements improved his performance. Doubling the density improved performance only when there was no background orientation noise, performance was worse when background noise was increased.

Conclusions: HJA performs poorly when background elements are easier to group or align. His performance is improved when grouping is reduced. V1 appears to be insufficient to perform texture segmentation when the background of the display is homogeneous. Texture segmentation must, therefore, rely on information coming from, or through, ventral extra-striate areas to suppress the effects of alignment in early visual areas.

56.329 **Perception of illusory transparent surface by young infants**

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Most developmental studies consistently show that only infants aged at least 6-7 months and older can perceptually integrate disconnected image fragments and complete missing structures based solely on pictorial information (e.g. Bertenthal, 1980). Here, we show an example of early emergence of visual completion using purely static two-dimensional pictorial information. We created mixed polarity Kanizsa figures that are either consistent or inconsistent with perception of an illusory transparent surface. Both configurations have the same local geometry and also contain very similar contrast polarity variations across the four inducers. The perception of transparency is manipulated by the distribution of contrast polarity variations in each configuration.

A total of 48 Japanese infants aged 3-4 and 5-6 months participated in the preferential looking study.

In the Experiment 1, we presented either the transparent or the non-transparent Kanizsa figure side by side with their respective control configurations that consisted of identical but rotated elements. We found that both 3-4 and 5-6 months significantly preferred the transparent Kanizsa figure to its rotated control. There was no such preference between the non-transparent Kanizsa figure and its rotated control configuration.

In the Experiment 2, we directly compared infants' preference between the two types of Kaniza figures. As the two types of the Kanizsa figures slightly differed in terms of the local contrast intensity, we presented the rotated version of these figures side by side as a control condition. We found that both 3-4 and 5-6 months significantly preferred the Kanizsa figure that induces perception of illusory transparent surface than the one which does not. No preference was observed in the control condition. The results from two experiments clearly demonstrate that both 3-4 and 5-6 months perceived the illusory transparent surface in the mixed polarity Kanizsa figure.

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56.330 **V1 BOLD response to image regions defined by 1st and 2nd order luminance contrast**

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The edges of an object in a natural image can be defined by various contrasts such as luminance, color, and texture. Edges created by texture boundaries can be as perceptually salient as those created by simple luminance contrast. Early visual cortex is responsive to first-order (luminance) and second-order (orientation) contrasts (Larsson, Landy, Heeger 2006). Here, we measure BOLD responses to region transitions defined by luminance and luminance variance, referred to as first- and second-order contrasts.

To compare early visual responses defined by first and second-order contrasts, we used either a luminance increment or a luminance variance increment to define a foveal disk subtending 4°, against an 8° background of dynamic white noise (mean gray, 25% contrast) The dynamic noise reduced the effects of neural and retinal adaptation. We used the method of adjustment to find the point of subjective equality (PSE) for the salience of luminance increments relative to a 50% Michelson contrast increment. We then measured BOLD fMRI responses in the occipital lobe using a block design. For each stimulus type (first- or second-order contrast), the mean luminance and variance of the central disk were constant throughout the scan. The background mean luminance or variance was modulated to match the disk interior during "off" blocks, and lowered during the "on" blocks (to define the disk). We used a block localizer consisting of checkerboard annuli to select regions of interest inside and outside the disk for analysis.

Response to the image regions outside the disk was significantly modulated in the second-order contrast, but not the luminance case. Inside the disk, we observed a biphasic positive BOLD modulation: a positive transient response when the disk appeared and when the disk disappeared.

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56.331 **Perceptual filling-in of an artificial scotoma shows retinotopic specificity in human visual cortex**

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When a featureless achromatic target is placed on a textured pattern and steadily viewed in peripheral vision, after a few seconds it seems to fill-in with the surrounding texture, similar to the experience of patients with scotomas from damage to the visual pathways. Such texture filling-in is thought to occur in early visual cortex, but the neural signals associated with texture filling-in of artificial scotomas in humans have not been fully explored. Here we used functional MRI to show that texture filling-in reflects retinotopically specific reductions in activity in human V1 and V2, accompanied by persistent signals associated with the invisible target.

56.332 **Influence of medial axis structure on the discrimination of texture-defined shapes**

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We studied the relationship between texture orientation and shape medial axes in the discrimination of texture-defined shapes. Orientation-based texture segmentation is well-studied, but has rarely been investigated using texture patches with complex shape. We found that alignment between texture orientation and the skeletal axis of a figural region improved the segmentation strength of the figure from a randomly oriented background. When texture was aligned with the figure axis, shape discriminations were made at lower threshold texture coherence levels than when the offset between texture orientation and figure axis was 45 degrees. Performance recovered as the offset was increased further to the maximum of 90 degrees. The alignment effect is attributable to the orientation of the skeletal axis itself, not the orientation of the figure edges; these two factors were deconfounded in our "peanut"-like shapes where contours undulated relative to the main axis orientation. A second study using multi-part shapes showed a similar pattern of results: performance was best when the texture was locally aligned with the skeletal axis of the enclosing part, superior even to the classically optimal case of uniform texture orientation. We conclude that the influence of shape and axial structure extends to early processes by which texture elements are aggregated to form the object itself. We discuss the implications of this conclusion for theories both of texture aggregation and of shape representation.

56.333 **Edge Alignment Effects for Gradient Cuts in Figure-Ground Organization**

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In previous research (VSS 2007) we reported that perception of depth and figure-ground organization is strongly affected by Gradient Cuts (GCs): edges that intersect ("cut") the equiluminance contours of a shading gradient. In particular, GCs biased the gradient side to appear as a farther ground when the size of the angle between the EquiLuminant Contours and the shared edge (the ELC angle), is greater than zero, with the probability of the GC side being seen as closer/figural dropping essentially to zero when the ELC angle reaches about 15°. In Experiment 1 of the present research we show that the ELC angle cannot account for substantial variations in figural/depth judgments that occurred when we manipulated the alignment between the concavities/convexities of a triangular zig-zag edge and the dark and light striations of a multi-cycle gradient region that was cut by the edge at angles substantially greater than 15°. Using bipartite images with central shared edges defined by symmetric and asymmetric triangle waves, we found that alignment of GC edge concavities with the dark striations produced a strong figural bias, and that the alignment of GC edge convexities with the dark striations produced an opposite ground bias. Experiment 2 ruled out an alternative explanation in terms of striation width, since the dark striations in Experiment 1 were thinner than the light striations. Gratings with equally wide light and dark striations and gratings that were contrast-reversed versions of those in Experiment 1 showed that striation polarity (light vs. dark) dominated striation width (wide vs. narrow) in governing these figural/depth effects. We model the data in terms of the number of junctions of various types (light or dark T-, Y-, and arrow-junctions). We also provide an ecological argument about why alignment of edge-concavities and convexities with light and dark striations should matter.

56.334 **Testing for Robustness in Visual Localization of Dot Clusters Without Part Structure**

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Previous findings indicate that observers estimate the center of dot clusters by averaging dot locations. More recent work with clusters made up of a large cluster and a partially-overlapping small cluster demonstrated that the visual system gives less weight to points in the small cluster to the extent that it can be segmented away from the large cluster (Cohen, Singh, Maloney, VSS2006; Juni, Singh, OPAM2006). Here we test whether the visual system is robust when dot clusters cannot be readily segmented. If it is, then points away from the center will receive less weight in estimating the center. Methods. Stimuli were comprised of a single isotropic bivariate Gaussian cluster containing 60 dots (SD=1.3°). The cluster appeared for 250ms at one of seven equally spaced locations horizontally. There were three conditions. In each we added 10 dots uniformly distributed in a small circular region (radius=1.09°) that was either 1.95° to the left, 1.95° to the right, or centered. Using a 2AFC task, observers indicated whether the entire cluster's center was to the right or left of a reference. Analysis. We fit psychometric functions to estimate PSEs for the three conditions. We used these to estimate the influence of adding dots at left, right and center—i.e., to estimate the weight given to the added dots. Four observers completed the experiment (3x7x50=1050 trials). Results. Two observers did not exhibit any significant robustness: they assigned equal weight to points near the center and away from the center of the distribution, effectively computing the average. The remaining two observers exhibited significant robustness with the average weight given the off-center added dots 0.38 and 0.66 of the weight assigned to the rest of the dots. Conclusion. At least some human observers use robust estimators in estimating the center of dot clusters with no evident part structure.

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56.335 **Redundancy enhances the integration of symmetry information**

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Dakin and Herbert (1998) showed that symmetry detection relies predominantly on stimulus information from a limited region around the symmetry axis. Rainville and Kingdom (2002) showed that this so-called integration region (IR) scales with stimulus density such that the amount of information in the IR is constant. We investigated whether this constancy applies to the amount of raw stimulus information or to the amount of nonredundant information that, from an information-theoretic perspective, remains after perceptual processing. We tested the effect of global redundancy using stimuli featuring one, two, or four symmetry axes, and we tested the effect of local redundancy by introducing local correlations such as co-orientation of elements. Results show that the IR scales with both local and global redundancy. This suggests that the visual system is capable of integrating more information if the information is redundant.

56.336 **Perceptual organization in Autism and Asperger Syndrome**

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Some perceptual theories of autism have postulated that autistics (and others along the spectrum) may process visual information at an "earlier" level. For example, hierarchical stimuli may be processed at a more local level, and there may be less susceptibility to visual illusions of size and shape that rely on contextual information. The current experiments tested perceptual grouping in autistics and those with Asperger's Syndrome, setting up a 2AFC procedure where one choice corresponded to grouping at an "early" or more retinal level, and the other choice corresponded to grouping at a "later" level, after such processes as amodal completion and illusory contour formation. Results did not support a difference in processing styles between adolescents on the autistic spectrum and controls, suggesting that if there is a difference in perceptual organization, it is subtle.

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56.337 **Would letters forming a word survive motion-induced blindness?**

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Motion-induced blindness (MIB) refers to fluctuation in awareness of salient stimuli superimposed on a moving mask (Bonneh et al., 2001). MIB is known to be influenced by various perceptual grouping cues (Mitroff, Scholl, 2005). However, a question remains whether grouping of separate stimuli into a meaningful perceptual unit would be enough to prevent them from independent perceptual disappearance and reappearance. In other words, is there a word superiority effect (Cattell, 1886) for letter stimuli which are expected to be independently fluctuating in awareness due to MIB? In our experiment, we analyzed dynamics of MIB measured as disappearance frequency and duration for separate letter stimuli forming a word as compared to standard dot stimuli and meaningless letter strings.

Four types of stimuli organized in a line above the fixation were presented to 21 subjects against the moving pattern in a counterbalanced block design: three yellow dots similar to used by Bonneh et al., three yellow empty circles (O's), three letters forming an easily readable Russian word (KOT, which means "a cat"), and three consonants, with two of them repeating the framing consonants of the word (KHT). No statistically significant differences either in the amount of disappearances of separate stimuli or in the total duration of disappearances between four conditions have been revealed. Thus, in spite of the recent neurophysiological evidence of early influences of WSE upon visual processes (Martin et al., 2006), letters against the moving mask seem to suffer from MIB before they can be grouped into a meaningful word.

56.338 **Similarity grouping is feature selection**

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Through the influence of grouping cues such as physical connection or sharing similar features, we often treat objects in the world as belonging together. While there is ample work exploring the behavior of these cues and their relative dominance, less is known about the mechanisms underlying how they are processed. Using a novel paradigm, we demonstrate a fundamental division between the mechanisms of connectivity grouping, which appears to be processed in parallel across the visual field, and similarity grouping, which appears to be constructed for only one group at a time.

In a number estimation task, subjects judged which of two consecutive displays contained more objects. At the same time, one display had its objects grouped into pairs by either a 1-pixel connecting line, or local similarity of shape, color, orientation, or luminance. Past work showed that when objects were grouped by a line, subjects could not avoid counting groups instead of individual objects, and underestimated the number of objects in the grouped displays. This underestimation helped performance when the smaller display was grouped, and hurt performance when the larger display was grouped.

In the present study, connectivity grouping again led to strong underestimation. Strikingly, none of the similarity grouping cues led to any underestimation. Because number estimation over an entire scene is only affected by grouping processes that operate in parallel, connectivity grouping must be processed in parallel. In contrast, we argue that similarity grouping is serially constructed for one group at a time, via attentional selection of the dimension of similarity. Counterintuitively, this predicts that when we attend to a group of red objects, the grouping among a set of green objects falls apart. This dissociation has been invisible with past tasks based on introspection, which can only reveal the nature of the currently attended group.

56.339 **An Objective Measure of the Relative Strength of Perceptual Grouping Cues Using Object-Based Attention**

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The principles of perceptual grouping (i.e., common motion, color similarity, proximity, collinearity, etc.) were described nearly a century ago by the Gestalt psychologists. Despite abundant qualitative and phenomenological evidence, a quantitative measure of the relative strength of these grouping cues has eluded researchers. We report data from a new method that provides an objective, quantitative measure of grouping strength. Stimuli were a modified version of the Egly et al. (JEP: General, 1994) double-rectangle display to which we added orthogonal occluders (cf. Moore et al., Psych. Sci., 1998) creating four discrete surface patches which could be grouped two different ways. Each trial began with a linking display that biased grouping in one direction. For example, during color similarity linking, two patches were green while the remaining two were blue-green. An attention cue then appeared at one patch followed by a target (a convex or concave change in the contour of one of the four patches) at one of three locations: the cued location (70%), the uncued patch in the cued object (15%), or the patch in the uncued object equidistant to the cue (15%). Discrimination response times were faster to uncued targets on the cued object than to those on the uncued object (the same-object advantage) for each grouping principle we tested. Furthermore, by manipulating an intrinsic parameter of each grouping principle (e.g., chromatic difference for color similarity; motion phase for common motion), we were able to parametrically manipulate the strength of grouping. Data obtained with this method constrain predictions about which grouping principles will dominate when two or more cues conflict. This method provides a means for testing a variety of hypotheses concerning perceptual organization.

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56.340 **State-Dependent Dynamic Grouping and the Perception of Motion**

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A major legacy of the Gestalt Psychology movement was the determination that perceptual organization is based on laws of grouping. In many of their demonstrations, effects of grouping variables on the compositional structure of a stimulus are perceptually realized as qualitative changes in the spatial pattern perceived for the stimulus (e.g., multi-element grids of dots are grouped into horizontal rows or vertical columns). This, however, is not generally the case when multiple surfaces are connected to form an object. Changing the luminance of one surface of an object can change the object's compositional structure without resulting in the perception of a qualitatively different spatial pattern. We now show, however, that changes in the compositional structure of objects can be perceptually realized through motion created by dynamic grouping, even without qualitative changes in the perceived spatial pattern. (Such changes co-occurred with motion in an earlier study of how grouping/parsing affects on motion perception; Tse, Cavanagh & Nakayama, 1998.) Method. Stimuli were composed of two or three connected surfaces, one of which changed in luminance. Motion was perceived within the changing surface, as in the line motion illusion. Results. We have found that changes in grouping variables (luminance and texture similarity; good continuation) that increase a surface's affinity with an adjacent surface result in motion perception away from the boundary separating the surfaces. Motion is toward the boundary when affinity decreases. Moreover, the likelihood of a change in affinity resulting in motion perception depends on the nonlinear summation of the affinities ascribable to individual grouping variables (specifically, an accelerating nonlinearity), and the surface's affinity-state prior to the change in grouping variables. Additional experiments have shown that compositional structure affects how motion due to dynamic grouping and motion due to changes in edge and surface contrast function in tandem.

56.341 **Perceptual grouping in a spiking laminar cortical model**

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Visual grouping of collinear fragments is thought to rely largely on long-range horizontal connections in layer 2/3 of primary visual cortex (Gilbert et al., 1996) and extrastriate cortex (Von der Heydt et al., 1984). Such interactions have been incorporated into neural models of perceptual grouping (Grossberg and Mingolla, 1985), which have been extended to LAMINART models that incorporate detailed laminar circuitry (Grossberg and Raizada, 2000). These models have explained and predicted a wealth of psychophysical, anatomical, and neurophysiological evidence. They have not, however, incorporated spiking dynamics to address data that depend on how individual spikes and bursts of spikes are influenced, in particular synchronized, by perceptual grouping circuits. The current spiking laminar cortical model includes identified cells in, among others, layers 6, 4 and 2/3 of both V1 and V2. Model cells are implemented as two compartments, where one compartment is a dendrite and the other one is a soma governed by Hodgkin-Huxley equations. Cells are connected via AMPA and GABA synapses and are constrained by slow conduction speeds for long-range horizontal connections (Bullier, 2001). The model is simulated on a variety of diagnostic experimental conditions. Numerical results show that the model, when constrained by realistic spiking dynamics, can account for electrophysiological data about spikes, while also displaying essential psychophysical properties of perceptual grouping.

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56.342 **Perceptual Structure Facilitates Spatial Filtering**

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Our goal is to better understand object-based attention using the spatial filtering paradigm. In our version of spatial filtering (Palmer & Moore, submitted), observers are asked to detect stimuli at a cued location (targets), while ignoring otherwise identical stimuli that are presented at nearby locations (foils). Contrast of targets and foils are varied in order to obtain psychometric functions for both the target and the foil at various spatial separations. The foil psychometric function provides a measure of the extent to which stimuli in uncued locations are processed despite efforts to ignore them. Results from this paradigm show large effects of separation on the asymptote of the foil psychometric function and little or no effect on the threshold. These results rule out contrast gain as the primary mechanism of selection, and instead are consistent with an all-or-none mixture as the selection mechanism. We used this paradigm to measure an effect of perceptual structure on spatial filtering. We presented an outline rectangle in the visual field near where targets and foils appeared. The rectangle provided no specific information about the target location, but instead provided a visual context on which the spatial filtering paradigm was superimposed. Results showed an effect of perceptual structure on spatial filtering. Specifically, selection of a target location across a boundary from a foil location was substantially better than when they were not separated by a boundary. Additional experiments investigate the extent to which spatial filtering in this context can be accounted for by a contrast gain or an all-or-none mixture model.

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Tuesday, May 13, 2:30 - 6:30 pm
Poster Session, Royal Palm Ballroom 6-8

Motion: Spatial Interactions and Aftereffects
Perception and Action: New Issues

Motion: Spatial Interactions and Aftereffects

56.401 **The effects of aging on the bandwidths of directionally-selective mechanisms**

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Psychophysical studies show that motion detection thresholds are elevated, and the accuracy of perceived direction is diminished, in older human subjects (Bennett et al., 2007, Vision Res, 47, 799-809). This result is consistent with the hypothesis that the bandwidth of directionally-selective channels widens with age. The current experiment examined this hypothesis directly by estimating directional selectivity in groups of younger (n=7; mean age = 20.6) and older (n=7; mean age = 67) subjects using a notched-noise masking technique. The stimuli were 500 ms presentations of random dot kinematograms that drifted coherently to the right (0 deg) or left (180 deg) at 5 deg/sec. The subject's task was to identify the direction of motion, and thresholds were estimated by varying dot contrast. The dots were embedded within a mask comprised of high-contrast dots that moved in random directions on each frame. The direction of each mask dot was drawn from a random distribution spanning 360 deg, with the restriction that the direction could not fall within the ranges of 0±n and 180±n deg. The width of the noise notch, 2n, was varied from 0 to 179 deg in separate blocks. In both groups, thresholds increased as 2n increased from 0 to 10, and then decreased gradually as 2n increased to 179 deg. However, thresholds decreased more rapidly in younger subjects: specifically, the quadratic trend in the threshold-vs-notch function was significantly greater in younger subjects (F(1,96)=5.03, p=.027). This result is consistent with the claim that directionally-selective channels are more broadly tuned in older subjects. We currently are extending this result to other dot speeds and a broader range of older subjects.

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56.402 **The Effect of Retinal Eccentricity on the Discrimination Of Global Motion Direction**

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The present study examined sensitivity to the direction of global motion presented to the retinal periphery. The stimuli consisted of two sequentially presented random-dot cinematograms (RDCs) of different average angular directions. The direction of each individual dot was drawn separately from a Gaussian distribution of directions every 6th frame (12 frames total at 85 Hz). The standard deviation of this distribution was manipulated to vary the level of noise. The values used were 0, 4.5, 18, and 36 degrees. To examine the effects of retinal eccentricity the RDCs were offset from a focal point by 0, 8, 22, or 40 degrees of a visual angle. To ensure that that the participants gaze maintained fixation on the focal point, an Eyelink II eye tracking system was employed. 5 college age participants were asked to discriminate between the two sequentially presented displays at all four retinal eccentricities. Additionally, noise was examined to determine if there would be any interaction effects at different retinal eccentricities. The results indicate main effects of eccentricity and noise level. The interaction of noise and eccentricity was not significant. Post hoc analyses indicated significant differences between the 0 and 40 degree eccentricities. These results indicate there is a significant loss in the ability to discriminate global motion only at extreme eccentricities. To assess if this loss could be attributed to a general loss of visual acuity in the retinal periphery a modified Landolt-C test was administered at retinal eccentricities that matched those used in this study. The results indicate a significant decrease in acuity for the 0 and 8 deg retinal eccentricities when compared to the 40 degree eccentricity. These results suggest that pooling velocity to recover global motion is preserved at more eccentric regions in the visual field despite the loss in acuity.

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56.403 **Local and global inhibitory influences associated with large-field stimuli**

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We recorded human initial ocular-following responses (OFRs) when vertical sine-wave gratings were subject to horizontal motion in the form of successive ¼-wavelength steps. The gratings could occupy the full screen (45° wide, 30° high) or a number of horizontal strips, each 1° high and extending the full width of the display. These strips were equally spaced vertically. In Experiment 1, the gratings had a contrast of 32%. Increasing the number of strips could reduce the response latency by up to 20 ms, so the magnitude of the initial OFRs was estimated from the change in eye position over the initial open-loop period measured with respect to response onset. A single (centered) strip (covering 3.3% of the screen) elicited robust OFRs, and 3 strips (10% coverage) were sufficient to elicit the maximum OFR. Increasing the number of strips to 15 (50% coverage) had little impact, i.e., responses had asymptoted, and further increasing the coverage to 100% (full screen image) actually decreased the OFR so that it was now less than that elicited with only 1 strip. In Experiment 2, the contrast of the gratings could be fixed at one of four levels ranging from 8% to 64% and the OFR showed essentially the same pattern of results except that the lower the contrast, the lower the level at which the responses asymptoted. This indicated that the asymptote was not due simply to some upper limit on the magnitude of the eye movement or the underlying motion signals. We postulate that this asymptote is the result of normalization due to global divisive inhibition. We further suggest that the decrease in the OFR when the image filled the screen was due to the increased continuity of the gratings which we postulate would favor the local inhibitory surround mechanisms over the central excitatory ones.

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56.404 **Judgment of absolute direction in natural scenes**

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Much of our understanding of motion perception derives from studies employing 2AFC judgments about the motion of simple grating or dot patterns. The validity of such an approach is predicated on subjects' errors being Gaussian-distributed and (largely) unbiased. However it is increasingly clear that the operation of the human visual system is optimized to guide real behaviour in real visual environments. To examine the validity of these assumptions using more natural stimuli and tasks, we had subjects make a judgment of the absolute direction of a translating fractal or natural scene (by adjusting the orientation of a subsequently viewed line). We analysed pooled direction-estimates to estimate the bias, variance, skew and kurtosis of error distributions as a function of motion direction. Our results broadly confirm several known phenomena such as the oblique effect for motion (OEM; best discrimination around cardinal directions), and reference repulsion (the tendency not to report motion in the cardinal directions). However we also report several new phenomena. First estimates are much more biased around oblique directions, but not greatly more variable, and this can contribute substantially to the OEM. Second, subjects' errors are not only somewhat more tightly distributed around the cardinals (the OEM) but are more leptokurtic ("peaky"/heavy-tailed), a property that violates the assumptions of psychophysical threshold estimation, elicits lower thresholds, and is likely to be linked to the orientation structure of natural scenes.

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56.405 **Seeing multiple global directions: A maximum capacity limit of three**

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Though much is known about the global-motion stage, relatively little research has addressed the number of global directions that can be perceived simultaneously. Recently, a restricted capacity has been reported for the detection of transparent motion, which occurs when multiple global directions are present within the same spatial region. No more than two transparent-motion signals can be detected simultaneously when defined by direction differences, though three signals can be seen when distributed across multiple independent global-motion systems. The aim of the present study was to determine whether this three-signal capacity reflects the specific mechanisms of transparent-motion detection or a more general restriction on the detection of global-motion signals, particularly in light of the higher capacities reported for visual attention and multiple object tracking. Using both transparent motion and spatially segregated stimuli, observers were required to indicate which of two temporal intervals contained the most signal directions. Simultaneous processing was ensured through brief durations (200ms) and comparisons between n and n+1 directions, eg. 3 vs. 4. When spatially segregated signals were interleaved in patches across the entire stimulus, no more than two directions were seen, as with transparent motion. In contrast, separating the signal directions into distinct spatial regions allowed the detection of up to three signals. Importantly, the signal intensities required to detect multiple directions did not vary across these signal arrangements. This suggests that the two-signal capacity results from signal-to-noise pooling across the entire stimulus, while the higher capacity for spatially distinct signal regions reflects independent global pooling within each signal region. Together, these results demonstrate that the capacity limit of three is not restricted to transparent-motion detection. Rather, it represents a strict upper limit for global-motion processing that is insensitive to manipulations of signal intensity.

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56.406 **Access to retinal image movement during pursuit eye movement is only direct at high motion coherence**

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Observers can directly access retinal motion signals prior to the stage that combines retinal movement with eye-velocity information (Freeman, Sumnall & Snowden, 2007, Perception, 36S, 4). We investigated whether this remains true for motion stimuli decoded by the dorsal pathway, primarily because this region also receives extra-retinal input. Speed discrimination thresholds were measured for low and high motion coherence using different mixtures of pursuit eye movement. On each trial, observers pursued a target dot for 2s. Midway through the pursuit, a large dot pattern was presented for 0.25±0.01s, during which the target disappeared. The stimulus consisted of signal and noise dots. The retinal speed of the signal dots varied according to a staircase around a pedestal of 4deg/s. Retinal motion was always in the opposite direction to pursuit. The retinal speed of noise dots was constant at 4deg/s. In the 'homogeneous' condition, intra-interval pursuit target motion was constant (4,4; 8,8; 12,12deg/s). In the 'heterogeneous' condition, intra-interval pursuit varied (4,8; 8,12; 4,12deg/s). These were crossed with coherence levels of 100, 50 and 35.4% signal. Psychometric functions were constructed either as a function of objective speed or retinal speed. The latter was based on eye movement recordings. Results showed no difference between homogeneous and heterogeneous retinal thresholds for low noise conditions. Observers therefore had direct access to the relevant retinal signal. In support of this, the ratio of retinal to objective threshold was less than one in the heterogeneous condition. However, in the high noise condition, the homogeneous retinal threshold was about half that of the heterogeneous threshold. Moreover, the ratio of retinal to objective thresholds rose to around 4 in the heterogeneous condition. These results suggest that when the relevant retinal signal resides in the dorsal pathway, extra-retinal signals are automatically combined and direct access is prevented.

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56.407 Diminished center-surround inhibition in patients with a history of depression

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Center-surround antagonism is one of the most fundamental properties of the visual system and is thought to rely on interactions involving the neurotransmitter GABA. The perceptual consequences of this antagonism have been demonstrated in psychophysical studies of visual motion processing (Tadin et al., Nature 2003). Increasing the size of a low contrast stimulus will increase its discriminability due to spatial summation. Increasing the size of a high contrast stimulus, however, results in spatial suppression, and behavioral performance is impaired. Interestingly, this spatial suppression is not exhibited in older adults, presumably because of decreased GABAergic interactions (Betts et al., Neuron 2005). Using a visual motion processing paradigm, we tested whether surround inhibition is similarly diminished in medication-free patients with a history of recurrent unipolar depression, a disorder which has been linked to reduced levels of occipital GABA (Bhagwagar et al., Biol Psych 2007). Participants viewed drifting gratings of either low (2.8%) or high (92%) contrast and small (0.7 deg) or large (5.0 deg) size. The task was a two-alternative forced choice discriminating between leftward and rightward direction of motion. The duration of each exposure was stair-cased to obtain the threshold duration for each of the four conditions. Both healthy control and recovered depressed participants exhibited comparable amounts of summation for the low contrast stimuli. However, the patient population showed significantly reduced spatial suppression for the high contrast stimuli compared to the age-matched controls. This suggests that decreased GABA levels associated with depression may have ubiquitous and persistent consequences, even for basic sensory processing.

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56.408 A model of V1-to-MT connectivity accounts for motion perception anisotropies in the human visual system

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We used the motion aftereffect (MAE) to psychophysically characterize tuning of motion perception in the human visual system. Hiris and Blake (1992) measured the strength of the MAE for random dot kinematogram (RDK) adapter stimuli containing either one direction of motion or a range of directions and found that the MAE was stronger when the adapter stimulus included a moderate range of directions. Thus, the function relating MAE strength and the range of directions in the adapter stimulus provides information regarding the bandwidth of direction tuning of motion perception. We compared the directional anisotropy in MAE bandwidth to the well-known oblique effect in motion direction discrimination. In agreement with previous research, we found that subjects had lower motion direction discrimination thresholds for cardinal compared to oblique directions (Gros et al., 1998). For each subject, we then measured MAE bandwidth for a cardinal and for an oblique direction. The MAE bandwidth was consistently smaller for the cardinal direction, suggesting a fundamental similarity between motion direction discrimination and tuning of the MAE.

We adapted a computational model of V1-to-MT connectivity (Rust et al., 2006), introducing anisotropies in the connections between V1 and MT that result in larger bandwidth of tuning in MT cells tuned to oblique compared to cells tuned to cardinal directions. Model simulations predict an oblique effect for both direction discrimination and MAE tuning, consistent with our experimental results. The model is also in accord with a recent report that the magnitude of the oblique effect in direction discrimination is inversely proportional to the bandwidth of the stimulus (Dakin et al. 2005). Finally, our model also predicts anisotropies in the tuning of large populations of cells in areas MT and V1, and we are currently testing this prediction using fMRI.

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56.409 Static and flicker MAE for global motion

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[Purpose] After the exposure to overlapped sinusoidal gratings with different spatial frequencies moving in the opposite directions, motion aftereffect of the high spatial frequency grating was seen with a static test while that of the low spatial frequency was seen with a flicker test and we interpreted the results by assuming the slow and fast motion detectors (VSS '06). There was no difference in flicker MAE between the global and local motion while longer MAE was found for global motion in static MAE, suggesting selective contribution of the slow motion detector to global motion (VSS '07). The purpose of the study is to investigate how the slow and fast motion detectors differ in contribution to global motion perception.

[Experiment] We measured MAE duration of rotation or expansion/contraction using four gabor patches arranged circularly (above, right, below and left of the fixation). Each patch had two sinusoidal components with different spatial frequencies (0.53 and 2.13 c/deg), which moved in the opposite directions at 5 Hz. In one condition, the four patches presented simultaneously while top and bottom pair and left and right pair were presented alternately every one second in the other condition. A blank field was presented every one second to equate the duration of local adaptation in the four-patch conditions to that in two-patch alteration. After 10, 20 or 40s of adaptation, MAE duration was measured in the static or the flicker (4 Hz) version of the four gabor patches.

[Results] The static MAE showed longer duration after the four-patch adaptation than after two-patch adaptation. In contrast, the flicker MAE showed similar duration in all adaptation conditions. The results indicate that the output from the slow motion detector is integrated for seeing global motion.

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56.410 Motion aftereffect and motion fading: Same underlying mechanisms?

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Purpose: Prolonged viewing of a moving stimulus results in illusory motion of a test stimulus in the opposite direction (MAE) and illusory slowing (motion fading, MF) of the adaptation stimulus. The two phenomena address different aspects of motion, but they might (or might not) be effects of the same underlying neural mechanisms. Here we studied this hypothesis. Methods: In 3 experiments, we compared MAE and MF directly with the same adaptation stimuli and the same observers. Magnitudes of MAE and MF for different adaptation durations, 1st and 2nd order stimuli, monocular and dichoptic presentation, and center/surround structure with high and low contrast were recorded. Results: MAE and MF size varied similarly as a function of adaptation duration and for 1st and 2nd order stimuli. Interocular transfer (IOT) for MAE was significantly smaller for 1st than 2nd order stimuli, but for MF, IOT was equivalent for both stimulus kinds. MAE was stronger for high than low contrast stimuli, but MF was better for low than high contrast stimuli. Conclusion: The results support the hypothesis that both phenomena do not arise from the same underlying neural mechanisms, and that MF is determined more by mechanisms at higher levels of processing.

56.411 Adaptation precedes inhibition for motion direction interactions

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Neural adaptation and inhibition are thought to underlie the direction aftereffect (DAE) and direction repulsion, respectively. With these phenomena one over-estimates the difference between a test's motion direction and that of a previous adaptor (DAE) or simultaneous distractor (direction repulsion). Two sets of experiments addressed whether these phenomena reflect neural activity at the same or different stages of motion processing. In the first series of experiments we used a recently reported phenomenon, the binary direction aftereffect, to demonstrate that the DAE precedes direction repulsion. The binary direction aftereffect was induced by adapting to a transparent, mixed-speed stimulus in which fast dots moved 25 deg off vertical and slow dots moved 25 deg to the other side of vertical. When viewing a post-adaptation test stimulus containing fast and slow dots moving vertically, both speed sets were perceived as moving in an off-vertical direction away from their respective adaptor speeds. When a single-speed test stimulus was used, the speed-specific aftereffect was significantly reduced. This difference in DAE magnitude between mixed- and single-speed test stimuli was consistent with direction repulsion occurring subsequent to direction adaptation within the test stimulus. The second series of experiments had observers adapt to a direction repulsion stimulus, and then judge the direction of a uni-directional test stimulus. The test stimulus direction was half way between one of the adaptor directions and its perceived direction. If the DAE precedes direction repulsion, one would predict that apparent test direction would be determined by the physical directions of the adaptor. If direction repulsion precedes the DAE, apparent test direction would be determined by the perceived directions of the adaptor. Observers' responses were consistent with a DAE induced by the physical adapting directions. The results of these experiments demonstrate that the DAE precedes direction repulsion in the visual motion processing hierarchy.

56.412 **Visual Velocity Aftereffects in Radial Flow: Inherited and Unique Features**

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A realistic radial flow field contains a range of local velocities, yet global movement is perceived at a single speed. The present study explores the contribution of complex motion sensors to this velocity percept, by recording changes in speed perception and speed sensitivity after adaptation to "scrambled", or to coherently expanding/contracting large-scale radial flow. A drifting concentric sine grating, conveying motion in depth, was confined to non-abutting display sectors, defining different global patterns of flow. After adapting to a flow pattern in one display region, observers compared its speed to that in a non-adapted region. Velocity aftereffects (VAE-s) from continuous unchanging motion were independent of the pattern of flow: apparent speed was reduced and speed discrimination improved in inverse proportion to the speed of the test. Sensitivity to speed differences, however, was pattern specific - it was superior in expansion. Also, adapted expansion recovered its apparent speed when tested against non-adapted contraction, and direction reversals of the adapter attenuated scrambled, but not coherent VAE-s. No VAE-s were recorded for test motions opposite to the adapted direction. We conclude that higher-order optic flow mechanisms are not uniquely involved in velocity estimation per se, but modulate velocity judgments in response to changes in the ongoing flow. Independent expanding and contracting velocities rival and do not suppress one another when juxtaposed in space or in time. This unique motion opponency appears to be transient and depends on the 3D quality of the flow. It ensures that the speed of approaching objects is correctly perceived, regardless of stimulus history.

56.413 **System Dynamics Modeling of the Optic Flow Motion Aftereffect**

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We present a system dynamics model of a simulated real-world optic-flow motion aftereffect (i.e., illusory sense of backward self-motion induced by prolonged viewing of expansive optic flow). To induce the motion aftereffect (MAE), observers viewed on a large display a simulated real-world scene in perspective view over which self-motion was simulated (simulated height above the ground plane = 5 m). The scene was composed of uniform gray terrain upon which a variable number of vertical poles were placed. The poles, whose number ranged from 36 to 576 poles per square km, served as carriers of optic flow information. We also examined terrain with texture. Observers adapted to the optic flow for a duration of either 10, 30, 120, 240 or 480 seconds. Following adaptation, observers viewed a static version of the scene (i.e., the last frame of the simulation) which served as a stationary test pattern. Because the test pattern was static, the response of low-level as well as higher level motion mechanisms likely contributed to the aftereffect. Results: aftereffect duration was approximately proportional to the square root of adaptation duration up to the longest adaptation duration tested (480 secs), at which point aftereffect duration was approximately 50 secs. Moreover, when the MAE was measured across different combinations of speed of simulated self-motion and pole density, the aftereffect was tuned to speed rather than the temporal frequency of stimulation. A system dynamics simulation of the Grunewald-Lankeet computational model (e.g., van de Grind, van der Smagt & Verstraten, 2004) showed that their model does not predict relatively long MAE durations, such as those found in the present study. We discuss how modifications to their mathematical model can be made to account for such data.

56.414 **The involvement of local motion adaptation in global motion aftereffect**

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Bex, Metha & Makous (1999) have reported that adaptation to a circular global motion generated by four Gabor patches induce a global motion aftereffect (MAE) in four Gabor test-patches located in-between adaptation patches. However, these results could result from a spillover of local motion energy or existence of motion receptive fields much larger than the adapting and test patches. In order to test this possibility, in this study, we varied the number of test patches and compared the duration of MAE. The adaptation stimulus was an array of four Gabor patches similar to Bex et al., and one, four, and eight test patches were used. The patches in the one- and four-patch conditions overlapped with those of adapting patches. In eight-patch condition, four patches overlap with the adaptor but the other four were placed at in-between positions. It was found that MAE in the four-patch condition was strongest. The result that MAE is stronger in the four- than in the eight-patch condition strongly argues that the global MAE reported by Bex et al. was really a global MAE, since if it was caused by a spillover or large RFs, the eight-patch condition in this study should produce stronger MAE than the four-patch condition. The efficiency in tapping the global MAE should be higher with eight patches. When eight patches were used in adaptation and MAE was tested by four and eight patches, eight patches produced stronger MAE. Thus, the reduction in the eight-patch condition in the four-patch experiment was probably caused by some inhibitory or subtractive process when local, component MAEs are integrated. These results, therefore, suggest that global MAE has two components. One is caused by adaptation of a high-level global motion mechanism, and the other comes from reorganization of low-level local MAE.

56.415 **Making sense of motion adaptation**

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One of the fundamental tenets of sensory biology is that sensory systems adapt to environmental change. It has been argued that adaptation should have the effect of optimizing sensitivity to properties of the variable environment (Sakitt and Barlow, 1982; Wainwright, 1999; Stocker and Simoncelli, 2005). Previous efforts to support this premise in motion adaptation have produced controversial results (e.g., Clifford and Wenderoth, 1999; Krekelberg, van Wezel, and Albright, 2006). We have developed a normative-economic theory of motion adaptation which assumes that adaptation in the visual system amounts to finding a new balance of stimulus and measurement uncertainties as the stimulation changes. Stimulus uncertainty is determined by the statistics of stimulation whereas measurement uncertainty is determined by the uncertainty principle of measurement (Gabor, 1946; Gepshtein, Tyukin, and Kubovy, 2007). The theory is economic in the sense that it prescribes how system resources – motion sensitive cells – ought to be reallocated across the parameters of stimulation in face of variable environment. The theory predicts specific changes of the spatiotemporal sensitivity surface (Kelly, 1979) as a function of environmental statistics, such as to minimize errors in the estimation of speed, stimulus location, and stimulus frequency content. The adaptive optimization is manifested both as global changes in behavioral spatiotemporal sensitivity and as changes in tuning of the motion-sensitive neurons. The theory predicts a counterintuitive pattern of sensitivity change similar to the one that have puzzled researchers of motion adaptation. For example, sensitivity to the adapting speed either increases or decreases depending on the parameters of stimuli used to measure the effect of adaptation; sensitivity also changes for speeds very different from the adapting speed.

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Perception and Action: New Issues

56.416 Neural mechanisms underlying grapheme-colour synesthesia

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In grapheme-colour synesthesia, perception of a grapheme induces the percept of a specific colour. In the present study, the neural processes underlying grapheme-colour synesthesia were investigated using an oddball paradigm and EEG recordings.

For each of the 8 synesthetes, we presented a set of 6 different graphemes that elicited a synesthetic colour experience within one colour category (e.g. yellow (standards)). These standards were presented in black on a grey background. There were two types of oddballs: first, graphemes that induced a synesthetic colour from a different colour category (e.g. red) than the standards; and second, physically coloured graphemes. Each of the 8 control participants received the stimuli that were similar to the stimuli of one of the synesthetes. The task was to respond as quickly as possible when an oddball stimulus appeared.

The reaction times of synesthetes to physically coloured oddballs were comparable to those of the controls. Reaction times to 'synesthetic' oddballs, however, were significantly longer (on average 53ms).

The P300 ERP component measured at Pz showed a significantly larger amplitude for the physically coloured oddball compared to the standards in control participants and synesthetes. Moreover, the synesthetes also revealed a larger amplitude for synesthetic oddballs compared to the standards. Interestingly, the P300 related to the synesthetic oddball was significantly delayed (56.5 ms on average) compared to that of the physical oddballs. This delay shows a striking resemblance to the delay in reaction times for synesthetic oddballs. In conclusion, the synesthetic percept takes longer to develop than a normal colour percept and this is reflected in the ERPs as well as the reaction times.

56.417 Duration estimation of one's own reactive and proactive motor responses

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Can one reliably estimate the timing of his/her own motor actions? The question is answered positively for "reactive" and "proactive" tasks. In the reactive case, subjects generated a simple RT to a light-flash. In the proactive task, subjects pressed a key (anticipation-RT or ART) in synchrony with a virtual or actual/norm third flash in a sequence of three flashes presented at a constant pace (400, 500 or 600 ms interflash intervals). RT and ART key-presses did or did not entail a simultaneous visual feedback (light-flash). Immediately after their action, subjects provided a binary 'fast'/'slow' meta-judgment of their RT or ART. Subjects were presented subsequently with playbacks (Pbk) of the recorded RT and ART stimulus-response sequences – with the recorded key-presses replaced with light-flashes – and provided a binary response on either the absolute duration between the first and second flashes (RT_Pbk), or on the duration between the second and third flashes relative to that between the first and second flashes (ART_Pbk). Metajudgment means were within milliseconds from the actually produced RT and ART. Compared to the variances of the latter two and to those of the corresponding playbacks, metajudgment variances were x3-4 and x2-3 larger, respectively. Visual feedback did not profit Meta_RT (as expected), but decreased Meta_ART variance by about x1.3, much less than expected from optimal cue summation. Instead, the presence of the norm decreased the Meta_ART variance by more than x10 (cross-trials calibration). The data support the notion that duration is mostly determined from assessing the timing of its bounding events one of which, for the metajudgment case, must be proprioceptive. On this assumption, the derived timing variability of a proprioceptive event is about 3 times that of a visual event. The significance of other noise sources (decision, motor, memory) is under test.

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56.418 Implicit measurement of uncertainty during classification of ambiguous photographs

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Experiments on perception often require decisions about difficult to discriminate stimuli, even when the observer is uncertain. Measurements of uncertainty, in addition to conventional measurement of performance can be useful in understanding perceptual experience. In this report we detail an implicit measurement of uncertainty in non-human primates that reflects the difficulty of discriminating stimuli and seems related to the strength of the neural signal in a discrimination task. We examined behavior and neural responses in inferotemporal cortex in two monkeys during performance of a two-alternative-forced-choice delayed match to sample task (2AFC-DMS task). The task required classification of a sample image as one of two choices; the monkey reported the choice by making a saccade to one of two choice images. Two of the sample images were identical to the two choices, but other samples were difficult to classify because they were altered versions of the choices. Performance with altered samples followed a predictable pattern, in which samples identical to the choices were easiest to classify and performance worsening as the dissimilarity of the samples from the choices increased. To obtain reward, monkeys had to saccade to the correct choice and maintain fixation on that choice for 500 ms. During this period, monkeys aborted over 60% of responses in incorrect easy trials, indicating an awareness that they had chosen incorrectly. The proportion of aborted incorrect trials decreased systematically as a function of the difficulty of the task, indicating decreasing awareness of incorrect responses. We sorted neural responses based on this measure of uncertainty – trials where the monkey aborted trials, compared to completed trials. Neural response selectivity for the sample images was higher in completed trials than aborted trials. These data suggest that the monkeys were aware of uncertainty, and that the uncertainty reflects the neural selectivity for the sample image.

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56.419 Motor Simulation & the Effects of Energetic & Emotional Costs of Depicted Actions in Picture Perception

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Psychological studies (Proffitt, 2006) have demonstrated that what one sees is influenced by one's goals, physiological state, and emotions. These studies demonstrate that there is a positive correlation between the physical demands (energetic cost) and perceived valence (emotional cost) of a task and the appearance of slant and egocentric distance in the environment. The studies are compelling. However, one can question whether their results are due to changes in the way participants perceived the orientation and extent of their environment or are instead artifacts of the way they judged the difficulty of expected tasks in particular contexts. We asked participants to sketch the rough spatial layout of several paintings as accurately as possible. In this type of task participants continuously compare what they have drawn against what they perceive. Therefore, participants performance can be interpreted as a means to directly measure of the spatial metric of perception. We chose two paintings by Andrew Wyeth as target images: "Christina's World" and "Winter, 1946." Participants were asked to draw the spatial arrangement of the key features of the scene depicted in the target painting twice: prior to being presented with biographical information about the subject of the painting condition; and then again after being told the biographical information that altered the perceived task demands or emotional valence of the events they depicted. We predicted that participants' drawings would differ in the two conditions indicating that: change in the energetic or emotional costs of the depicted action would cause them to perceive the depicted orientation of hills as steeper and distance between key landmarks as longer. Results from the energetic cost condition support this prediction. We will discuss our results and the suggestion that these types of effects reflect a role for motor simulation in perception (Witt, 2005).

56.420 **The effect of biking effort on perceived distance and slant**

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Previous research suggests that one's physiological state affects their perception of spatial layout. For example, the perceived steepness of hills is influenced by fatigue, poor physical condition, declining health, or being encumbered by a heavy backpack (Bhalla & Proffitt, 1999). This study extended previous work by investigating the effect of effort on perceived distance as well as perceived slant. Participants were avid cyclists who completed an intense bike ride covering either 66 or 100 miles. Participants made distance and slant estimates the day before the ride and immediately following completion of the ride. Participants verbally estimated the distance to 5 different targets which ranged between 4 and 14 meters and were placed in front of the observer. Different sets of distances were used for pre-ride and post-ride measures, although participants viewed 8m and 11m targets in both sets. Following either their pre-ride or post-ride distance estimates, participants verbally estimated the slant of a downhill slope. For both distance and slant estimates, there was a main effect of bicycling effort. That is, participants perceived targets to be farther away and slant to be steeper after expending energy and becoming fatigued from an intense bike ride. These results broaden the hypothesis that perception of spatial layout can be influenced by a person's physiological state to include the spatial layout of distances as well as slopes.

56.421 **High-precision capture of perceived velocity during passive translations**

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Although self-motion perception is believed to rely heavily on visual cues, the inertial system also provides valuable information about movement through space. How the brain integrates inertial signals to update position can be better understood through a detailed characterization of self-motion perception during passive transport. In this study, we employed an intuitive method for measuring the perception of self-motion in real-world coordinates. Participants were passively translated by a robotic wheelchair in the absence of visual and auditory cues. The traveled trajectories consisted of twelve straight paths, five to six meters in length, each with a unique velocity profile. As participants moved, they pointed continuously toward a stationary target viewed at the beginning of each trial. By using an optical tracking system to measure the position of a hand-held pointing device, we were able to calculate participants' perceived locations with a high degree of spatial and temporal precision. Differentiating perceived location yielded absolute instantaneous perceived velocity (in units of meters per second), a variable that, to the best of our knowledge, has not previously been measured. Results indicate that pointing behavior is updated as a function of changes in wheelchair velocity, and that this behavior reflects differences in starting position relative to the target. During periods of constant, nonzero velocity, the perceived velocity of all participants decreases systematically over the course of the trajectory. This suggests that the inertial signal is integrated in a leaky fashion, even during the relatively short paths used in this experiment. This methodology allows us to characterize such nonveridical aspects of self-motion perception with more precision than has been achieved in the past. The continuous-pointing paradigm used here can also be effectively adapted for use in other research domains, including spatial updating, vection, and visual-vestibular integration.

56.422 **Basketball Free Throw Accuracy Unaffected by Projected Background Displays Showing Motion or Emotion**

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It is common for fans at basketball games to try to hinder opposing free throw shooters by moving or behaving provocatively within their view. Distraction ideas that have been informally tested at college and professional games include presenting uniform motion by having fans move in concert, and showing provocative pictures near the endline. Yet, substantial research in perception-action supports that actions like ball throwing may be resistant to potential distortions and distractions. In the current study, we examine if images projected directly onto a white basketball backboard can affect shooting accuracy. Presumably this type of background stimulus represents a theoretical extreme that occurs immediately adjacent to the shooter's intended target, and may be approximated in real games which use clear Lucite backboards. The images that we projected onto the backboard included either continuous motion gradients to produce systematic movement, or provocative pictures to distract attention. The moving stimuli varied in speed (fast or slow), texture (dot or line), and direction (laterally or in depth). The emotionally distracting images varied in pleasantness. Ten participants each shot 44 free throws under the various background conditions, and ball position was measured using an eight-camera VICON motion-capture system. Our findings show that while there may be some systematic effects of background stimuli, there was not a significant general decrement in shooting accuracy. In particular, shooting accuracy with displayed motion in depth did not significantly differ from that with either lateral motion or blank control conditions, and with pleasant pictures it did not differ from with unpleasant ones. The findings suggest that background antics are not likely to have a notable impact on the free throw shooting accuracy of skilled players. More generally the findings provide further support for the robustness and independence of the perception-action system to resist distortion and distraction.

56.423 **Spatiotemporal statistics of motion through natural environments**

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The environments in which we live and the tasks we must perform to survive and reproduce have shaped the design of our perceptual systems through evolution and experience. Therefore, direct measurement of the statistical regularities in natural scenes has great potential value for advancing our understanding of visual perception. To study the perception of motion, Dong and Atick (1995) measured the spatiotemporal Fourier power spectrum of image sequences sampled from commercial and homemade movies. They found that the power spectrum was well fit by modeling the world as a collection of surfaces of 1/f noise translating relative to the image plane with a speed drawn from a power-law distribution. Unfortunately, their measurements were not specific to any perceptual task.

In order to study the natural scene statistics of motion in the context of a specific perceptual task, heading estimation, we measured scene statistics from movies of first-person translation through a forest environment. Image sequences were gathered in natural scenes using a calibrated camera mounted on a custom built sliding rail. Additionally, artificial image sequences were generated using a raytracer with a model of forest scenes based on measured natural scene statistics.

The power spectrum of the natural and artificial movies resemble each other qualitatively. At low temporal frequencies or at high spatial frequencies the power spectrum behaves as one would expect from Dong and Atick's translational motion model. At higher temporal or lower spatial frequencies, however, the power spectrum differs dramatically from the translational model's predictions. A likely explanation is that the expansion motion in the scene breaks the model's translational assumption. These results imply that it is important to sample natural scene statistics in a task specific manner. Also, the results suggest that using artificially generated scenes statistics can be a valuable supplement to natural scene measurements.

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56.424 **Frequency-phase analysis of postural sway induced by visual motion and galvanic vestibular stimulation**

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Postural control is influenced by vision and vestibular senses. The purpose of this study was to investigate temporal properties of visual, vestibular and cross-modal controls of posture. Visual motion of random-dots (5000dots, lateral cyclic motion, sinusoidal speed modulation, travel distance 11.6deg) was presented on a large-screen (width 2.43 x height 1.82m) by a rear-projector. Galvanic vestibular stimulation (GVS) was applied through left and right mastoid processes (0.1-0.5mA, sinusoidal amplitude modulation). Both visual motion and GVS induced lateral (leftward-rightward) postural sway back and forth. Observers' center of pressure was measure by a force plate at 60Hz.

In Experiment 1, either visual motion or GVS was presented for each trial. We varied the frequency of visual motion and GVS modulation at 0.1, 0.2, and 0.3Hz. Thus, the independent variables were the stimulus modality (Vision or GVS) and the frequency (0.1, 0.2, 0.3Hz). The sway data were analyzed using FFT, and its power and phase at the stimulus frequency were calculated. In results, GVS induced much stronger sway than visual motion. The GVS-induced sway was weaker for 0.3Hz modulation than lower frequencies. Phase (lag) of induced sway increased as stimulus frequency became higher (Vision: 13, 15, 20deg for 0.1, 0.2, 0.3Hz, GVS: 28, 97, 124deg). These results suggest that temporal lag of sway behind sensory stimuli is not accounted by phase constant, but better understood by time constant (250ms for vision, 1100ms for GVS) or their combination.

In Experiment 2 for the cross-modal sway, both visual motion and GVS were presented at the same frequency (0.2Hz) with different phase lags (0-360deg at 45deg step). We found the Visual-and-GVS-induced sway was strongest when vision lagged 90deg behind GVS, and weakest when GVS lagged 90deg behind vision. These results suggest that the vision and GVS are integrated in a weak fusion model to control posture.

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56.425 **Estimating Absolute Distances with Blurred Vision**

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Humans are able to accurately walk while blindfolded to the location of a previously viewed target, a paradigm called a visually-directed walking task. Task success requires accurately converting visual estimates of absolute distance into walked estimates. However, people underestimate distances when visual depth cues are severely reduced, as when targets are viewed in the dark (Ooi, Wu & He, 2001; Ooi, Wu & He, 2006). One possibility is that underestimation results from combining visual distance information with a prior bias for an upward sloping ground plane that results in perceptually shorter distances to targets (Ooi, et al., 2006). If so, then as visual information becomes unreliable, reliance on prior biases may increase resulting in greater underestimation. The current study investigated this hypothesis by blurring vision to manipulate variability in visual distance estimation. Twelve normally-sighted participants viewed targets in a hallway under three monocular viewing conditions: no blur, low blur (average Snellen acuity of 20/180), and high blur (20/675). Targets were pairs of high-intensity Light-Emitting Diodes located on the floor 3 to 11 meters from the observer. After viewing a target, participants walked to its perceived location blindfolded. Results indicated that the variability of distance estimates increased with both blur and target distance (standard deviations of participants' estimates for the 11 meter target: No Blur: 1.15 m; Low Blur: 1.78 m; High Blur: 2.32 m). Similarly, underestimation increased on average with increasing blur and distance (walked distances to the 11 meter target: No Blur: M = 9.92 m, SE = 0.25 m; Low Blur: M = 8.80 m, SE = 0.49 m; High Blur: M = 8.93 m, SE = 0.56 m). These findings show that blurred vision leads to greater variability and greater underestimation in visual estimates of distances, consistent with an increased reliance on prior biases for object distances.

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56.426 **A dissociation between haptic and visual distortion of perceived length**

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Analogues of many common visual illusions are found in the haptic modality possibly because haptic space is calibrated by vision. For the visual modality, we previously reported that deviations from a right angle in the L-configuration of the horizontal-vertical (HV) illusion led to an increase in the illusion if the angle was obtuse but to a decrease if the angle was acute. These findings are inconsistent with theories that postulate a visual anisotropy as the main basis for the HV illusion and they are furthermore not predicted by existing perspective theories. Here we test if this pattern reflects a distortion in length perception that also holds for the modality of haptic exploration.

Method: Seven naïve participants using their index finger haptically scanned two joined edges (one horizontal, the other diagonal or vertical) arranged in six different configurations: an acute (45°), right (90°) or obtuse (135°) angle in an L or mirror-L configuration, all lying within the horizontal plane. Participants scanned the first edge (either the horizontal or diagonal/vertical) and then indicated its perceived length by scanning along the second edge for what they perceived to be an equal distance.

Results: In contrast to the pattern observed for the visual distortion, haptic scanning errors indicated an HV illusion that was significantly larger for the right angle configurations (average illusion extent: 8.6%) than for the obtuse and acute angles (both 3%).

Conclusions: Contrary to what would be predicted if haptic space was calibrated by vision or if a common distortion of space acted on both modalities, we report a dissociation between vision and haptics in the perception of relative length. The pattern of haptic errors followed known motor biases, specifically, the overestimation of radial relative to tangential movements, rather than the distortion observed in the visual sense.

56.427 **Virtual limbs and body space: The effects of the rubber hand illusion**

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Hari and Jousmaki (1996) found that motor activity is initiated more efficiently in response to stimuli located on the responding hand as opposed to near the hand. In previous research, we have found a similar preference for stimuli located on controllable virtual limbs, and concluded that control over a virtual limb is crucial for the incorporation of that limb into body space (Short & Ward, in prep). However, it is well established in the rubber hand illusion that control is not necessary for incorporation, so we report here three experiments investigating the role of visuo-tactile feedback as a mediating factor in the preference for stimuli located on the body. The aim of these studies was to determine whether the experience of visuo-tactile sensation associated with the virtual limbs ('rubber hand illusion') could reinstate the preference for stimuli located on a limb not under the control of the participant. Our first experiment found that a rubber hand illusion could be invoked for a virtual limb. Our second and third experiments revealed that prior experience of concurrent visual and tactile feedback appeared to reinstate the bias for stimuli located on non-controllable virtual hands. We discuss these findings in relationship to current theories of personal space and body schema, and suggest that, since it is often the case that sensory feedback is only experienced from an object that is under control (such as the physical body), sensory feedback from a virtual limb (even illusory sensory feedback, as in the current experiments) may lead to the assumption that the limb is likely to be under control, irrespective of actual evidence of command over the object.

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56.428 **HAL: Human Activity language**

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We propose a linguistic approach to model human activity. This approach is able to address several problems related to action interpretation in a single framework. The Human Activity Language (HAL) consists of kinetology, morphology, and syntax. Kinetology, the phonology of human movement, finds basic primitives for human motion (segmentation) and associates them with symbols (symbolization). The input is measurements of human movement in 3D (signals), as for example produced by motion capture systems. This way, kinetology provides a non-arbitrary grounded symbolic representation for human movement that allows synthesis, analysis, and symbolic manipulation. The morphology of a human action is related to the inference of essential parts of the movement (morpho-kinetology) and its structure (morpho-syntax). In order to learn the morphemes and their structure, we present a grammatical inference methodology and introduce a parallel learning algorithm to induce a grammar system representing a single action. In practice, morphology is concerned with the construction of a vocabulary of actions or a praxicon. The syntax of human activities involves the construction of sentences using action morphemes. A sentence may range from a single action morpheme (nuclear syntax) to a sequence of sets of morphemes. A single morpheme is decomposed into analogs of lexical categories: nouns, adjectives, verbs, and adverbs. The sets of morphemes represent simultaneous actions (parallel syntax) and a sequence of movements is related to the concatenation of activities (sequential syntax). Nuclear syntax, especially adverbs, is related to the motion interpolation problem, parallel syntax addresses the slicing problem, and sequential syntax is proposed as an alternative method to the transitioning problem. Consequences of the framework to recognition of Action, imitation and Cognitive Science will be discussed.

56.429 **Prestidigitation: Easier to Fool the Eye than the Hand**

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Processing in the dorsal and ventral visual pathways has been studied in brain-damaged subjects. We sought to understand processing in these visual pathways in the normal human brain. To do this, we asked subjects to respond in two different ways to the same visual stimuli.

A target that emerged from the top or the bottom of the display traversed a field of leftward or rightward moving distracters, which induced an illusory deflection of the target (the Duncker illusion). In the hand-eye condition, the display was arranged such that the subject's hand was on the same virtual plane as the target and distracters. The subject's goal was to "stab" the target with a stylus before it reached a horizontal bar spanning the center of the display; we believe the dorsal pathway mediates such hand-eye coordination. In the cognitive condition, the subject saw the same display and decided where the target would have intercepted the central bar. The subject indicated a choice on a virtual keypad that appeared after the display concluded; we believe the ventral pathway mediates such cognitive tasks.

We found the effect of illusory motion in the cognitive condition but not in the hand-eye condition. In the cognitive condition, when the distracters were moving leftwards the subject reported the target to be headed to the right of the actual location, and vice versa. In the hand-eye condition, the motion of the distracters did not affect the subject's response. These results suggest a way to examine the two visual pathways separately in the normal human brain. By manipulating properties of the stimuli and distracters we are learning more about normal visual processing.

URL: http://tigger.uic.edu/~mikel/VSS/VSS2008_JA.pdf

56.430 **The French Drop Sleight: Deceptive Biological Motion**

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Purpose: To demonstrate the salience of an effect of the French drop sleight of hand illusion between expert, intermediate, and novice magicians. In addition, the extended purpose is to isolate the differences in motion between the three skill levels of the magicians and their contribution to the deception. Methods: Participants were asked to judge which hand of the coin was in after viewing a clip of one of three magicians (novice, intermediate, expert) in one of two conditions: either the magician taking the coin (true motion) or the magician giving the illusion of taking coin but actually keeping it in the same hand (deceptive motion). The performers were then outfitted with pressure sensors on the gripping fingers and the modulation of pressure was noted between both the true and deceptive conditions and across all three skill levels. Similarly, the magicians' trajectory of motion was observed using motion sensors equally placed along the arm, wrist, hand, and fingers of the three magicians in both conditions. Results: An effect was found between the three magicians (novice, intermediate, expert) with the participants responding less than chance when viewing expert, around chance when viewing intermediate, and better than chance when viewing the novice. It was also found that the change in pressure as the well as the trajectory differed across the three magicians. Conclusion: The greater majority of past literature in this field deals with the overt social cues of biological illusion yet this study highlights the distinct, biomechanical mechanism of such deceptive movement, suggesting that change in apparent pressure and trajectory are the key elements in this type of illusionary motion.

URL: ebv.skidmore.edu

56.431 **Moving thought: Directed movement guides insight in problem solving**

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Recent theories of embodied cognition suggest that cognitive processes are rooted in the body's interactions with the physical world. They propose that the mind uses the body to accomplish cognitive goals, both through direct action and by tapping into perceptual and motor resources to represent and manipulate information. In this study, we go beyond these claims, showing that cognitive processes can actually arise from and be influenced by the manner in which our bodies interact with our immediate environment. We investigated how movement interventions affected participants' ability to solve a classic insight problem. Participants attempted to solve Maier's two-string problem while occasionally taking 'exercise breaks' during which they moved their arms either in a manner related to the problem's solution (swinging arms group) or in a manner inconsistent with the solution (stretching arms group). Although many participants were unaware of the relationship between their arm movement 'exercises' and the problem-solving task, participants who moved their arms in a manner that suggested the problem's solution were 56% more likely to solve the problem than those in the inconsistent movement group. These results are consistent with our recent findings (Thomas & Lleras, 2007) that directed eye movements can also induce insight in another complex problem, Duncker's radiation problem. Together these series of findings strongly suggest that movement interventions influence cognition; in other words, our movements can guide our thoughts.

Tuesday, May 13, 2:30 - 6:30 pm
Poster Session, Orchid Ballroom

Multisensory Processing: High Level
Search 3

Multisensory Processing: High Level

56.501 **The Neural Representation of Dynamic Real-World Auditory/Visual Events**

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Events in the world are inherently multimodal. A ball bouncing provides correlated auditory and visual information to the senses. How are such events neurally represented? One possibility is that these distinct sources are integrated into a coherent percept of the event. Alternatively, auditory and visual information may be separably represented, but linked via semantic knowledge or their correlated temporal structure. We investigated this using event-related fMRI. Participants viewed and/or heard 2.5s environmental events, for example, paper ripping or door knocking, in two unimodal and three multimodal conditions:

1. Auditory only (ripping sound)
2. Visual only (movie of paper ripping)
3. Congruent Auditory/Visual (sound + movie of same instance)
4. Semantically Incongruent A/V (ripping sound + movie of knocking)
5. Temporally Incongruent A/V (ripping sound + movie of different ripping instance)

Of interest is the encoding of Congruent and Semantically Incongruent A/V events. The integrated proposal predicts sensory brain regions showing a differential response to semantic incongruencies, while under the separate representation account, there should be no difference. Critically, this multimodal response must be stronger than the responses for unimodal stimuli. We also consider whether integration processes function at the level of semantic congruity or at a fine-grained temporal level that binds sound to vision. The Congruent and Temporally Incongruent comparison addresses whether integrated multimodal responses arise due to A/V information from within the same semantic category. Alternatively, a single event gives rise to a high correlation between onsets, offsets, and temporal structures between domains. Such correlated information may be the "glue" that allows the brain to combine perceptually-distinct information into coherent representations of events. Preliminary results provide support for the perceptual integration of auditory and visual information originating from a common source, that is, one in which there is a correlation between the temporal structure across modalities.

56.502 Cross-modal Language Processing in the Visual Cortex of the Congenitally Blind

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In blindness, the visual cortex supports novel non-visual functions through mechanisms of cross-modal plasticity. Several fMRI studies suggest that cross-modal activation is related to semantic representation. It is unknown if these cross-modal responses to language processing reflect particular semantic categories. Further, it is unknown the extent to which these responses relate to the structural and metabolic alterations of visual cortex that accompany blindness.

We studied congenitally blind subjects and sighted controls using BOLD fMRI while they performed a semantic decision task. During scanning, subjects judged the plausibility of spoken sentences drawn from three semantic categories: visual ('the door is cracked); auditory ('the bee is buzzing'); and tactile ('the cloth is velvety'). Control stimuli consisted of sentences played backward (lacking semantic content) and white noise. In addition to these functional data, resting ASL-based perfusion and diffusion tensor imaging data were collected.

We have obtained preliminary data from 3 blind subjects and 2 controls. All three blind subjects demonstrated activation of occipital cortex, including the calcarine sulcus, for the contrast of forward- and backward-sentences vs. white noise, and further for forward-sentences vs. backward sentences. Visual cortex activity was not seen in control subjects. There was greater activation within visual areas in the left hemisphere compared to the right (% signal change L 1.34±0.64 vs. R 0.78±0.58; $t = 3.6$, $p = 0.07$). There were no significant differences in activation between semantic categories in any brain areas in these data. With additional subjects this comparison will be revisited. Also, extent of cross-modal activation will be related to the resting perfusion of occipital gray matter and the fractional anisotropy of occipital white matter.

56.503 Auditory recognition in dyslexics improves with visual and motor-visual practice

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Dyslexics differ from typical readers in visual and auditory perception. Dyslexics have wide and diffuse perceptual modes either in the visual or in the auditory domain and about 70% of them in both while those of typical readers are narrower in both domains.

Would practicing a regimen of practice for remediation of dyslexia result in the modification and changes of the perceptual modes?

After the initial psychometric testing, the auditory and visual perceptual modes of 16 Italian dyslexic children were characterized by measuring recognition of central and peripheral stimuli. The stimuli were pairs of letters, one in the center and the other in the periphery in vision and centrally uttered words in the cocktail-party effect in audition. Following, the dyslexic children were given a regimen of practice that included novel small-scale hand-eye coordination tasks and reading with a window-mask. After about six months and 30 minutes daily of practice, on average, the children were retested. The average reading scores showed significant improvements in most measures, there was a mild narrowing of the visual perceptual mode and surprisingly significant improvements of recognition of the centrally uttered words in the presence of speech mask. The recognition of the surrounding speech mask did not change much, hence the peripheral to central recognition ratio diminished, resulting in the narrowing of the auditory perceptual mode.

The resulting improvement of the auditory perceptual mode as a consequence of visual and motor-visual practice suggests a multi-modal factor that is common to the visual and auditory perceptual mode. We suggest it to be attention.

56.504 Characteristic sounds facilitate vigilance when targets are rare in visual search

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Characteristic sounds (without location information) facilitate target localization in visual search (VSS 2007). For example, when the target is a cat, a simultaneously presented "meow" sound speeds localization of the cat compared to other sounds and no sounds. Previously, the target was always present and different on each trial (indicated at the trial beginning). We tested whether this object-specific auditory-visual facilitation might benefit target detection in a vigilance paradigm when targets are rare and always of a specific category. Participants looked for different exemplars from a single category (guns or cats), pressing one button to indicate target presence and another button to indicate target absence. Targets were rare (10%). Each participant was tested in three blocks totaling 450 trials. In the target-consistent-sound block, participants heard sounds characteristic of the target category on every trial (different "meow" sounds if cats were the target category, and different gun sounds if guns were the target category). In the control condition, participants heard sounds characteristic of the other category on every trial (different gun sounds if cats were the target category, and different "meow" sounds if guns were the target category). In the third condition, participants heard no sounds (with the block order counterbalanced across participants). Target detection and distractor rejection were both significantly faster when target-consistent sounds were presented on every trial compared to when irrelevant sounds or no sounds were presented (with no evidence of a speed-accuracy trade-off), indicating that characteristic sounds increased target discriminability rather than simply biasing target responses. Thus, when people repeatedly search for rare targets of a specific category, presenting sounds characteristic of the target category on every trial facilitates target detection. If this auditory-visual facilitation persists for a longer time scale (hours), the technique could be applied to rare-target searches in real-life situations as in baggage screening.

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56.505 Plasticity of Crossmodal Spatiotemporal Effects in a Visual Search Task

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In this study spatiotemporal effects of audiovisual facilitation, and plasticity of this mechanism, were examined using a visual search task. Auditory cues preceding visual targets facilitate visual discrimination when the stimulus onset asynchrony (SOA) is short, <300ms, and inhibit visual discrimination when the SOA is long, >300ms. These crossmodal effects are spatially specific. The spatial specificity of the short-term enhancement of these effects can also be manipulated using oriented test stimuli and task irrelevant perceptual learning (TIPL), indicating that new crossmodal spatial cuing effects can be learned in the absence of focused attention (Beer, Batson & Watanabe, 2006). Additionally, there is a trend of interocular transfer with regard to the long-term inhibition of this effect for discrimination of high-level stimuli, such as faces and houses, yet no transfer or long-term effects are seen for oriented stimuli (Batson, Beer, Seitz & Watanabe, 2007). These findings suggest the involvement of more than one mechanism in the short- and long-term plasticity of audiovisual crossmodal links. To test this hypothesis, crossmodal pairings from the initial experiments (Beer, Batson & Watanabe 2006; Batson, Seitz & Watanabe 2007) will be applied to a visual search paradigm, adopted from Ahissar & Hochstein (1993; 1995). Previous experiments had only one visual stimulus per trial; therefore we will investigate the strength of both initial and learned audiovisual effects on a visual search task targeting an odd element amongst an array of distractors. In addition, TIPL sessions will be varied over conditions to test separately for plasticity of crossmodal spatial and specificity (orientation) effects. This will be done by varying location of training, and by training a subset of subjects on one of the two target orientations, respectively. Preliminary results suggest that innate audiovisual connections aid short-term facilitation in a spatially specific manner, in agreement with single-stimulus discrimination results.

56.506 Videogame players demonstrate enhanced multisensory abilities

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Videogame experiences have been found to influence attention and perception, increasing accuracy and reducing response times. While effects to date have focused on visual processing, experience with action videogames requires a sophisticated blend of visual, auditory, and tactile integration. Whether videogame playing affects perception more globally, in senses other than vision, remains unknown. Here we show that, in contrast to non-videogame-players (NVGPs), videogame-players (VGPs) exhibit enhanced abilities to match what they hear to what they see. Videogame playing status was assessed via a post-experiment questionnaire. On each trial, participants heard a sample sequence of tones played too rapidly to count. Subsequently, they were instructed to choose the numerical match from two simultaneous arrays of visual elements (one choice always matched the sample). Numerical values were large numbers with 26 possible ratios of correct numerical choice to incorrect numerical choice. Participants thus experienced a range of easy to difficult trials, from the easiest ratio of .2 (e.g., 10 vs. 50) to the most difficult ratio of .9 (e.g., 45 vs. 50). For the easier ratios, VGPs were more accurate than NVGPs (93.0% vs. 82.8%) and faster (1101ms vs. 1269ms). For the difficult ratios, VGPs were more accurate (66.0% vs. 55.6%) but slower (1554ms vs. 1349ms). VGPs demonstrated a strong relationship between difficulty and response time (R2=.793), while NVGPs responded with equal speed regardless of trial difficulty (R2=.025). For easy numerical comparisons, VGPs' enhanced abilities likely stem from a perceptual or response-based advantage; they were more accurate and faster. However, the VGPs' superior accuracy for difficult comparisons likely arises from a metacognitive benefit; VGPs slowed their responding to achieve higher accuracy. VGPs appeared more motivated to perform this estimation task and adjusted their time-on-task based upon decision difficulty. Thus, videogame play is associated with both enhanced attentional and metacognitive multisensory processing.

56.507 The brain integrates visual and haptic information from different spatial locations when using a tool

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Several studies suggest that size estimates from visual and haptic modalities are combined in a statistically optimal fashion (Ernst & Banks, 2002). Recently, Gepshtein et al. (2005) showed that optimal integration occurs only if the two signals originate from the same perceived spatial location. Here we show that when using a tool to explore an object haptically, optimal integration is largely restored despite spatial separation between haptic and visual input. Our method was similar to Gepshtein et al.'s. We used a two-interval forced-choice task to measure discrimination thresholds for judging the distance between two planes. We first measured thresholds in visual- and haptic-alone conditions, in order to predict performance when both cues were available. We then measured thresholds when both cues were available, at spatial offsets between 0 and 100 mm, in (i) a no-tool condition, and (ii) a with-tool condition, in which subjects grasped the stimulus with visually defined "sticks" attached to the finger and thumb. Tool length varied with spatial offset so that the ends of the tool always aligned with the visual stimulus. The tool was extinguished before contact with the planes, so the information available was identical in no-tool and with-tool conditions. In the no-tool condition we replicated Gepshtein et al.'s result. With zero offset, two-cue thresholds were as predicted by optimal cue integration, increasing to single-cue levels at 100 mm offset. In the with-tool condition, thresholds were significantly lower than single-cue performance at all spatial offsets and were close, though not equal, to the prediction of optimal cue integration. We conclude that the amount of integration of visual and haptic information is not determined by the spatial separation of the hand and visual object, but by a more sophisticated mapping process that can take into account the dynamics and geometry of tools.

56.508 Enhanced detection of visual stimuli projected on a tool

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The recruitment of bimodal visual-tactile neurons may explain the enhanced processing of visual stimuli near the hand. The present study investigated whether or not the 'hand-related enhancement effect' would extend to a novel tool after training. Participants (N=32) were asked to press a button as rapidly as possible with their right hand when they detected a target projected onto the surface of their left hand, a fake hand, or a tool. After the baseline session, all subjects were tested when holding the fake hand and tool with their left hand. The stimuli were presented on the hairy surface of the fake hand and the top surface of the tool. 16 subjects were then trained to use the fake hand (FH-group) and 16 to use the tool (Tool-group) to move a ball around complex path with their left hand. After training, all subjects were again tested when holding the tool and the fake hand. Finally, three baseline conditions were re-tested. We found that the participants initially responded faster to stimuli projected onto their real hand (307ms) than to stimuli presented on fake hand (318ms) or the tool (331ms), p<.004. After training, participants in the FH-group now responded faster to the target lights projected on the fake hand than they did before training (p=.004). Similarly, participants in the Tool-group showed the same pattern with the tool (p<.000). Finally, the FH-group (but not the Tool-group) responded faster to targets on the hairy as opposed to the glabrous surface of the fake hand (p=.005), even when they were not holding the fake hand, whereas the Tool-group (but not the FH-group) responded faster to targets on the top of the tool compared to the bottom (p=.029). These findings suggest that an enhancement effect can be induced in tools and other inanimate objects with training.

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56.509 Left/right asymmetries in the contribution of body orientation to the perceptual upright

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INTRODUCTION: The direction of the orientation at which objects and characters are most easily recognized, the perceived upright has been modelled as a weighted vector sum of the directions defined by the body's long axis (egocentric), gravity, and visible cues (Dyde et al. 2006, Exp. Brain Res.). This model predicts symmetrical responses such that subjects lying left or right side down relative to gravity should exhibit mirror symmetric patterns of responses. Such symmetry is also expected if torsional eye orientation dependent upon body orientation relative to gravity or visual orientation relative to the body is included in the model.

METHODS: Nineteen subjects drawn from researchers and students at York University participated. The Oriented Character Recognition Test (OCHART - described in Dyde et al. 2006) was administered while subjects viewed several orientations of visual background while either upright, left side down, or right side down relative to gravity. OCHART identifies the perceptual upright using the perceived identity of letters.

RESULTS: Responses revealed a systematic difference between the response pattern when lying left side down and lying right side down. This asymmetry can be modelled by a leftwise bias in the perceived orientation of the body relative to its actual orientation.

DISCUSSION: The asymmetry in the effect of body orientation is reminiscent of the left-leaning asymmetry in determining the direction of light coming from above (Mamassian & Goutcher 2001 Cognition 81:B1). The asymmetry might reflect a similar tendency to perceive the body as tilted.

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56.510 Integration of the multi-sensory information for the perception of gravitational vertical

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Tilt of stimulus in the wide visual field causes the sensation of body tilt, indicating that visual information affects the perceived orientation of gravity in addition to vestibular and somatosensory information. However, the details of the multi-sensory integration process for perceiving the gravitational vertical are not fully illustrated. The purpose of this study is to investigate the properties of the integration process for the perception of gravitational vertical.

In the experiment, we manipulated the orientations of visual stimuli and subject's body about the roll axis, and collected data of perceived gravitational vertical. To tilt subject's body, we used a seat, which could rotate with subject's body locked on it. A LCD monitor with 30cm diameter aperture was placed in front of subject's head to present the pictures of landscapes as visual stimuli. There was a black disc in the center of the pictures and a line segment was placed in the disc. The subject aligned the segment to the orientation of perceived gravitational vertical using keypad in his hand.

Results showed that visual information affected the perception of gravitational vertical systematically. When the orientation indicated by visual stimuli was close to the real gravitational vertical, perceived gravitational vertical approached to the vertical of visual stimuli. On the other hand, when the orientation indicated by visual stimuli was very different from gravitational vertical, the effect of the visual stimuli was not observed. Neither the weighted liner summation model nor the vector summation model fits to these results. We propose a new model of multi-sensory integration for the perception of gravitational vertical.

56.511 Blood pressure response to roll depends on both visual and non-visual factors

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Both physical body roll and illusory roll evoked by full-field visual motion induce changes in blood pressure (BP) (Aoki et al. 2000 Clin. Aut. Res. 10: 23). How do these BP responses combine when both vestibular and visual information concerning roll are present? Subjects sat in a padded chair inside a 9ft diameter sphere, the inside surface of which was covered in high-contrast random dots. The chair and sphere could be independently rotated about the subjects' roll axis. Subjects were physically rolled clockwise from upright to right-ear-down at 7.6°/s, which took 12s. The sphere was rotated either alone, or so as to enhance (counter clockwise), oppose (clockwise), or null (clockwise at 7.6°/s) simultaneous physical roll. BP was continuously monitored by a finger plethysmograph throughout the movement and for several seconds following. Verbal reports of perceived body orientation were noted. BP typically increased from baseline levels during physical roll in the dark and the increase was maintained while subjects remained right-ear-down. The BP response to visually evoked roll was a transient increase reaching a peak at ~6s. The BP changes in response to combinations of physical and visual roll were well described by a weighted linear sum of the responses to physical and visual motion presented separately even when the sphere remained earth stationary (the natural cue combination). The magnitude of perceived roll reported was accurate during roll in the dark and was systematically modulated by visual motion. These BP changes suggest that the autonomic responses to combinations of visual and vestibular cues reflect integration of information from the two systems.

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56.512 One visual stimulus provides two tactile sensations simultaneously

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In the rubber hand illusion, people feel the tactile sensation from the stimulation of a rubber hand placed in front of them, instead of from own hand, which is also stimulated but hidden under a table. This illusion suggests that the visual sense can control tactile sensation. However, it is unclear how we resolve the inconsistency between the visual and somatic senses when the two senses are mismatched. Here we show that, using a visual stimulus alone, participants felt as if the palm and the back of fifth finger of own hand was touched simultaneously when the palm of own hand and the back of rubber hand were facing upward while they observed that the back of first finger of rubber hand was stimulated. In our rubber hand illusion, we found that two tactile sensations can be induced by one visual stimulus. When the visual and somatic senses are mismatched, only the visual sense regarding the spatial location and the somatic sense regarding the direction of the hand are integrated. This illusion suggests that somatic senses contribute to tactile sensation as well as visual senses, and that the visuo-somatic integration is modulated in part by a neural mechanism with low spatial resolution in multi-sensory area.

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56.513 Exploring here, seeing where? Visualization with in-situ vs. ex-situ viewing

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Previous studies of aperture viewing showed that a figure moving behind a narrow slit can be perceived as integrated, even though only a small part of it is visible at any time. Here we allow subjects to explore a hidden virtual target by moving an imaging probe over it, exposing a series of cross-sectional slices. These were displayed either in-situ, at the location of the target, using an augmented-reality display, or ex-situ, at a LCD display displaced approximately 1 m from the target. Experiment 1 examined subjects' ability to identify letters and digits through such exploration. In-situ viewing led to faster identification; however, both devices produced errors indicative of local feature processing, such as mirror-image reversals (e.g., the misidentification of S as 3). To preclude this strategy, Experiment 2 required subjects to identify whether a rotated letter was normal or mirror-imaged. In-situ viewing produced the classic function associated with the cognitive process of mental rotation, such that the response time increased linearly with the departure of the tested letter from the normal upright. In contrast, ex-situ viewing yielded much longer response time for letters oriented along obliques, consistent with feature-based strategies (Jolicoeur, 1990). Experiment 3 used unfamiliar shapes to test effects of memory load and spatiotemporal complexity. The results indicate that effective integration of whole objects from spatiotemporally distributed components demands not only displaying object segments revealed by exploration, but also co-locating the hidden object and the process of exploration in a common reference frame.

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56.514 Gawking and Fondling: Multimodal Perception of 3D Shape

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Our visual and haptic perceptual systems are responsible for creating our mental representations of 3-D shapes. Alas, it has been shown that the two systems do not always work congruently. Some results hypothesize an advantage to the visual system for some tasks while others suggest the haptic system may contribute more useful information. The specific nature of these discrepancies, especially with respect to complex 3-D shape perception, remain somewhat a mystery. Past studies have used geometrically complex, but statistically ambiguous objects as stimuli, while still other studies have used well-determined yet geometrically simple objects. This study attempts to bridge these two stimulus categories. Complex, natural appearing, noisy 3-D stimuli were statistically specified in the Fourier domain and manufactured using a 3-D printer. A series of paired-comparison experiments examined observers' uni-modal (visual-visual and haptic-haptic) and cross-modal (visual-haptic) perceptual abilities. Performance in the uni-modal conditions were similar to one another and uni-modal presentation fared better than cross-modal. Also, the spatial frequency of object features affected performance differentially across the range used in this experiment. When visually grouped by observers, the statistical nature of these features explain the groupings, yet there were no such patterns when the stimuli were grouped haptically. The existence of non-universal (i.e. modality-specific) representations would explain the poor cross-modal performance. Our current findings suggest that either each system creates a unique representation or the systems utilize a common representation but each in a different fashion. Vision shows a distinct advantage when dealing with higher frequency objects but both modalities are effective when comparing objects that differ by a large amount.

URL: http://ebv.skidmore.edu

Search 3

56.515 Search for mean(ing): Parallel processes mediate ensemble coding

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As we interact with the visual world, we encounter substantial redundancy. A field of grass, for example, is comprised of many similar blades of grass. Coding every one of these elements is an inefficient representation scheme, and thus the visual system engages in ensemble coding, a heuristic that represents large amounts of information through summary statistics. Ensemble coding occurs across several dimensions–observers can extract a precise estimation of the mean size of an array of dots, the mean orientation of a set of gabors, and even the mean emotion of a set of faces. Although it is clear the visual system favors a statistical representation of sets, the mechanism of ensemble coding remains unresolved. Some evidence suggests that parallel processes mediate ensemble coding, while other research shows that serial processes offer a more parsimonious explanation. Using a modified visual search task, we present evidence that supports ensemble coding as a parallel process. On every trial, observers saw a set of 1-6 faces that varied in expression from neutral to disgusted, simultaneously presented with a single test face. In one condition, observers had to indicate whether the test face was a member of the set (regular search). In the other condition, observers had to indicate whether the test face was more neutral or more disgusted than the mean emotion of the set (mean search). Reaction times for the regular search condition showed a significant increase as a function of set size (a positive slope), the hallmark of serial search processes. The reaction times for the mean search, however, showed no such dependence on set size, suggesting that observers were able to extract a statistical representation regardless of the number of items used to establish the mean emotion. This result supports the hypothesis that ensemble coding is mediated by parallel processes.

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56.516 Visual search after frontal eye field lesions in humans

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A role for the frontal eye fields (FEFs) in visual search has been supported by converging evidence from numerous cognitive neuroscience approaches, including fMRI and TMS in humans and single-cell recording and inactivation studies in monkeys. However, evidence for FEF involvement from human focal lesion studies is conspicuously absent from the literature. Here, we report data from feature and conjunction search tasks in patients with focal FEF lesions and controls. For both search tasks, arrays of either four or eight search items were used to calculate set size effects. To diminish the influence of response on visual search, we employed an adaptive procedure which estimated the stimulus duration necessary for 75% accuracy in each task. Importantly, target detection was assessed separately for the left and right visual fields, and left and right staircases were interleaved within a block. As in healthy participants, patients required longer presentation durations for conjunction compared to feature search. Initial results from two patients with right FEF lesions indicate that the set size effect in contralesional conjunction search was disproportionately impaired compared to ipsilesional conjunction search. Results will be discussed in the context of other neurodisruptive findings.

56.517 Visual search in real-world scenes: Effects of target cue specificity and cue lead time on component search processes

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Visual search studies typically report unitary search times. Using eyetracking, we divided visual search in naturalistic scenes into three epochs: initiation, scanning, and decision. We manipulated the nature of the target cue (picture or word) and cue lead time, and examined their effects on search time as a whole, and on the three search epochs. Results indicated that scanning and decision times are influenced by the nature of the cue, whereas the time to initiate the search is influenced by cue lead time. A pictorial template facilitates scanning by allowing both faster rejection of fixated distracters and an improved selection of the next fixation. A pictorial template also affects the decision process by enabling faster acceptance of the target. We then examined the role of colour in a target cue. Using the same paradigm, we kept cue lead time constant and manipulated the cue (full-colour picture, grey-scale picture, or word). Search was again more efficient with picture cues, suggesting that template specificity facilitates scanning. Search was also faster with colour than grey-scale picture cues, but this effect was primarily due to faster decision time. Overall, the results suggest that a more specific search template facilitates distracter reject decisions in each non-target fixation, facilitates the selection of the next fixation, and facilitates the accept decision once at the target. Cuing the visual system with the shape of the target plays a particularly important role in real-world search, while cuing the colour plays a somewhat less important role. The results also indicate that eyetracking can be used to better understand the processes underlying visual search.

56.518 The role of local and global clutter in visual search

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In visual search, preattentive processes locate potential target regions. Selective attention is then deployed to these regions to determine if the target is present. Generally, as the number of distractors in a display increases, this process becomes less efficient. The current studies examined the role of global visual clutter in the ability to deploy attention to target regions containing relatively more or less local clutter. Participants searched aerial maps with varying degrees of clutter for a predetermined target. A 2x3x3 factorial design was employed. The three factors examined were local clutter (high and low), global clutter (high, medium, and low) and distractor set size (4, 8, and 16). A clutter algorithm analyzing two components, color density and saliency, was used to determine levels of local and global clutter. Color density is a measure of how tightly packed similarly colored pixels are in the image and saliency is calculated using the distance in color space between two adjacent colors. The target on each trial was either an inverted V or an inverted W. When the target was an inverted V the distractors were inverted Ws and vice versa and the number of distractors varied across trials. Participants were faster to detect targets in low local clutter regions and faster to detect targets in low global clutter maps. There was also a significant local/global clutter interaction driven by larger effects of local clutter as global clutter increased. In addition, there was no effect of distractor set size on search time. Therefore, the preattentive process of detecting regions that are likely to contain the target is less efficient as the amount of global clutter increases. Furthermore, in complex images where it is difficult to determine the number of distractors, measuring global and local clutter may be a better predictor of search efficiency.

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56.519 Dissociating preattentive vision and preattentive attentional guidance

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In Feature Integration Theory (FIT; Treisman & Sato, 1990), efficient visual search performance can either be driven by preattentive vision, or by focused attention that is effectively guided by preattentive information. Whereas independent dimensional modules handle basic feature detection, a salience map of locations serves to guide attention in other searches. Recent theoretical models have largely abandoned this distinction; for example, the guided search theory (Wolfe, 1994) assumes that all searches are guided by a salience map. Based on an assumption that preattentive vision does not signal location information, the present study investigated and provided evidence for a distinction between searches that rely on preattentive vision and searches that rely on attentional guidance. Participants detected features or judged target locations (left or right side of the display); because location information is needed for the location judgement task, the salience map should be implicated in responses. Results showed a dissociation between tasks in terms of both dimension-switching costs and cross-dimension attentional capture, in which dimension-switching occurred only in the target detection task and attentional capture occurred only in the location judgement task. These results reflect the use of two different mechanisms, one dimension-specific and the other dimension-general, which map onto existing proposals for dimensional modules and the salience map. In a feature discrimination task, results precluded an explanation based on response mode (detection versus discrimination). We conclude that the FIT architecture should be adopted to explain the current results, and that a variety of visual attention findings can be addressed within this framework.

56.520 **Do T-junctions slow down visual search?**

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Four visual search experiments tested whether there is amodal completion in early vision. In our experiments, the search rates slowed down both for displays where amodal completion would and, critically, for displays where amodal completion would not interfere with the distinction between target and distractor. Any effect on search rates previously attributed to early amodal completion (Rensink and Enns, 1998) might therefore be better described by a more parsimonious account of early vision. In this account, early vision is not capable of assigning relative depth to objects that are seemingly occupying the same position in space (as indicated by T-junctions), and focal attention is needed to determine what is in front and what is behind. It might be that once attention is more focused, amodal completion gets the opportunity to exert its influence and reduce the distinction between target and distractor, slowing search down further. Note however that under this account it is the presence of T-junctions that is responsible for the initial need for more focused attention, and that the influence of amodal completion is contingent on this.

56.521 **A colour-orientation asymmetry for priming within a search trial: Previewing features of individual search items immediately before conjunction search**

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A conjunction search target can be distinguished from distractors based on the combination of relevant features (e.g., a red horizontal bar, presented among green horizontal bars and red vertical bars). Olds and Fockler (2004) developed a modified conjunction search paradigm, where one of two relevant features, for each search item, was previewed immediately before the intact search display. In a colour-orientation-preview condition, the colour of each display item was previewed for 1 second, followed by a 1-second preview of the orientation of each display item. An orientation-colour-preview condition presented the orientation-preview display first. Observers' search of the immediately subsequent intact display was better if the colour-preview came before the orientation-preview than if the orientation-preview came first.

Related to this asymmetry, Hannus et al. (2006) matched feature discriminability for colour feature search, with feature discriminability for orientation feature search, and used those feature values to create a colour/orientation conjunction search. Observers made more saccades to items that matched the target colour than to items that matched the target orientation, even though those feature differences were matched for discriminability in feature search.

The present experiments replicated the results of Olds and Fockler (2004) with different coloured stimuli. Furthermore, a mixed-preview condition simultaneously previewed the colours of half of the display items, and the orientations of the other items; a mixed-mixed-preview condition presented an initial mixed-preview display, followed by another mixed-preview display in which the other feature of each item was previewed for 1 second. The mixed-mixed-preview failed to facilitate search, even though it included the same information as the colour-orientation-preview (1 second per feature, per item) which greatly facilitated search. The striking difference in facilitation, between previewing one feature at a time and previewing mixtures of features, is discussed in the context of the literature on perceptual grouping and scene segmentation.

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56.522 **Selection and timing of gaze fixations in visual conjunction search**

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Vision is an active process that requires a sequence of saccadic eye movements interrupted by periods of fixation during which details of the foveal image are analyzed and the next detail in the periphery is selected. To understand how the brain regulates this visual behavior, we developed a task in which monkeys could freely search for a target amongst 15 distractor stimuli spaced by 10 deg on a grid. Monkeys were given >5 s to locate the search target by foveating it for >500 ms. Each target was a unique conjunction of color (red/green) and form (circle/square), and distractors could share either one feature with the target (same-color/same-form) or none (opposite). The monkey made a single targeting saccade in 20% of trials but a total of 4 saccades, on average, were made in a single trial (range: 1-15). The great majority of saccades (94%) were directed to the nearest stimuli (10 & 14 deg), and fewer saccades were made when the target was one of these stimuli than when located remotely (3.5 vs. 5.5). Saccade probability to the different distractors was variable, with most being directed towards same-color distractors, fewer towards same-form and even fewer to opposite distractors (57, 16, 6%). Fixation duration for these distractors co-varied with the probability of targeting them, being longer for same-color distractors, shorter for same-form, and even shorter for opposite distractors (118, 53, 29 ms). These short fixation durations, along with the observation that they were significantly shorter than the initial response time following display onset (200 ms), indicate that saccade programming and visual processing occurred in parallel. Beyond showing that top-down influences guide visual search by biasing both the processes regulating where and when to look next, this study promises to be a valuable approach to simultaneously investigate the neural mechanisms underlying these processes.

56.523 **Pop-out for interocular conflict**

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Outline: Wolfe and Franzel (1988) concluded that an element containing interocular conflict does not 'pop out' during visual search. Here we show that this absence of pop out was mainly due to the specific setup used in their experiments and that a target with interocular conflict does pop out during search.

Method: Observers performed a search task on elements either containing interocular conflict (horizontal and vertical orientations) or not. Elements were placed in a circular arrangement centered around the fixation point. Two basic conditions were tested: (1) a conflict target among non-conflict distractors and (2) a non-conflict target among conflict distractors. For each condition we varied set size. A target was present on 50% of the trials. Observers pressed a button indicating that a target was present or absent.

Results: The absence of 'pop-out' in the Wolfe and Franzel study (1988) was found while presenting left- and right-eye images in alternating sequence at 30 Hz using a shutter arrangement. Using mirrors, we show that 'pop out' of interocular conflict does occur when the images are presented simultaneously. Search was faster for a conflict target among non-conflict distractors than for a non-conflict target among conflict distractors. Moreover, search times increased with increasing set-size when searching for the non-conflict target (slope: 120 ms), but were constant when searching for the conflict target (slope: 15 ms). This search asymmetry was not evident when the same stimulus was fused and presented to both eyes without conflict, eliminating the possibility that a feature in the fused percept was responsible for pop-out. In addition, search times did not depend on the alternation rate of the individual (conflict) elements. We conclude that interocular conflict is a pop out feature during visual search.

Wolfe, J.M., & Franzel, S.L. (1988). Binocularity and visual search. Perception & Psychophysics, 44, 81-93.

56.524 **Rapidly resuming visual search and same/different judgments: The influence of task difficulty and stimulus complexity**

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Reentrant visual processing is theorized to operate in cycles of extraction and confirmation. On first pass, extraction generates perceptual hypotheses, which are then tested by selectively re-sampling from lower levels in the visual hierarchy. It is possible to probe the information contained in these perceptual hypotheses by interrupting and then reinitiating a visual task. A response signature known as rapid resumption provides evidence of perceptual hypothesis confirmation. Here we present two sets of experiments exploring the dynamics and constraints on perceptual hypothesis confirmation. First, in a modified visual search task, we dissociate target detection and response selection by adding a level of response selection following target detection. This design permits testing whether rapid resumption reflects localizing or identifying visual targets. Second, we present convergent evidence using interrupted and resumed pattern matching in a same/different task. Observers are able to rapidly resume both 'same' and 'different' trials. Interestingly, in all target detection and same/different tasks, the temporal distribution of rapid responses appears to be largely unaffected by stimulus complexity and task difficulty. This strongly contrasts with responses made during constant presentation, and with responses made subsequent to an initial confirmation window. When observers fail to rapidly resume, a later peak of responses is sensitive to stimulus complexity and task difficulty. These findings suggest that the confirmation stage of perceptual processing is robustly consistent across task difficulty and stimulus complexity.

56.525 **Selectivity for multiple orientations in visual search**

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Observer strategies in visual search for targets containing multiple orientations were considered in the study. We used our efficient search framework (Tavassoli et al., 2007), a reverse-correlation based technique distinguishing between non-foveal and foveal processes, to examine how observers search for low-contrast targets created from sums (Experiment 1) and mosaics (Experiment 2) of Gabors. Eye movements were recorded while observers searched for one target randomly embedded in one tile of a grid of 1/f noise tiles. Fixated noise-only tiles (non-foveal false alarms) and a subset of these noise tiles selected by the observer as target candidate (foveal false alarm category) were analyzed off-line. We present several key findings. First, we show a strong presence of visual guidance in saccadic targeting in search for our composite targets, demonstrated by selectivity for spatial frequencies and (in some cases) orientations close to the characteristics of each target. Second, we show that, in most cases, the multiple orientations composing the targets were represented in both saccadic programming and target selection, but were not always equally weighted. Third, different mosaic configurations produced different tunings in orientation, but visibly idiosyncratic to each observer (Experiment 2). A local spectral analysis on subregions of noise tiles was performed to examine the use of phase. Fourth, a curious presence of close-to-vertical structures is observed in the results, although the search targets did not contain vertically-oriented structures (Experiment 2).

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56.526 **Feature- and location-based attention in color/orientation conjunctive visual search**

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Purpose. Performance in visual search tasks where the target differs from distractors by a conjunction of features can improve when a precue signals to observers to limit their search by attending to a subset of elements. Our goal was to study how performance in color-orientation conjunctive searches changes when observers attend to a pre-cued location, color, or orientation, and the temporal characteristics of these precue effects.

Methods. The search stimuli consisted of eleven elements, formed by combining horizontal/vertical (H/V) with red/green (R/G), spaced uniformly around a circle at 6°eccentricity. Either one (target) or none of the elements differed from others (distractors). There were 4 possible combinations of target/distractors, randomly presented across target-present trials (equal to target-absent trials) in an odd-man-out paradigm: RV or GH target among RH and GV distractors; RH or GV target among RV and GH distractors. Task was to respond on target presence/absence. Location, color (sensory or symbolic), or orientation precues (duration 50 ms) preceded stimulus (duration 300 ms) with variable ISI. Precues were either neutral or informative with 80% validity. Reaction time and accuracy, as well as their ratio, were used as measures of performance.

Results. The data patterns are similar across observers. Color (sensory and symbolic) and location precues improved search performance. The magnitude of improvement varied as the ISI changed for symbolic color and location cues, but kept constant for sensory color cue. The sensory color cue exhibited its effect in directing visual search as early as 0 ms ISI. These effects were not observed for orientation precue.

Conclusions. Results confirm earlier findings that color is a better cue than orientation; we are currently exploring experiments with reduced color contrast (de-saturated colors). The findings also suggested significant differences in the temporal profile of feature- and location-based attention in visual search.

56.527 **Modeling interactions between visually-responsive and movement-related neurons in FEF during saccade visual search**

Braden A. Purcell[1] (braden.a.purcell@vanderbilt.edu), Richard P. Heitz[1], Jeremiah Y. Cohen[1,4], Gordon D. Logan[1,2], Jeffrey D. Schall[1,2,3], Thomas J. Palmeri[1,2]; [1]Department of Psychology, Vanderbilt University, [2]Center for Integrative & Cognitive Neuroscience, [3]Vanderbilt Vision Research Center, [4]Vanderbilt Brain Institute

Neural activity in the frontal eye field (FEF) has been implicated in mapping visual information about object importance to explicit decisions about where to move the eyes (Schall, 2001). These components seem to be represented by two classes of neurons: visual neurons respond differentially according to the relevance of visual stimuli and movement neurons exhibit pre-motor activity before saccadic eye movements. Boucher et al. (2007) accounted for the behavior of movement cells as accumulators to a threshold, but the activity of visual cells was ignored. We evaluated the hypothesis that movement cell activity can be accounted for in terms of input from visual cells. Single-unit neurophysiological data were recorded from visual neurons in the FEF of awake behaving macaque monkeys performing a visual search task. For a given cell, trials were classified by whether the target or a distractor appeared in the cell's receptive field. Simulations sampled recorded activity from these two populations of trials. This activity serves as input to algorithms designed to account for the temporal dynamics of movement cell activity, as well as reaction time distributions and accuracy. At present, two models have been evaluated. The first model instantiates the hypothesis that movement cells compute the difference in activity of visual cells with the target in their receptive field and cells with a distractor in their receptive field. The second model instantiates the hypothesis that movement cells integrate this difference over time. In both cases, reaction time is defined as the time when this measure derived from visual activity crosses a threshold. Preliminary analyses indicate that the latter provides a better quantitative account of reaction time distributions. However, further model exploration is necessary to conclude whether either of these models provides the best account of not only the behavioral data but neurophysiological data as well.

Acknowledgement: Supported by AFOSR, NSF SBE-0542013, NEI R01-EY08890, P30-EY08126, VU ACCRE and Ingram Chair of Neuroscience.

56.528 **Bayesian Theory of Visual Search**

Jeffrey Beck[1,2] (jbeck@bcs.rochester.edu), Wei Ji Ma[1], Vidhya Navalpakkam[2]; [1]Brain and Cognitive Sciences, University of Rochester, [2]Division of Biology, Caltech

Human performance in searching for a tilted target among vertical distractors is well described by signal detection theory (SDT) models which combine the outputs of noisy detectors using a maximum or summation operation. These theories assume each detector is a neuron best tuned to the target, and a detector's response to the target or distractor follows a Gaussian distribution. However, recent work questions the validity of SDT assumptions in search tasks with more complex stimulus distributions. Instead, a saliency-based signal-to-noise ratio was proposed to measure task difficulty. A drawback of this theory is that it cannot predict receiver operating characteristics (ROCs). We reconcile and generalize both approaches by developing a fully Bayesian model of visual search. We study detection of a target among distractors, where target and distractor features are drawn from arbitrary, but known, distributions. At each location in the display, the feature (such as orientation) is coded in a population of neurons with Poisson-like variability. Decisions are based on log odds of target presence given the responses of all neurons at each location (unlike SDT, where decisions are based on the neurons best tuned to the target). Log odds are computed via a nonlinear operation on the location-specific log odds, which incorporate the feature distributions. This model

1) reproduces behavioral effects and ROCs in simple visual search, such set size effects, target-distractor similarity, and distractor heterogeneity;

2) explains behavior in complex search conditions, e.g. flanking distractors;

3) can in special cases be approximated by the maximum or sum rule. Additionally, we show in some cases the decision variable from the Bayes-optimal computation is approximately Gaussian and can be linked to SDT. Finally, we demonstrate how the Bayesian approach can predict which neurons are most informative and argue that attention provides task relevant prior information.

56.529 **Predicting search efficiency with a low-level visual difference model**

P. George Lovell[1] (p.g.lovell@bristol.ac.uk), Iain D. Gilchrist[1], David J. Tolhurst[2], Michelle To[2], Tomasz Troscianko[2]; [1]Department of Experimental Psychology, University of Bristol, [2]Department of Physiology, Development and Neuroscience, University of Cambridge

Duncan and Humphreys (Psychological Review, 96(3), 1989) predicted that visual search efficiency would vary as a function of both target-distractor and distractor-distractor similarity. However, applying such concepts to search for targets in images containing complex, naturalistic, objects is made difficult because it is hard to quantify the degree of similarity (or difference) between elements of the image. Given that we now have metrics which predict image differences reasonably well (Visual Difference Predictors, or VDPs, Parraga et.al. Vision Research, 45, 2005), we wish to be able to use the output of these metrics so that they predict search performance in scenes containing natural objects. We thus generate search images (consisting of a target and distractors in discrete locations on a uniform background, c.f. traditional search experiments) in which increases in target-distractor similarity or in distractor-distractor heterogeneity should both result in decreased search efficiency. The current study examines observers' (n=5) visual search efficiency for natural objects while manipulating these factors whilst also manipulating display size. Observers were shown a new target for each block of trials.

Observer reaction times were modeled with neural-networks, the inputs of which were the VDP's predictions of visual similarity. This resulted in reliable predictions of search efficiency. A post-hoc examination of the neural-net activation patterns enabled reconstruction of the original Duncan and Humphreys' prediction of search efficiency as a function of target-distractor and distractor-distractor similarity.

We have therefore demonstrated the possibility of using VDPs to predict search performance in natural images, showing the utility of the Duncan and Humphreys model for such scenes. Further work is needed to develop this method to be able to predict search performance in scenes in which the background is continuous.

URL: EPSRC/DSTL (EP/E037372/1 Bristol EP/E037097/1 Cambridge)

56.530 **Effect of subjective probability on search termination**

Kazuya Ishibashi[1] (isibasi@lit.kobe-u.ac.jp), Shinichi Kita[1]; [1]Kobe University

Observers make a perceptual decision based on subjective probability of visual stimuli, and thereby achieve a solution against tasks such as luminance judgment, motion detection, temporal order judgment and so forth. The present study offers arguments for the usage of subjective probability, especially for the adherence of prior probability, which is likely to be neglected in cognitive decision. To examine the hypothesis that observers search visual targets effectively relying on subjective probability, we conducted a conjunctive visual search experiment. For the analysis of subjective probability, we manipulated posterior probability which was defined with the combination of prior and conditional probability. We defined prior probability by setting present-trial ratios to 10%, 50% and 90%, and conditional probability by setting a high and a low probability cue appearing in 80% and 20% of the present-trial, respectively. For the evaluation of the effect of subjective probability, two types of measurement were adopted: values of criterion in the sense of signal detection theory and search termination times, i.e., "no" response times, which have been shown to increase in accordance with target frequency. The results of the experiment showed that increasing prior and conditional probability brought about slower response times for "no" responses and a remarkable shift of the criterion value towards the peak of "yes" responses. Inquiries on target frequency of each cue in each condition showed that the observers were aware of subjective probability almost identical with posterior probability calculated on the basis of prior and conditional probability. These results suggest that subjective probability in visual search can be approximated with great precision by taking into account both prior and conditional probability and that search termination times rely on the probability information.

56.531 **Coordinating Spatial Attention: Using Shared Gaze to Augment Search and Rescue**

Mark Neider[1] (mneider@uiuc.edu), Michelle W. Voss[1], Arthur F. Kramer[1]; [1]Beckman Institute, University of Illinois at Urbana-Champaign

The coordination of spatial attention between observers is an element of many tasks. Facilitating this coordination requires that spatial information be communicated between observers, typically through verbal dialogue. However, verbal descriptions of spatial information can be ambiguous. In contrast, shared gaze has been shown to be highly efficient at focusing joint attention between partners in complex collaborative search tasks. We examined the utility of shared gaze in a dynamic helicopter search and rescue task. Paired observers searched for a hiker in a simulated low altitude fly-over of Yellowstone National Park. Both observers were required to locate the hiker before it left the screen. Each observer wore an eye/head tracker, was seated in a separate room, and viewed an independent display. Performance was assessed in three communication conditions: shared gaze (SG), shared verbal (SV), and shared gaze with verbal (SG+V). Surprisingly, observers were slowest to converge on the target in the SG condition (~1.7s); performance in the SV (1s) and SV+G (960ms) conditions was roughly equivalent. To assess whether our findings could be attributed to distraction from the gaze cursor, or ease of the task, new observers performed the same task in both shared gaze onset (gaze cursor appeared once one partner had located the target; SGO) and static display experiments. In the SGO experiment observers were as quick to co-locate the target as in SV condition of the first experiment in which gaze information was constant; in the static display experiment observers were faster at co-locating the target in the SG condition compared to the SV condition. Our data suggest that shared gaze is useful for coordinating spatial attention, but this utility exists on a continuum. In easier search tasks gaze information is wasted, and perhaps even distracting; in difficult search tasks shared gaze provides clear benefits over verbal communication.

Wednesday Sessions

Wednesday, May 14, 8:30 - 10:00 am
Talk Session, Vista Ballroom

Binocular Mechanisms 3

Moderator: Laurie Wilcox

8:30 am

61.11 Are the Positions of Corresponding Points Adaptive for Natural Viewing?

Martin Banks[1] (martybanks@berkeley.edu), Kai Schreiber[2]; [1]Vision Science, Psychology, Neuroscience, UC Berkeley, [2]Neuroscience, Rutgers University

In stereopsis, the visual system must match retinal-image points that correspond to the same point in space. Part of the solution to this matching problem is the existence of corresponding retinal points. These point pairs have special status: matching solutions are biased toward them; the region of single vision straddles them; the precision of binocular depth perception is highest for spatial locations that project to them. Thus, it is important to know the regions in space that stimulate or come closest to stimulating corresponding points. Near the eyes' vertical meridians, corresponding points are sheared horizontally in a pattern called the Helmholtz shear. As a result, the empirical vertical horopter is a top-back slanted line in the midsagittal plane. Near the eyes' horizontal meridians, corresponding points are shifted horizontally in a pattern called the Hering-Hillebrand deviation. Because of this, the empirical horizontal horopter in the visual plane is less concave than it would be without the shift. We examined whether the shear and deviation patterns of correspondence place the zone of single vision and finest stereopsis usefully relative to the natural environment. Helmholtz claimed that the vertical horopter's slant is adaptive because it places the horopter close to the ground plane even as the observer fixates different positions along the ground, provided that eye position obeys Listing's Law. We describe modern misinterpretations of Helmholtz's claim that do not consider fixations in the ground at finite distances. We also show that the horizontal extension of the horopter cannot lie in the ground plane: because of the Hering-Hillebrand deviation, the horizontal extension is convex so the sides lie progressively farther below ground. Considering both the shear and deviation, corresponding-point positions are most adaptive for viewing near planar surfaces rather than the ground.

Acknowledgement: NIH

8:45 am

61.12 Comparison of depth percepts created by binocular disparity, Panum's limiting case, and monoptic depth

Kazuho Fukuda[1] (kfukuda@yorku.ca), Laurie M. Wilcox[1], Robert S. Allison[1], Ian P. Howard[1]; [1]Centre for Vision Research, York University, Toronto, Canada

Sensations of depth can be produced by diplopic images with horizontal disparity beyond the fusion limit (conventional stereopsis), a monocular image flanking a binocular image (Panum's limiting case), and an eccentric monocular image (monoptic depth, Kaye 1978; Wilcox et al. 2007). Conceivably, depth perception in Panum's limiting case could be explained by stereopsis (double-duty matching, Hering 1879), monoptic depth or another mechanism entirely. Our goal is to determine which of these options is valid.

Subjects judged the magnitude of perceived depth of a target stimulus viewed for 67 ms relative to a prior fixation point. The target was (1) a monocular vertical line with variable horizontal offset relative to a midline monocular line seen by the other eye (stereoscopic), (2) a monocular line with variable offset relative to a midline binocular line (Panum's limiting case), and (3) a monocular line with variable offset relative to the prior fixation point (monoptic).

For Panum's limiting case, apparent depth at first increased with increasing lateral offset of the monocular line. However, this occurred only for offsets of up to 15 and 45 arcmin on the temporal and nasal side of retina, respectively. At larger offsets, depth was similar to that perceived from monoptic targets. In contrast, perceived depth from stereopsis increased with increasing disparity of up to 1° and remained constant up to a disparity of at least 2° (stimuli became diplopic at 30 arcmin). The magnitude of perceived depth was much smaller in monoptic compared with stereoscopic conditions, at all offsets. The distinct properties of depth perceived with these three types of stimuli suggest that they have different physiological substrates, and that depth from Panum's limiting case is not simply due to stereoscopic matching.

Acknowledgement: Supported by grants form the National Sciences and Engineering Council of Canada and the Canadian Institutes of Health Research.

9:00 am

61.13 Sensitivity to disparity modulations in ground plane surfaces

Brian Rogers[1] (bjr@psy.ox.ac.uk), Charlotte Colam[1], Christopher Cant[1]; [1]Department of Experimental Psychology, University of Oxford, UK

Tyler (1974, Nature 251 140-2) and Rogers and Graham (1982, Vision Research 22 216-70) have shown that sensitivity to horizontally oriented disparity corrugations is maximal at a corrugation frequency of between 0.3 and 0.5 cycles/deg and falls off at both lower and higher frequencies. A similar band-pass characteristic has also been observed for vertically oriented corrugations except that sensitivity is poorer at low corrugation frequencies for most observers – the stereoscopic anisotropy. In contrast, almost nothing is known about the visual system's sensitivity to disparity modulations of ground plane surfaces. In the present study, disparity thresholds were measured using a 2AFC procedure for sinusoidal depth corrugations of the ground plane (furrows) lying either along (near-to-far) or across (left-to-right) the observer's line-of-sight. Ground plane stereoscopic images were produced by projecting two large (2 m x 1.5m) random texture patterns onto two floor-mounted screens on either side of the observer. The images were viewed via a mirror stereoscope so that the corrugated surface appeared to extend into the distance in front of the observer. The number of corrugations across the surface was varied between 2 and 32, corresponding to corrugation frequencies of between ~0.1 and 2.0 cycles/deg in the central region of the display. Lowest thresholds were found to be between 5 and 10 arc sec (peak-to-trough) for corrugations oriented across the line-of-sight, at an optimum corrugation frequency of ~0.5 cycles/deg. Thresholds were slightly higher (x1.5) for corrugations oriented in a near-far direction, providing evidence for an analogous anisotropy in the perception of ground plane surfaces. Thresholds were also determined for discriminating (i) the slant of planar surfaces away from the horizontal and (ii) the direction of curvature (convex vs concave) of surfaces close to the ground plane. Slant and curvature thresholds were also found to be in the hyperacuity range - corresponding to an ability to detect (i) planar surfaces with 2-4 deg of slant away from the horizontal and (ii) curved surfaces with a radius of curvature > 15 m.

9:15 am

61.14 How does perceived depth depend on disparity direction?

Yu-Chin Chai[1] (sunnia.chai@gmail.com), Bart Farell[1]; [1]Syracuse University, Institute for Sensory Research

The stereo matching direction is underdetermined for gratings and other 1-D patterns—the 'aperture effect'—but can range over 360° for 2-D patterns, such as plaids. How does perceived depth vary with disparity direction? To find an answer, we measured the perceived depth between a grating and a plaid and between two plaids. The results show that two relative disparity signals underlie perceived depth.

A central grating or plaid bounded by a circular Gaussian window, and a surrounding plaid bounded by an annular Gaussian window, appeared simultaneously for 150 ms. We fixed the disparity direction and magnitude of the surrounding plaid and varied the disparity magnitude of the central grating or plaid across trials. Subjects judged the central pattern as 'near' or 'far' relative to the surrounding plaid. We measured the disparity of the center carrier yielding a perceived depth match between center and surround as a function of the orientation of the central grating and the disparity direction of the central plaid.

A grating matched the plaid in depth when the grating had a disparity equal to the projection of the plaid's disparity vector onto the disparity axis perpendicular to the grating's orientation; this is the disparity the grating would have had it been a component of the plaid. The depth match was unaffected by the relative horizontal disparity of the two stimuli. By contrast, two plaids were perceived to match in depth when their disparities had equal horizontal components, regardless of any vertical disparity difference within at least ±60° of horizontal.

Perceived depth has been thought to depend on horizontal disparity or on the horizontal:vertical disparity ratio. Our results show that neither of these rules is general. However, a modified intersection-of-constraints computation accounts for all the data.

Acknowledgement: NIH Grant EY 012286

9:30 am

61.15 Sensory Eye Dominance is Retinal Location Specific and Affects Stereopsis

Jingping Xu[1] (j0xu0007@louisville.edu), Zijiang J. He[1], Teng Leng Ooi[2]; [1]University of Louisville, [2]Pennsylvania College of Optometry

Sensory eye dominance (SED) refers to one eye having a competitive advantage over the fellow eye when viewing a pair of binocular rivalry stimuli with equal strength (Ooi & He, 2001). SED is largely related to the interocular inhibitory mechanism underlying various binocular percepts. To date, we have only measured the global SED using a binocular rivalry display that stimulates large visual field coverage. We now measured the local SED at various retinal locations (SED Perimetry) using a binocular rivalry method similar to that used in the global SED and a QUEST procedure. We selected 17 different retinal locations that included one at the fovea, eight at 2deg and eight at 4deg eccentricity. At each test location, we measured the SED by presenting a binocular rivalry display (vertical vs. horizontal grating) on an 11x11deg gray background (35 cd/m2) for 0.5 sec. At the fovea the spatial frequency and size of the rivalry grating discs were 5cpd and 0.75deg, respectively; and at the peripheral locations the discs were scaled according to the retinal eccentricity. Furthermore, at each test location we measured: (i) The right and left eye's contrast sensitivity using monocular gratings having the same parameters as the binocular rivalry display; (ii) Stereo threshold of a front disc defined by random-dots; (iii) Choice reaction time to the onset of the random-dots defined disc with either 6 min front or back binocular disparity. We found that: (1) both the sign (right or left eye) and magnitude of the local SED vary with test location, indicating that the local SED is retinal location specific; (2) the local SED cannot be attributed to the difference in monocular contrast sensitivity; (3) both the stereo threshold and reaction time tend to increase with the magnitude of the local SED, suggesting that SED can impede stereo processing.

Acknowledgement: National Institutes of Health (EY015804)

09:45

61.16 Humans use stereo and haptic distance cues to improve physical object size estimates

Peter Battaglia[1] (batt0086@umn.edu), Marc Ernst[2], Paul Schrater[1, 3], Max Di Luca[2], Tonja Machulla[2], Daniel Kersten[1]; [1]Psychology Department, University of Minnesota, [2]Max Planck Institute for Biological Cybernetics, Tübingen, [3]Computer Science Department, University of Minnesota

An object's visual image size is an ambiguous cue to its physical size. But if the object's distance is known, the physical size may be disambiguated and more accurately estimated. We asked whether humans use distance cues to improve size judgments. We presented participants with a virtual ball that changed in physical size (imagine a balloon inflating or deflating) as well as distance simultaneously, and asked them to discriminate whether the physical size increased or decreased. With only visual image size information, size-change discrimination was poor. When additional haptic and/or stereo distance-change cues were provided, size-change judgments improved significantly. We conclude that the brain exploits its knowledge of how image size, physical size, and distance are related to improve perceptual size judgments. We compared participants' use of distance cues with predictions of an ideal observer that incorporates distance cues in proportion to their reliability to quantify human behavior. We independently measured participants' stereo and haptic distance discrimination performance, applied these empirical reliability measurements in the ideal model, and found participants use stereo information to a similar degree as the ideal observer, but use haptic information less than the ideal observer. This result was confirmed by an additional conflict condition in which haptic and stereo distance-change cues indicated different values and their relative use could be measured. Lastly, we ran a condition in which participants gripped the object with two fingers, so that a direct size-change cue was available, and found participants integrated direct and indirect size-change cues to improve performance.

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Wednesday, May 14, 8:30 - 10:00 am
Talk Session, Royal Palm Ballroom 4-5

Attention to Locations and Features

Moderator: Jan Theeuwes

8:30 am

61.21 Differentiating Patients from Controls Based on Correlation between Salience and Gaze

Po-He Tseng[1] (pohetsn@gmail.com), Ian G. M. Cameron[2], Doug Munoz[2], Laurent Itti[1,3]; [1]Department of Computer Science, University of Southern California, [2]Centre for Neuroscience Studies and Department of Physiology, Queen's University, [3]Neuroscience Program, University of Southern California

Several studies have shown that eye movements and certain complex visual functions are influenced by diseases such as Parkinson's Disease (PD) and Attention Deficit Hyperactivity Disorder (ADHD). Here we examine how bottom-up (stimulus-driven) attentional selection mechanisms may differ between patient and control populations, and we take advantage of the difference to develop classifiers to differentiate patients from controls. We tracked gaze of four groups of observers (15 control children, aged 7-14; 6 ADHD children, aged 9-15; 12 control elderly, aged 66-79; and 9 PD elderly, aged 53-68) while they freely viewed MTV-style videos. These stimuli are composed of short (2-4 seconds), unrelated clips of natural scenes to reduce top-down (contextual) expectations and emphasize bottom-up influences on gaze allocations at the scene change. We used a saliency model to compute bottom-up saliency maps for every video frame. Saliency maps can be computed from a full set of features (color, intensity, orientation, flicker, motion) or from individual features. Support-vector-machine classifiers (with Radial-Basis Function Kernel) were built for each feature contributing the saliency map and for the combination of them. Leave-one-out was used to train and test the classifiers. Two classification experiments were performed: (1) between ADHD and control children; (2) between PD and control elderly. Saliency maps computed with all features can well differentiate patients and control populations (correctness: experiment 1 - 100%;

experiment 2 - 95.24%). Additionally, saliency maps computed from any one feature performed nearly as well (both experiments' results are 0-5% worse). Moreover, 0-250 ms after scene change is the most discriminative period for the classification. This study demonstrates that the bottom-up mechanism is greatly influenced by PD and ADHD, and the difference can serve as a probable diagnosis tool for clinical applications.

Acknowledgement: This work was supported by grants from The National Science Foundation and the Human Frontier Science Program.

8:45 am

61.22 Spatial Attention Accelerates Inter-Hemispheric Transfer Time

Ayelet Landau[1] (ayeletlandau@berkeley.edu), Lynn Robertson[1,2]; [1]Psychology Department, UC Berkeley, [2]Department of Veteran Affairs, Martinez

The present study was designed to examine perceptual responses under different spatial attention conditions to lateralized stimuli. EEG was recorded from scalp electrodes while participants were either attending or ignoring faces presented to the right or left of fixation. Event Related Potentials (ERPs) to interspersed faces were measured for two attention conditions (attend-face/ignore-face). Each display contained a symbol at the center of fixation and a lateralized presentation of a face. Faces either appeared to the left of fixation or to the right of fixation (in separate blocks). In the attend-face condition, participants were monitoring the peripheral faces covertly for an inverted face. In the ignore-face condition participants were instructed to monitor the symbols for an 'x' and pay no attention to the subsequently presented face while maintaining fixation. ERPs to attended and ignored faces were compared in a group of 16 neurologically healthy participants. General perceptual markers (P1) and indices of face processing (N170) were modulated by spatial attention. The nature of this modulation for faces was different for right visual field (RVF) and left visual field (LVF). Most importantly, analysis of peak latencies for both P1 and N170 revealed a robust acceleration in the interhemispheric transfer with spatial attention. When the face was attended the time difference between ipsilateral and contralateral response over extrastriate channels was smaller compared to when the faces were ignored. The acceleration in transfer time between the hemispheres was symmetric and equal for LVF and RVF presented faces. These findings suggest that the speed of hemispheric cross-talk in addition to amplitude modulations is influenced by spatial attention in the visual modality.

9:00 am

61.23 Surface-based, unpaired feature representations mediate detection of change to feature pairings

Jun Saiki[1] (saiki@cv.jinkan.kyoto-u.ac.jp), Alex O. Holcombe[2]; [1]Graduate School of Human and Environmental Studies, Kyoto University, Kyoto, Japan, [2]School of Psychology, University of Sydney, Sydney, Australia

In a transparent motion display, with multiple motions and colors presented in the same region, if a new color appears, noticing this change is easy. However, when the color-motion pairing of all the dots is reversed, but no new colors are introduced, we find that detection of the change is difficult. Our results suggest that color-motion pairings are not readily available to change detection.

Transparent motion was created with a field of dots. Half moved leftward, half moved rightward, half were red, and half were green. We manipulated the consistency of color and motion pairing— the proportion of red (green) dots moving in a particular direction. In the 0% consistency condition, half of the red dots moved left and half moved right, and the same for the green dots. Here, swapping the colors of all dots does not change which colors each surface has. In the 100% consistency condition, all dots moving in one direction are red before the swap and green after the swap, such that each surface's color changes completely. To avoid tracking of individual dots, a concurrent secondary task at fixation was included. Observers had great difficulty in detecting a color swap in the zero consistency condition (d'=1.2), and performance improved dramatically as the consistency increased (d'=3.0 for 100% consistency), suggesting that a color swap could be detected only when a surface's color changed. This effect of consistency was observed even when all dots had the same direction (which was perceived as a single surface). But with stationary dots, performance was perfect, suggesting that the impairment was specific to tracking of moving dots. Taken together, these results show that humans are remarkably blind to changes in local color-motion binding, unless these changes lead to a change in the features that belong to a surface.

Acknowledgement: Support from Global COE (D07 to Kyoto Univ.) and Grant-in-Aid for scientific research (C) (#19500226) from JSPS to JS, and an Australian Research Council DP to AOH.

9:15 am

61.24 Attention biases decisions but does not alter appearance

Keith A. Schneider[1,2] (ks@rcbi.rochester.edu), Marcell Komlos[1]; [1]Rochester Center for Brain Imaging, University of Rochester, [2]Center for Visual Science, University of Rochester

Introduction: Whether attention intensifies the subjective perception of sensory attributes has been a topic of debate in experimental psychology for over one hundred years. Recently, some studies have shown that transient peripheral attentional cues can increase the perceived contrast and other attributes of stimuli. These studies have been interpreted as demonstrating a link between neural theories and the phenomenology of attention. In a previous study, we were unable to reproduce the effect of attention on perceived contrast except for very low contrasts, near the threshold of detection, and the characteristics of those effects suggested they were the result of sensory interactions between the cues and targets rather than attention. To further investigate the discrepancy, we decided to replicate published studies, using their exact superthreshold stimuli and procedures, and also to introduce different types of behavioral judgments.

Methods: Two Gabor patch targets with separate contrasts were simultaneously and briefly presented. One was pre-cued by a transient small black dot. Fourteen subjects compared the contrasts of the two targets using three different types of perceptual judgments in separate sessions: 1. whether the two targets had the same or different contrast (equality judgment); 2. which target had the higher contrast (comparative judgment); 3. the comparative judgment plus determining the orientation of the target deemed to have the higher contrast.

Results: The two comparative judgments showed significant increases in contrast of the cued target across the range of contrasts tested. However, the equality judgment showed no effect at any contrast.

Conclusion: The equality judgment is not susceptible to the same type of biases as the comparative judgment. Since the attentional effects depend on the decision process, we must conclude that while attention may incite post-perceptual biases in the decision process, it does not prohibit the veridical perception of sensory attributes—attention does not deceive us.

9:30 am

61.25 Exogenous attention: Less effort, more learning!

Marisa Carrasco[1] (marisa.carrasco@nyu.edu), Abby Rosenbaum[1], Anna Marie Giordano[1]; [1]New York University

Goal: In a perceptual learning task in which observers trained with neutral cue and peripheral cue (attention) trials simultaneously, we observed that exogenous attention led to stronger perceptual learning (Carrasco, Giordano & Looser, VSS 07). Here, we compared perceptual learning for observers trained exclusively in either endogenous (sustained) attention, exogenous (transient attention), or a neutral condition. We assessed the effects of training using a speed-accuracy trade-off (SAT) procedure.

Methods: Observers performed a conjunction (orientation X spatial frequency) 2-AFC orientation discrimination task in which a cue preceded a target (3-cpd tilted Gabor) presented with 7 distracters (3-cpd vertical and 2-cpd tilted Gabors) at 8 isoeccentric locations. There were three cue conditions: exogenous (dot adjacent to target location), neutral (central dot) or endogenous (central bar indicating target location). A response tone prompted observers to respond after various lags (40–1500 ms). Observers completed 5 consecutive training sessions (1/day) then completed 3 sessions of a transfer task in which the identity of the target and one of the distracters was switched (target: 2-cpd tilted Gabor; distracters: 2-cpd vertical and 3-cpd tilted Gabors).

Results & Conclusion: In the training task perceptual learning occurred for the neutral condition for both discriminability and temporal dynamics. Exogenous and endogenous attention magnified the benefit, more so for the former than the latter. In the transfer task, performance for the neutral condition shows a decrement in both discriminability and temporal dynamics. However, performance kept improving for discriminability with both transient and sustained attention. With regard to temporal dynamics, transient attention continues to speed processing, whereas sustained attention yields performance that levels off. In conclusion, these results indicate that both types of attention improve perceptual learning, and that exogenous attention yields the strongest benefits, even though it is less effortful than endogenous attention.

Acknowledgement: Grant: NIH R01 EY016200-01A2

09:45

61.26 The Size of Attentional Window Modulates Attentional Capture

Jan Theeuwes[1] (J.Theeuwes@psy.vu.nl), Artem V. Belopolsky[1]; [1]Department of Cognitive Psychology, Vrije Universiteit, Amsterdam

The classic work of Jonides & Yantis (1988 Perception & Psychophysics, 43, 346-354) showed that attention was not captured by elements having a unique color, shape or luminance. Subsequent work by Theeuwes (1992 Perception & Psychophysics, 51, 599-606) demonstrated that in some conditions static singleton do capture attention and that this capture is not under top-down control. One possible explanatory mechanism is to assume that observers are able to either focus their attention on a limited area in visual space or to spread attention across the visual field. In the current study we show that in a task in which observers have to focus attention, salient singleton outside the focus of attention do not capture attention anymore. However, when this very same task is used and observers are instructed to spread their attention, static singleton capture attention. Our findings have implications for models of visual attention. We propose that salience computations across the visual field are more or less restricted to the attentional window of the observer. The size of the attentional window appears to be under top-down control. However, within the attentional window salience computations occur in an automatic, bottom-up fashion, and the location having the highest salience is prioritized (cf. Itti & Koch, 2000 Vision Research, 40, 489-1506).

Wednesday, May 14, 10:30 am - 12:00 pm Talk Session, Vista Ballroom

Color Appearance

Moderator: Donald MacLeod

10:30 am

62.11 Are there phenomenal complementaries?

Donald MacLeod[1] (dmacleod@ucsd.edu), Pamela Pallett[1], Erin Krizay[1]; [1]Psychology Department, UC San Diego

Color charts can capture some aspects of the phenomenal structure of color experience in a coordinate system with two bipolar axes, one for redness (positive) vs. greenness (negative) and the other for yellowness vs blueness. This leads to an arrangement in which perceptually unitary ('unique') red and green are found in opposite directions from white at the origin, and blue and yellow are similarly opposite, while the blue/yellow and red/green directions are mutually orthogonal. The neural representation of color by color-opponent signals is often viewed as supportive of such schemes. But the pervasive rectifying nonlinearity of neural responses, and the marked asymmetry between excitatory and inhibitor response dictated by the relatively low spontaneous firing rate, are more suggestive of an idealization with multiple monopolar signals for redness, greenness, yellowness and blueness. Wuth mutually orthogonal monopolar coordinates for the four primary signals, the isoluminant colors occupy the surface of a hypercube in the 4D space; white is at one corner. To test this scheme experimentally, subjects first identified examples of unique red, green, yellow, and blue perceived as equidistant from white. We then asked whether these colors are perceptually equidistant from each other, as the hypercube model predicts. One of the set of colors judged equidistant from white, for instance the red, was presented with adjustable purity, and subjects adjusted the purity as needed to make it as different from the green as from the blue or the yellow. On the hypercube model, no adjustment should be needed. But if there were perceptual red/green opponency, one would expect subjects to select a less saturated red than the one chosen in the first phase of the experiment. Results are close to the predictions of the hypercube surface model, with significant but small deviations.

Acknowledgement: EY01711

10:45 am

62.12 Chromatic appearance depends on the rate of change of the colour signal (the "slew" rate)

Andrew Stockman[1] (a.stockman@ucl.ac.uk), Hannah Smithson[2], Jonathan Aboshiha[1], Peter West[1], Caterina Ripamonti[1]; [1]Institute of Ophthalmology, University College London, [2]Department of Psychology, Durham University

At low to moderate flicker frequencies (6 to 13 Hz), the overall mean colour appearances of M- and L-cone-isolating sawtooth stimuli depend on whether the direction of the sawtooth is rapid-on (slowly-off) or rapid-off (slowly-on). Rapid-on-L-cone and rapid-off-M-cone sawtooth stimuli appear greener, while rapid-off-L-cone and rapid-on-M-cone sawtooth stimuli appear redder, even though they have the same mean chromaticities. These changes can be explained by supposing that chromatic mechanisms are better able to track the slowly changing part of the sawtooth than its quickly changing part. Thus, their mean output will always be skewed in the direction of the slow change. By investigating how chromatic detection and discrimination depends on the slopes and amplitudes of the sawtooth waveforms, we can understand more about the temporal properties of the underlying chromatic mechanisms. Our findings are inconsistent with models of red-green opponent colour processing that incorporate only simple filters or nonlinearities. However, they are broadly consistent with models that are limited by a maximum rate of change in the colour signal from red to green or vice versa (i.e., the colour change is "slew-rate-limited") preceded by a stage of temporal integration.

Acknowledgement: BBSRC, Fight for Sight

11:00 am

62.13 Pattern classification on BOLD signals reveals a novel mechanism underlying color filling-in

Po-Jang Hsieh[1] (po-jang.hsieh@dartmouth.edu), Peter Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Filling-in occurs when a retinally stabilized object undergoes perceptual fading. It is commonly believed that information about the apparently vanished object is lost and replaced solely by information arising from the surrounding background. Here we propose a new theory according to which the mechanism of filling-in is in fact a process of feature mixing, whereby features on either side of a perceptually faded boundary merge additively. Our psychophysical data show that, after prolonged viewing of visual stimuli composed of different colors in the background and the foreground, the filled-in percept is the additive mixture of the two colors. fMRI results using multi-voxel pattern analysis reveal that while subjects were in a perceptual fading/filling-in state (after prolonged viewing of blue disks on a red background), the BOLD activation pattern in V1 behaves as if the subjects were perceiving a perceptually mixed color (purple). Together, these results imply that the mechanism of "filling-in" is in fact a process of featural mixing.

11:15 am

62.14 Predicting illuminant-shifted cone excitations: superiority of a non-parametric approach over von Kries' coefficient rule

David H. Foster[1] (d.h.foster@manchester.ac.uk), Kamila Żychaluk[1]; [1]School of Electrical and Electronic Engineering, University of Manchester

The spectrum of the light reflected from a scene into the eye is the product of the scene's spectral reflecting properties and the spectrum of the illumination. As the illuminant changes, the excitations in each class of cone receptors of the eye change. A simple but accurate estimate of these changes in excitations is provided by the coefficient rule of von Kries, which conventionally incorporates two assumptions: that cone excitations depend on activity only within each cone class and that this dependence constitutes a simple scaling. Being able to predict the effects of an illuminant change allows it to be discounted as part of achieving an invariant perception of surface color, that is, color constancy. Both assumptions are important in modeling the mechanisms of color constancy. Although accounting for almost all of the variation in cone responses, von Kries' rule does show some systematic departures from proportionality. The aim of the present work was to test whether a non-parametric approach to predicting cone excitations, that is, one that does not depend on a particular parametric model of the effects of illumination, might be more accurate. Computer simulations were performed with hyperspectral images of natural scenes under separate illuminants drawn from combinations of sunlight, sky light, and filtered daylight transmitted through the forest canopy. Vegetated scenes were used rather than non-vegetated scenes as they were expected to reveal greater deviations from von Kries' rule. It was found that a non-parametric model based on locally weighted regression gave a significantly better fit than von Kries' scaling, suggesting that the departures from proportionality, although small, might be important. The improved performance of non-parametric fitting was achieved without compromising the basic assumption that excitations in each cone class depend on activity only within that class.

Acknowledgement: Supported by EPSRC Grant No. EP/C003470/1

11:30 am

62.15 **Colour Constancy of Polychromatic Surfaces**

Anya Hurlbert[1] (anya.hurlbert@ncl.ac.uk), Milena Vurro[1], Yazhu Ling[1]; [1]Institute of Neuroscience, Newcastle University, UK

Natural surfaces tend to have heterogeneous surface reflectances, which are nonuniform in both chromaticity and luminance. This feature of natural surfaces is not captured by traditional studies of colour perception, which typically employ stimuli of uniform colour and brightness. In a computational model, we consider the effect of surface 'polychromaticity' (Beeckmans, Philosophical Psychology, 2004) on colour appearance under changing illumination.

To quantify and characterise surface chromatic texture, we analysed the surface colour distributions of natural and man-made objects (including fruits, vegetables, foliage, and textiles), imaged under artificial daylight illumination using a tristimulus-calibrated camera system. The distribution of within-surface cone contrasts for a given object forms a distinct signature in three-dimensional cone-contrast space, which transforms predictably under changes in illumination. For many natural surfaces, the distribution is an elongated cluster whose vector direction in cone-contrast space remains roughly constant under illumination changes, provided the contrasts are calculated with respect to the illumination whitepoint. This feature provides a surface descriptor which remains stable under adaptation to the illumination, thereby potentially mediating colour constancy.

Acknowledgement: EPSRC

11:45 am

62.16 **Color averaging linked to contours, textures and orientation**

Stuart Anstis[1] (sanstis@ucsd.edu), Mark Vergeer[2], Rob van Lier[2]; [1]Psychology, UC San Diego, [2]Psychology, Nijmegen U

A blurry, multicolored plaid was made by superimposing two crossed colored sinusoidal gratings: a horizontal red/green grating, and a vertical blue/yellow grating. [Disregarding 'monocular rivalry', which may just be an artifact from eye movements], we have found ways to enhance the visibility of either the vertical or the horizontal grating. We superimposed thin black lines, spaced half a spatial period apart, on the plaid. Vertical lines made the plaid look like a blue/yellow vertical grating. Horizontal lines made it look like a horizontal red/green grating. The perceived were stable and homogeneous between the bars Similar effects were found for gratings that differed in spatial phase. A red/green and a blue/yellow vertical grating were superimposed shifted by 90°. Now superimposed vertical lines that lined up with the red-green grating made the plaid look like a vertical red/green grating. Displacing the vertical lines sideways to line up with the blue/yellow grating made the plaid look like a vertical blue/yellow grating. Instead of black contours, we can define regions with equiluminous second-order textures, with the same results. We conclude that the visual system combines or averages colors within regions defined by achromatic contours or textures. Another technique did not use superimposed lines, but relied on pre-adaptation to noisy vertical lines twinkling randomly in width and position. This adapted the visual system to vertical. Now the plaid of crossed gratings looked like a horizontal red-green grating. Conversely, adapting to noisy horizontal lines made the plaid look like a vertical blue/yellow grating. Thus the achromatic adapting orientation altered the perceived color of the test plaid. We conclude that the visual system enhances or suppresses colors together with orientation, perhaps owing to double-duty neural units tuned to both color and orientation.

Wednesday, May 14, 10:30 am - 12:00 pm Talk Session, Royal Palm Ballroom 4-5

Scene Perception 3

Moderator: Aude Oliva

10:30 am

62.21 **Search for arbitrary objects in natural scenes is remarkably efficient**

Jeremy Wolfe[1,2] (wolfe@search.bwh.harvard.edu), George Alvarez[3], Ruth Rosenholtz[3], Aude Oliva[3], Antonio Torralba[3], Yoana Kuzmova[1], Max Uhlenhuth[4]; [1]Brigham and Women's Hospital,Boston, MA, [2]Harvard Medical School, Boston, MA, [3]MIT, Cambridge, MA, [4]duPont Manual High School, Louisville, KY

In visual search tasks, the time required to find targets (reaction time - RT) is a function of the number of items in the display (set size). Targets can be found efficiently if they can be uniquely defined by the presence one of a limited set of features. Thus, for example, in search for red targets among blue distractors, the slope of the RT x set size function will be close to zero. Other tasks (e.g. search for a letter among various distracting letters) will be inefficient even if the items can be resolved and identified without eye movements. This holds for artificial tasks typically used in laboratory search experiments. What about searches in the real world where the target is not precisely specified ("Find a bottle.") and where one's goal changes from search to search (Find the bottle, now the fork, now the bread)? A major obstacle to studying such searches in real scenes has been that it is very hard to specify set size (How many objects are in your field of view right now? Does the keyboard constitute one object or many?) We adopted a brute force method, hand-labeling every object in a set of 100 indoor scenes and using the number of labeled items as a conservative estimate of set size. By this method, we placed scenes into set size bins from 20-30 to 80-90 items. On each trial, twelve observers searched for different targets, drawn at random from the set of labeled items. Targets were present on 50% of trials. Slopes of RT x set size functions averaged 4.6 msec/item for target-present, 4.7 for target-absent trials. Search in these scenes seems to be guided very effectively by something other than the usual attributes like color, orientation, etc. We propose that scene-based properties efficiently guide attention.

Acknowledgement: NIH:NIMH56020, AFOSR, DHS

URL: http://search.bwh.harvard.edu/new/

10:45 am

62.22 **High-level aftereffects to natural scenes**

Michelle Greene[1] (mrgreene@mit.edu), Aude Oliva[1]; [1]MIT, Brain and Cognitive Sciences

Adaptation is a ubiquitous phenomenon in the human visual system, allowing recalibration to the statistical regularities of its input. Previous work has shown that global scene properties such as openness and mean depth are informative dimensions of natural scene variation that are useful for both human and machine scene categorization (Oliva & Torralba, 2001; Greene & Oliva, 2006). A visual system that rapidly categorizes scenes using such statistical regularities should be continuously updated, and therefore prone to adaptation along these dimensions. Here we show that after adapting to one pole of a global scene property, observers show a scene property after-effect on subsequently presented test scenes. Observers were adapted to an RSVP stream of 100 images previously ranked by human observers to exemplify a pole of a global property (e.g. very large depth, Greene & Oliva, 2006). The images differed in their basic-level categories, other global properties, their objects and other low-level image features. After adaptation, observers were presented with a test scene and performed a binary classification along the global property dimension. Test images were drawn from the 25th, 50th and 75th percentiles of that global property to measure shifts in the psychometric function. Both poles of each global property were compared to a control RSVP stream of random images. All global properties showed significant main effects of adaptation ($p<0.01$, ranging from 6% to 22%), with the magnitude of the adaptation effects inversely related to adaptation duration. Additionally, adaptation after-effects were preserved when the test image was presented 10 degrees away from the adapted location, suggesting the origin of these after-effects is not solely due to low-level adaptation. Finally, we show systematic modulation of observers' basic-level scene categorization performances after adapting to global properties, suggesting a strong representational role of global properties in rapid scene categorization.

11:00 am

62.23 Cortical Dynamics of bistable form/motion binding: fMRI and eye movements

Jean Lorenceau[1] (jean.lorenceau@chups.jussieu.fr), Anne-Lise Paradis[1], Cédric Lamirel[1], Jean-Baptiste Poline[2], Eric Artiges[2], Bertrand Thirion[2], Anne Caclin[3]; [1]Laboratoire de Neurosciences Cognitives et Imagerie Cérébrale, LENA-UPR640 CNRS, UPMC, [2]Neurospin-CEA, [3]INSERM U280, Lyon, France

Recovering meaningful objects from the elementary retinal samples of a visual scene involves a cascade of binding processes unfolding along a visual hierarchy that splits into a dorsal and a ventral stream, each functionally specialized for the analysis of motion and form. Unified perception of moving forms thus requires interactions between these streams, but the nature and function of these interactions remain elusive. We address this issue using fMRI together with 3 versions of bistable moving 'aperture' stimuli whose interpretation fluctuates between a whole moving shape (bound state) and the independent motion of its parts (unbound state). We identified a dynamic balance of BOLD activity between dorsal and ventral visual areas tightly correlated with the dynamics of perceptual alternations: A transition towards a bound state is followed by a BOLD activation in V1 & LOC and a deactivation in hMT+. In contrast, a transition towards an unbound state entails a BOLD activation in hMT+, and a reduced activity in the LOC. During bound states, this network extends to V1, V2 & V3 suggesting the progressive involvement of recurrent LOC/V1/V2/V3 loops. This extended network is not seen during unbound states. Importantly, spontaneous alternations with unchanging stimuli and perceptual alternations induced by periodic changes of luminance, motion noise or shape, known to control form/motion binding, entail a similar network dynamics. Analyses of eye movements indicate that saccades and blinks are more frequent before transitions although overall too rare to account for BOLD contrasts. Altogether, these results suggest that ventral areas provide constraints to select motion components to be bound into a single motion within dorsal areas.

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11:15 am

62.24 A Model of Self-Consistent Perception

Alan Stocker[1,2] (alan.stocker@nyu.edu), Eero Simoncelli[1,2]; [1]Center for Neural Science, New York University, [2]Howard Hughes Medical Institute

Human perception is context-dependent. In addition to sensory context, data from recent psychophysical studies suggest that context can also include previous perceptual decisions (Baldassi etal. PLoS, 4(3):e56, 2006; Jazayeri and Movshon, Nature, 446:912ff, 2007). In both studies, subjects were asked to estimate a stimulus parameter (e.g., the exact orientation angle of a Gabor patch) after being forced to make a binary decision about that parameter (e.g., orientation to the left/right of vertical). On each individual trial, the subjects' estimates were consistent with their preceding decision (i.e., a decision of "left of vertical" was followed by an estimated direction left of vertical). In addition, the distributions of estimates were bimodal, indicating repulsion away from the decision boundary.

We present a probabilistic observer model that accounts for this perceptual behavior. Specifically, we adopt the general hypothesis that the brain attempts to perform optimal estimation of stimulus parameters based on noisy sensory evidence and prior expectations. However, we augment this hypothesis by assuming that the observer performs the secondary estimation task in the belief that his/her previous decision regarding the data was correct. Noisy sensory evidence may initially support both decisions, although with different probability. After making the decision, however, the observer discards all potential estimates that are not in agreement with the choice. This leads to the observed repulsive bias away from the decision boundary. The model fits the data well and makes quantitative predictions for novel experiments.

It is worth noting that the behavior of the model is suboptimal in terms of estimation performance. An optimal (Bayesian) observer model would compute estimates from the sensory evidence under each possible decision taken, and then average these estimates, weighting each according to the probability that the corresponding decision is correct. Thus, our model implies that humans sacrifice performance in order to maintain self-consistency.

11:30 am

62.25 Fixation durations in scene viewing: Experimental data and computational modeling

Antje Nuthmann[1] (Antje.Nuthmann@ed.ac.uk), Tim J. Smith[1], John M. Henderson[1]; [1]Department of Psychology, University of Edinburgh

Two important aspects of eye-movement control during scene viewing are where fixations tend to be directed (fixation position), and how long they typically remain there (fixation duration). While substantial behavioral and computational research has been devoted to fixation positions in scenes, relatively little is known about the mechanisms that control fixation durations during scene viewing.

We have recently investigated the degree to which fixation durations are under direct moment-to-moment control of the current visual scene using a scene onset delay paradigm. During saccades prior to specified critical fixations, the scene was removed from view so that when the eyes landed in fixation, the scene was absent. Following a pre-defined delay (0, 300, 400, 600, 800 ms, or infinite delay), the scene reappeared. Two populations of fixation durations were observed: A first (early) population of fixations that terminated during scene absence independently of the delay, and a second (late) population of fixations that increased in duration as delay increased.

Here, we propose a random timing model with inhibition and two-stage saccade programming to account for the observed fixation duration patterns. Model assumptions are consistent with current evidence concerning basic oculomotor control. First, an autonomous (i.e., random) saccade timer generates variations in fixation durations. Second, we assume that difficulties at the level of visual and cognitive processing can inhibit saccade initiation, essentially leading to longer fixation durations. Third, saccade programming is completed in two stages: an initial, labile stage that is subject to cancellation, and an ensuing, non-labile stage. The model was tested on the scene onset delay data. Simulations qualitatively reproduced the mixed-control pattern of fixation durations observed in the empirical data. We conclude that fixation durations, to a certain degree, reflect perceptual and cognitive activity in scene viewing; computational model simulations contribute to our understanding of the underlying processes.

11:45 am

62.26 Change blindness by substituting one natural image with another

Bruce Bridgeman[1] (bruceb@ucsc.edu), Philip Tseng[1]; [1]Department of Psychology, University of California, Santa Cruz

How is our visual representation of natural scenes constructed with constantly-moving eyes? We introduce a new change blindness paradigm, combining Blackmore et al's moving-image paradigm (1995) and Sampanes, Tseng, and Bridgeman's progressive transformation paradigm (in press). A picture jumps repeatedly to random locations on a screen, with a simultaneous change made to a local region of the image during the jump, until the image is finally "morphed" into another one in 13 steps. To avoid misalignments of parts of the old and the new images, a checkerboard of white squares is superimposed on the image while the remaining isolated visible squares are being substituted. When gist is altered between the pictures (e.g. a girl holding a glass of water vs. the same girl holding an eclair), changes are always detected. However, when gist stays the same between the two pictures (e.g. one dumpster vs. a different dumpster), participants fail to detect the the change 70% of the time. On the trials where they do detect changes, their detection rates accumulate slightly within the first four transforming steps, suggesting that a visual representation does take some time to be built. These responses then reach an asymptotic level and stay evenly distributed throughout the remaining 8 transforming steps. In other words, change detection does not get easier as changes accumulate, suggesting that each image is compared with its immediate predecessor. Together these results confirm the idea that only a few perceptual details and a gist can survive a saccadic eye movement or image jump and be retained to aid conscious detection. In addition, these details accumulate initially, and are refreshed after each sample. Therefore, our experience of a stable and detailed visual world is a construction from only a few previously fixated details, and a gist.

Wednesday, May 14, 8:30 am - 12:30 pm Poster Session, Royal Palm Ballroom 1-3

Attention: Inhibition and Capture
Perceptual Learning 3

Attention: Inhibition and Capture

63.301 Cortical control of salient-distracter interference during visual search: can attentional capture be top-down modulated?

Ignacio Vallines^{1,2} (vallines@lmu.de), En-Ju Lin[1], Hermann Müller[1]; [1]Neuro-Cognitive Psychology, Ludwig-Maximilian University of Munich, [2]Experimental Psychology, University of Regensburg

Visual search for a target among homogeneous distracters is notably disrupted by the presence of a salient singleton element in the display. This disrupting effect can be measured as a significant increase in the time needed to respond to the target, and is traditionally explained in terms of a reflexive, involuntary shift of focal attention to the distracter. In this event-related fMRI study, we demonstrate that the magnitude of this interference can be greatly attenuated by exerting top-down control. Observers had to detect and respond to a singleton form target amongst non-target items that could include a salient color singleton distracter, while the frequency of appearance of this distracter (i.e., observers' certainty about the occurrence of a distracter event) was systematically manipulated. The unexpected onset of a color distracter was found to engage areas of the superior parietal and the dorsolateral prefrontal cortex bilaterally. Matching brain activity in the medial frontal gyrus, we observed a significant reduction in the magnitude of interference when observers could anticipate the appearance of the singleton distracter, possibly reflecting active recalibration of dimensional weights (e.g., reducing the weight for color-based feature contrast signals). The small but significant amount of interference that remained even with high stimulus certainty was strongly related to the spatial position of the distracter with respect to the target: the closer the distracter to the target, the stronger the interference. This spatial effect was parametrically reflected in the activity levels of the right dorsolateral prefrontal cortex, which was also significantly engaged by the unexpected onset of the distracter, and seems to be relieved by stimulus certainty. Our data suggests that extra processing costs associated with attentional capture disappear almost completely when observers are allowed to recalibrate dimension-specific weights based on stimulus certainty, and the singleton distracter is spatially distant from the target.

63.302 Spatiotemporal dynamics in inhibition of return

Maha Adamo[1] (maha@psych.utoronto.ca), Carson Pun[1], Jay Pratt[1], Susanne Ferber[1]; [1]Department of Psychology, University of Toronto

Once attention has been disengaged from a non-predictive exogenous cue, processing of a target subsequently presented at the cued location is slowed relative to that of targets at uncued locations. This effect has been termed inhibition of return (IOR). Previous studies of IOR using multiple cueing paradigms have focused on either temporal or spatial dynamics in isolation. We argue, however, that space and time have to be considered in conjunction to understand the processes governing the allocation of attention. To test this notion, the present work examines the spatiotemporal distribution of IOR in a sequential cueing task, in which three cues were presented sequentially for 500ms each at three of six possible locations along an imaginary circle with 5° radius. Following a central reorienting cue of 500ms duration, a target appeared for 100ms at any of the six possible locations, which participants were instructed to detect by button press as rapidly as possible. In line with previous work, we found greatest IOR at the most recently cued locations, with decreasing magnitudes of IOR at locations cued earlier in the sequence. Importantly, the magnitude of IOR was affected by the spatial arrangement of the cues, such that targets appearing at the vector average of all cued locations showed greater IOR than those appearing at the edges of the spatial distribution. Therefore, we conclude that IOR is a function of both the positions and the timing of sequential cues, indicating that attention integrates spatial and temporal properties to optimize responses to new information.

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63.303 Influences of Abrupt vs. Ramped Stimulus Presentation on Location-based Inhibition of Return

Benjamin Guenther[1] (benguenther@gmail.com), James Brown[1]; [1]Department of Psychology, The University of Georgia

Purpose: Previous research by Guenther & Brown (VSS 2007) manipulated the relative balance of P and M activity finding relatively greater P activity to be associated with increased IOR and relatively greater M activity to be associated with decreased IOR. To further examine the roles of the P and M pathways in location-based IOR, the present research employed abrupt versus ramped stimulus presentations to manipulate the relative balance of P and M activity. It was predicted that since ramped stimuli would be processed less efficiently by the M system, ramped and abrupt stimuli would represent conditions of relatively less M (i.e., greater P) and relatively greater M activity respectively. Method: Cue and target onsets and offsets were either abrupt or ramped. They were presented either alone, in 2-D, or in 3-D objects, using timing parameters known to produce location-based IOR. Simple RT to target onset was measured. Results: Ramping had the expected sensory effects of reducing the M response as indicated by the increased RTs to ramped compared to abrupt targets. Direct RT comparisons of abrupt and ramped conditions were validated through a control experiment. Without objects, ramped and abrupt conditions produced similar IOR. With both 2-D and 3-D objects, IOR differences emerged with greater IOR to the relatively more P based, ramped condition and less IOR to the relatively more M based, abrupt condition. Conclusions: While SF appears to be a better way to produce P and M based differences in IOR (Guenther & Brown, VSS 2007), the interaction of abrupt vs. ramped presentation conditions with 2-D and 3-D objects supports the association of relatively greater P/ventral activity with increased IOR.

63.304 Object- and Location-based Inhibition of Return to Superimposed Surfaces

Marielle Johnson^{1,2} (marielle@yorku.ca), Mazyar Fallah^{1,2}, Heather Jordan^{1,3}; [1]Centre for Vision Research, York University, [2]School of Kinesiology and Health Science, York University, [3]Department of Psychology, York University

Previous studies have suggested the existence of spatial and object-based Inhibition of Return (IOR) effects, and proposed that they are driven by separate mechanisms. These studies have exclusively used objects occurring in spatially separate locations. Thus the object-based effects could be mediated by a location-based mechanism. To control for location, we superimposed two objects (random dot kinetograms). This study examines whether IOR is present for objects that are superimposed or requires that the objects are separated in space. We modified the traditional dynamic IOR displays (Tipper et al, 1991) by placing 2 superimposed surfaces in each of two peripheral locations (left vs right). Location-based IOR was observed regardless whether the target appeared on the cued or uncued surface. Critically, object-based IOR was not present; instead we found evidence of object-based facilitatory effects. Thus location-based but not object-based IOR is found with superimposed surfaces. In Experiment 2, we asked whether spatial separation is necessary throughout the trial or at time of cueing. These results have implications for the relative roles of subcortical oculomotor (e.g. superior colliculus) and cortical substrates for mediating IOR.

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63.305 Simultaneous feature-based inhibition of attention along multiple dimensions

Brian Levinthal[1] (levintha@uiuc.edu), Alejandro Lleras[1]; [1]University of Illinois at Urbana-Champaign

When observers perform an oddball feature search, their ability to select and discriminate a target is impaired if the feature that defines the target (e.g. "green") also defined a field of homogeneous distractors on an immediately preceding target-absent trial. This phenomenon is commonly referred to as the distractor previewing effect (DPE), a robust inter-trial effect that reflects an inhibitory bias against selecting a recently rejected feature. In our previous studies, we have demonstrated that the DPE only occurs for features in the dimension that defines the target (search-relevant features), and no inhibition is observed along dimensions that never define the target (search-irrelevant features). In the present study, participants searched for an oddball that could occur either in the color or shape dimension (but never in both). On target-absent trials, all objects were identical (homogenous on shape and color). In addition, each stimulus contained a slanted line and participants were asked to report the orientation of the oddball's slanted line (if an oddball was present). Our results indicate that feature-based inhibition of attention (as indicated by a significantly positive DPE) was formed and maintained for both color and shape following a target-absent display. Furthermore, we find that inter-trial inhibition in a given dimension is partially modulated by recent experience with this dimension: if the dimension that defines a target (e.g. color) is repeated on trial N-2 and trial N (trial N-1 being a target-absent trial), the non-target dimension (e.g. shape, in this case) has no effect on the observed DPE. However, if the target dimension is switched from trial N-2 to trial N, inhibition along the non-target dimension on trial N magnifies the DPE along the target dimension. We conclude that inhibitory marking of features can simultaneously occur along multiple search-relevant dimensions, and is biased by recent experience.

63.306 **Semantic Marking in Preview Search**

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In visual search tasks, if a subset of the search items (without the target) is presented at least 400ms before the full set is in view, visual search efficiency is improved dramatically, almost as if only the second set of items had been searched. This phenomenon is known as visual marking, and is thought to involve inhibitory-tagging of old items. This study investigates whether this inhibitory-tagging can be semantically mediated. Subjects searched for a sideway T among Ls of identical color and regular Ts and upside-down Ts of a second color, and reported the orientation of the target T. In addition, to eliminate the contribution of bottom-up attentional capture by the onset of the second set of items, we included a 200ms blank display between the initial preview and the final search display. In Experiment 1, we tested four conditions: feature search (T amongst Ls), conjunction search (T amongst full set of distractors) and two preview conditions. In the control-preview condition, all distractor Ts were presented first, before the full display appeared. In the semantic-preview condition, we simply showed the words “BLUE” or “RED” at fixation (and in blank ink). As in the control-preview condition, the color word indicated the color of the distractor Ts in the final display. Our results showed an identical preview benefit in both preview conditions, indicating that semantic knowledge of the color of a subset of distractors was sufficient for “marking” these items in the full display. In Experiment 2, we tested whether this “semantic marking” could be used to prioritize the target color. Surprisingly, search efficiency was identical in the control and “target-marking” preview conditions. These two experiments strongly suggest that advance knowledge of either the distractor color or the target color is sufficient to produce preview benefits.

63.307 **The spatial distribution of visual marking**

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In an inefficient visual search task, when a set of distractors (old items) is presented before a set of target and distractors (new items), the search becomes efficient and independent of the set size of old items (visual marking: Watson & Humphreys, 1997). This effect is said to occur because the locations of the old items are inhibited before the new items appear. This study used a probe-detection task to examine whether the inhibition occurs only at the locations of the old items or at and around the locations of old items. In Experiment 1, participants performed a preview search task in which they searched for a target among the old and new items in 2/3 of the trials. In these trials, the old items were presented for 1s before the new items were added. In the remaining trials (signaled by a tone), the displays were identical to the preview search trials, except that the participants had to detect a probe dot that appeared in the display after the new items appeared and the reaction time to detect the probe was measured. The result revealed that the reaction times at locations around the old items were longer than for the blank region where no items were presented, and as long as that at the location occupied by old items. In Experiment 2, we tested whether the inhibition around the old items was induced before or after the new items appeared because the inhibition of visual marking occurs beforehand. The result indicated that probe detection around the old location took longer than in the blank region before new items appeared. These results suggest that the inhibition of visual marking occurs not only at the location of old items, but also propagates around the location of the old items.

63.308 **What drives memory-driven attentional capture?**

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Following the biased competition model [Desimone, R. & Duncan, J. (1995), Neural mechanisms of selective visual attention, Annual Review of Neuroscience, 18, 193-222], an important question is whether visual attention (the ability to select relevant visual information) and visual working memory (the ability to retain relevant visual information) share the same content representations. Is visual attention biased by what we hold in memory? We have recently found that it is: Singleton distractors interfered more strongly with a visual search task when they were identical or related to the object held in memory. The current work investigated which factors are, and which factors are not important in generating memory-driven attention. Memory-driven attentional capture does not depend on whether articulatory suppression or other methods are used to induce the use of visual (rather than verbal) memory, nor on whether search is serial or parallel, or whether displays are homogeneous or heterogeneous. What is important is that the search task remains the same from trial to trial (consistent vs. varied mapping), and that the visual search items possess sufficient surface energy. The conclusion is that memory drives attention only when memory resources can be fully dedicated to the to-be-memorized representation, and there is sufficient stimulus-based activity for this memory representation to resonate with.

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63.309 **Individual differences in resistance to attentional capture**

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The storage capacity of visual short-term memory (VSTM) for simple objects is known to be severely restricted and to vary considerably across individuals. These individual differences in capacity have often been proposed to be due to variability in memory storage space. However, it is also possible that much of the variability stems from the efficiency of attentional control mechanisms that restrict access to VSTM. In previous experiments, we have found that low capacity subjects are poorer at keeping irrelevant items from being stored in VSTM than high capacity subjects. In the present study, we extend these findings by examining individual differences in the initial allocation of spatial attention towards target and distractor onsets. Here we found that when targets were presented in isolation or with task-irrelevant distractors, all subjects showed equivalent attentional modulations of the P1/N1 ERP components. However, when the target was accompanied by task-relevant (contingent) distractors, large differences across individuals were observed; while high capacity subjects maintained a tight focus upon the target location, the low capacity subjects involuntarily reallocated attentional focus to also include the distractor locations. These results suggest that individual differences in VSTM may stem from variability in resisting attentional capture by the initial onsets of contingent distractors.

63.310 **Attentional capture is reduced when distractors remain visible in rapidserial visual presentation**

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The identification of a target in a rapid visual stream of non-target letters is impaired by the abrupt onset of a task-irrelevant peripheral distractor. This impairment, known as attentional capture, is thought to occur because the attentional focus is diverted spatially from the central stream to the distractor. This study examined the hypothesis that attentional capture consists of attentional diversion to the distractor and re-orienting from the distractor to the target by manipulating the duration of the peripheral distractor. We predicted that if the offset does not capture attention, the identification accuracy would improve when the distractor disappears briefly. This is because it would be easier to disengage attention from a stimulus when it disappears than when it remains visible. However, if the offset also captures attention, the abrupt offset of the distractor would impair the accuracy. Observers identified a colored oddball letter (the target) embedded in a rapid stream of grey non-target letters. Peripheral distractors appeared 200 ms before the onset of the target. The duration of the distractor was 50 ms in the Short condition or 200 ms in the Long condition. The target identification accuracy was greater in the Long condition than in the Short condition. The same pattern of results was obtained when the distractors remained until the end of the stream presentation in the Long condition. The result suggests that attentional re-orienting from the distractor to the target is disrupted by offset of the distractor if it occurs immediately after its onset. We conclude that attentional capture is caused by two events: the abrupt onset and offset of the distractor.

63.311 Top-down control modulates the effect of capture based on distractor probability

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There are differing views regarding whether or not top-down control can mediate the effect of an irrelevant salient distractor during search for a target (e.g., Theeuwes, 1991 and Bacon and Egeth, 1994). Recent work in our lab (Moher et. al, 2007) has shown that the cost of a distractor in a visual search task differs depending on the probability of that distractor appearing in a given block. When a highly expected distractor appears, participants make faster saccades to a target and make fewer incorrect saccades compared to when an unexpected distractor appears. However,it was possible that implicit perceptual learning was causing participants to habituate the orienting response to more common distractors since the trials were blocked (Sokolov, 1975). In order to further investigate this prospect, we created a mixed-block design where participants received a cue prior to each trial informing them of the probability that a distractor would occur on the upcoming trial. In a visual search task where participants were required to respond with a manual response to the letter inside the unique shape in a display, the cost of a color distractor (the difference in reaction time between a correct response on a distractor versus a no-distractor trial) was greater in the 10% condition (154 ms) compared to the 90% condition (54 ms, $p<.05$). Initial eyetracking data suggest that the difference in error rates between distractor and no-distractor trials is greater with a 10% distractor probability cue (13%) compared to a 90% distractor probability cue (4%). Overall, these data suggest participants are able to use top-down control in order to adopt an attentional set consistent with their expectation of an upcoming irrelevant distractor, and that highly expected distractors cause less interference in the search for a target.

63.312 Modulation of Attentional Capture for Distractor Object in Serial Presentation Paradigm

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When frequent standard, rare target and rare distractor objects are serially presented, neural responses for distractors are increased by discrimination difficulty between the standard and target. This is shown by an enlargement of P3 event-related brain potentials (ERPs). In this study we investigated whether this increase of neural response is associated with the enhancement of attentional capture induced by stimulus salience or the enhancement of cognitive interference in maintenance of the standard/target representation. ERPs were recorded from participants while they performed a visual serial presentation paradigm (70 % standard, 15 % target, 15 % distractor). Four task conditions were defined by a combination of two distractor types (central or bilateral) and two levels of standard/target discrimination difficulty (easy or difficult). In the central condition, the distractor was serially presented at the central location as well as standard and target. In the bilateral condition, distractors were presented on both sides of the centrally presented standard; these flanking distractors appeared abruptly at a previously blank location, and thus they did not interfere with the maintenance of standard/target representation but had high stimulus salience. The results revealed that the P3 elicited by the distractor in the central condition was larger for the difficult task than for the easy task, as in previous studies. In contrast, in the bilateral condition, the distractor elicited large P3s in both the easy and difficult tasks. These results suggest that the increase of neural response by discrimination difficulty is associated with the enhancement of attentional capture induced by stimulus salience, rather than the enhancement of cognitive interference. Serially presented distractor objects may have high stimulus salience in the difficult task since the attentional bias toward the standard/target objects is increased to achieve a cautious discrimination between them, which may make distractor objects more salient within the stimulus context.

63.313 Is Contingent Attentional Capture Not Contingent on Working Memory?

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When people "tune" attention for a pre-specified feature (i.e., when they establish an "attentional set"), distractors containing that feature become particularly strong elicitors of reflexive attention shifts, whereas distractors that typically capture attention reflexively – but which do not match attentional set – lose their power to do so. This is referred to as the "contingent capture" of attention (Folk et al., 1992). Evidence suggests that working memory (WM) is critical for maintaining target representations in mind (Desimone & Duncan, 1995), and that WM contents may help guide attention (Pashler & Shiu, 1999). However, the dependence of contingent capture on WM availability has not been formally tested. One possibility, given that WM load can increase stimulus-driven capture (Lavie & de Fockert, 2005), is that such load will diminish the influence of attentional set. In three experiments, we directly tested this hypothesis: participants performed a typical contingent attentional capture task while under high or low WM load. In Experiment 1, WM was occupied by a concurrent digit string task, previously shown to increase stimulus-driven capture (Lavie & de Fockert, 2005). In Experiment 2, visual WM was taxed through a concurrent change detection task involving 1 (low load) or 3 (high load) abstract shapes. Finally, because some participants reported using verbal strategies to encode these shapes, in Experiment 3 participants performed a change detection task on a 5-X-5 grid containing 4 filled-in grid locations. Under low load, the initial grid always contained the same symmetrical filled-in locations; under high load the filled-in locations were randomized (participants reported using no verbal strategies during this manipulation). In all experiments, contingent capture remained robust regardless of WM load. These results suggest that once attentional set is configured, target properties may not need to be maintained in WM in order to affect attentional capture.

63.314 Perceptual Objects Capture Attention

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Previously we have demonstrated that the mere organization of some elements in the visual field into an object, with no abrupt onset or any other unique transient, attracts attention automatically (Kimchi, Yeshurun, & Cohen-Savransky, 2007). This study tested whether similar results will emerge when the target is not a part of the object and with simplified task demands. A matrix of 16 L elements in various orientations preceded the presentation of a Vernier target. The target was either added to the matrix or appeared after its offset. On half of the trials, 4 elements formed a square-like object in one of four possible locations. On a 1/4 of these trials the target appeared at the center of the object, and on the other 3/4 the target appeared in one of the other 3 possible locations. On half of the trials the elements did not form an object, and the target appeared in one of the 4 possible locations. Thus, the object was not predictive of the target location or the direction of the target's horizontal offset. Moreover, no featural uniqueness or abrupt onset was associated with the object.

Performance was better when the target appeared in the center of the object than in a different location than the object, even when the target appeared after the matrix offset. These findings support the hypothesis that a perceptual object captures attention, and demonstrate that this automatic deployment of attention does not depend on the target being a part of the object or on the involvement of high memory load. Moreover, because the target was not a part of the object, and because attentional effects were found even when the target appeared after the matrix offset, these findings suggest that the automatic deployment of attention to the object involves a spatial component.

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63.315 Co-Learning Analysis of Two Perceptual Learning Tasks with Identical Input Stimuli Supports the Reweighting Hypothesis

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Perceptual learning, even when it exhibits significant specificity to basic stimulus features such as retinal location or spatial frequency, may be accomplished either through enhancement of early sensory representations or through selective re-weighting of connections from the sensory representations to specific responses, or both. For most of the experiments in the literature (but see Ahissar & Hochstein, 1996; Fahle, 1997; Fahle & Morgan, 1996; Wilson, 1986), the two forms of plasticity make similar predictions (Petrov, Dosher & Lu, 2005). The strongest test of the two hypotheses must use training and transfer tasks that rely on the same sensory representation with different task-dependent decision structures. If training changes representations, transfer (or interference) must occur since the (changed) representational coding is common. If instead training re-weights a separate set of task connections to decision, then performance in the two tasks may still be independent. Here, we performed a co-learning analysis of two perceptual learning tasks based on identical input stimuli, following a very interesting study of Fahle and Morgan (1996) who used nearly identical input stimuli (a three dot pattern) in training bisection and vernier tasks. Two important modifications were made: (1) Identical input stimuli were used in the two tasks, and (2) Each task is trained alternately (800 trials) in turn, with multiple phases of testing on each task. The second modification is essential for distinguishing between independent co-learning and competitive (push-pull) co-learning. Two groups of subjects with counterbalanced order of training participated in the experiments. We found significant and independent learning of the two tasks. The pattern of result is consistent with the reweighting hypothesis of perceptual learning.

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63.316 Augmented Hebbian Learning Hypothesis in Perceptual Learning: Interaction between feedback and training accuracy

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Previous analyses of the role of feedback have suggested that perceptual learning may be accomplished through augmented Hebbian learning. (Petrov, Dosher, & Lu, 2005; Vaina et al., 1995) When there is feedback, the product of the feedback and the input is used to update the weights in the neural network; in the absence of feedback, the product of the value generated by the output unit and the input is used to update the weights. One prediction of this learning rule is that the ability to exhibit perceptual learning without feedback may depend on the training accuracy level. In contrast, a pure supervised error correction model will not learn without feedback, and a pure Hebbian learning model will not depend on the presence of feedback. We tested the predictions of these learning rules. The accelerated stochastic approximation method was used to track threshold contrasts at particular performance accuracy levels in a Gabor orientation identification task over 6 training days. Subjects were divided into 4 groups: high training accuracy (85% correct) with and without feedback, and low training accuracy (65%) with and without feedback. Contrast thresholds improved in the high training accuracy groups, independent of the feedback condition. However, threshold improved in the low training accuracy condition only in the presence of feedback but not in the absence of feedback. Furthermore, the learning rate did not depend on training accuracy in the feedback condition, nor did it depend on the feedback condition in the high training accuracy condition. The results are both qualitatively and quantitatively consistent with the predictions of an augmented Hebbian learning model, and are not consistent with pure supervised error correction and pure Hebbian learning models. The results lend further support for the augmented Hebbian learning hypothesis in perceptual learning.

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63.317 Perceptual learning in speed discrimination of radial motion

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We investigated specificity of learning as a function of motion direction and speed.

In 2AFC, five participants trained to discriminate which of the two radial inward motion stimuli was faster (1.93 versus 2.17 deg/sec, viewing distance: 114 cm). Five other participants trained with outward motion stimuli. Pre- and post-training, four psychometric functions of speed discrimination were measured per trainee (pedestal speed: 1.93, 2.17 deg/sec) × (direction: inward, outward). All 10 trainees improved their speed discrimination sensitivity after eight days of training. Interestingly, this learning transferred completely between inward and outward radial motions. This transfer was training specific, since little improvement was found from five control participants who skipped the training but the psychometric functions were measured similarly.

Experiment 2, conducted with 12 fresh trainees, was similar except that specificity to pedestal speed, rather than direction, was investigated. Specifically, pre- and post-training, inward radial motion stimuli were used to measure psychometric functions for the inward trainees at the viewing distance of 114 cm, and at 57 cm and 228 cm with the same stimuli. In effect, speed discrimination was measured when all stimulus speeds were doubled or halved. Likewise, outward stimuli were used for the outward trainees. All 12 trainees improved their discrimination sensitivity after eight days of training at viewing distance 114 cm. This learning partially transferred to viewing distances of 57 cm and 228 cm. Namely, discrimination was improved at both distances, but not as much as at the trained viewing distance (the interaction was statistically significant, $p = 0.03$).

In summary, we found that speed discrimination learning of radial motion transferred completely between inward and outward directions. However, this learning was partially specific to pedestal speed, when the viewing distance was manipulated while the stimulus remained unchanged.

63.318 A Hebbian-style Dynamic Systems Model of Configural Learning

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Configural learning is the process by which configural perceptual representations and processing mechanisms develop. Blaha and colleagues (Blaha & Busey, VSS 2007; Blaha & Townsend, Under Revision) characterized this process by a qualitative shift in processing capacity, reflecting a fundamental change in the efficiency of the visual information processing system. To capture these empirical findings, we developed a neurologically-plausible dynamic processing model of configural learning. We began with an interactive parallel processing model defined by simultaneously-operating linear accumulator channels (Townsend & Wenger, 2004). In this system, learning is defined by a non-linear, recursive function operating on both the within- and across-channel activation weight parameters of the linear accumulators. The activation weight parameters define the system's cross-talk, or the ways in which information from each channel interacts to facilitate or inhibit information accumulation in other channels. Over the course of simulated training, the learning function incrementally changes the activation weights, effectively adjusting the levels of interchannel cross-talk. We applied this model to Blaha and Townsend's (Under Revision; VSS 2006) configural learning data, in which participants unitized novel objects requiring conjunctive categorization of all object features. Unitization training of adult participants revealed a shift from extreme limited capacity to the super capacity processing efficiency characteristic of configural processing. Within the Hebbian-style model, the capacity limitations observed early in training were best captured by setting the interchannel cross-talk to be inhibitory (negative activation weights). As recursive feedback learning transformed the activation weight parameters to positive values, the model behavior mimicked the empirically observed shift to super capacity processing. The resulting trained model was a facilitatory parallel system exhibiting super capacity efficiency, in accordance with Wenger and Townsend's (2001) working definition of configural information processing

63.319 **Eye-dependent attentional modulation on motion sensitization from speed discrimination**

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Tseng et al (2006) found that (1) human motion sensitivity improved after one-week speed discrimination training and (2) attention modulated this improvement. Here we investigated if the learning effect and attentional modulation are eye-specific.

Our experiments contain three parts: pre-test, training, and post-test. During pre-test and post-test stages, observers view monocularly white dots containing 5%-50% moving coherence, and we obtained observers' 75% coherence threshold in eight directions for each eye.

Exp. 1 During learning stage, we presented (to the right eye only) a display with uni-direction moving dots containing a speed change event, and observers learned to discriminate speed increase from decrease hourly for 7 days on average. We found moderate sensitivity improvements towards all eight directions in the right eye, and a smaller improvement (60% of what observed in the right eye) in the left eye. Further analysis shows the improvement is not due to behavioral criterion shift. This interocular learning effect lasted for at least two weeks, indicating a long-persistent change in neural plasticity.

Exp. 2 To manipulate attention, we presented the same uni-direction motion stimuli (0 deg) to observers' right eye while to the left eye we presented similar dots moving at 90 deg. Perceptually, observers perceive a bivectorial transparent dot motion, and selective attention to the component motion with speed change is required to successfully detect the speed change. Attention generated a direction-selective sensitivity enhancement, and this modulation is restricted to the right eye only. In left eye, an overall sensitivity increase across all directions from interocular transfer is observed.

Conclusion: We demonstrated a long-term motion sensitization induced by a motion speed task. This sensitization transfers between eyes in all directions, and persists for weeks. Direction-specific modulation on sensitization from attention is found to be eye-dependent.

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63.320 **Sleep enables explicit figure-ground segmentation of unattended textures**

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We previously showed that actively practising to discriminate the orientation of a line-texture bar increases its saliency and modulates the ERP-component amplitudes reflecting texture segmentation, suggesting that increased saliency results from inhibition of incongruent local orientation (orthogonal to the bar) (Casco et al., 2004).

We now show an experience-dependent increase of saliency even when the texture is an irrelevant background to a central task engaging subject's attention. However, this improved perception in single randomly chosen target trials (Mack, Tang, Tuma, Kahn and Rock, 1992) does not occur in the two groups where, unexpectedly, orientation discrimination of the bar was asked either at the beginning (50% accuracy) or at the end (60% accuracy) of the 300-trials block. Instead, the group for whom the target trial was presented in a second block executed with a delay of several hours and at least one night's sleep showed a significant increase of saliency (72.5 % accuracy) but only when local elements were congruent to the global orientation of the bar. If the elements were incongruent, accuracy dropped to 41%, indicating that increased saliency relies on a larger response to local orientation within the bar. The electrophysiological correlate of this task-irrelevant improvement is a selective ERP modulation on the second day, consisting in a significant increase in the segmentation-component amplitude, but only when elicited by the congruent bar condition.

These results show that perceptual learning may not require attention to be directed on the stimulus. Task-relevant and task-irrelevant learning involve different mechanisms: the former based on inhibition of information irrelevant to the task (Casco et al., 2004) and leading to explicit figure-ground segmentation, the latter based on enhancement of response to local orientation in the texture bar, also resulting in figure-ground segmentation.

63.321 **Offline processing of memories induced by perceptual visual learning during subsequent wakefulness and sleep: a behavioral study**

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To further characterize perceptual memory consolidation during wakefulness and sleep, we used a coarse orientation discrimination task during which participants had to discern the orientation of orthogonal gratings embedded in increasing levels of background noise.

In a first study (N = 11), we showed that the learning effect in this task is retinotopic (position-specific) and orientation-specific. In a second experiment, we assessed the effect of nocturnal sleep, as opposed to the effect of time, on perceptual learning.

A first group of healthy volunteers was trained in the morning, tested in the evening and retested the next morning (Evening-Morning-Evening; EME; N = 11); a second group was trained in the evening, tested the next morning and retested in the evening (Morning-Evening-Morning, MEM, N = 13). Between training and testing (after a full night of sleep), EME subjects improved significantly ($p < 0.005$) more than MEM subjects (after 12 waking hours). Similarly, between test and retest, performance of MEM subjects (after a full night of sleep) improved significantly ($p < 0.00001$) more than in EME subjects (after 12 further waking hours).

These results suggest a beneficial effect of sleep on coarse orientation discrimination. Further studies are needed to characterize the neural correlates of perceptual learning and the 'offline' consolidation of perceptual memory.

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63.322 **Perceptual learning requires a minimal number of trials per session, but no sleep**

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A common assumption in perceptual learning is that the improvement of performance basically depends on the amount of training. However, other factors such as sleep and training intensity (trials per session) have also been shown to be important. We trained four groups with 1600 trials in total, using a Chevron discrimination task. Groups differed in the number of trials per session and the amount of sleep between sessions. One group trained two sessions on two consecutive days with 800 trials per session. Performance improved. Another group trained ten sessions on ten consecutive days with 160 trials per session. Performance did not improve. This result suggests that a minimal number of trials per session is necessary for perceptual learning. Next, we calculated the changes in performance between sessions for the groups which improved performance. No significant improvement of performance was found irrespective of the amount of sleep between sessions. Hence, perceptual learning with Chevrons seems to require a minimal number of trials per session, but no sleep.

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63.323 **Perceptual Training Yields Rapid Improvements in Visually Impaired Youth**

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Effective vision demands coordinated responses to information over a wide field of view, involving both central and peripheral regions. Visually impaired individuals often seem to under-utilize the peripheral field, even when the peripheral retina is unimpaired. Motivated by perceptual training studies with typically sighted adults, we examined whether perceptual training might yield improvements in peripheral perception of visually impaired youth.

Low-vision youth first performed a series of psychophysical tasks, in which impairments were most pronounced in periphery, compared to age-matched, typically sighted controls. Psychophysical tasks included measurements of: foveal acuity, motion discrimination, motion pop-out, visual crowding and visual search of naturalistic scenes. Next, we evaluated the effectiveness of three training regimens by comparing pre- and post-training performances in these psychophysical tasks. The training regimens were: (1) an action video-game, (2) a psychophysical task that combined attentional tracking with a spatially and temporally unpredictable motion discrimination task, and (3) a control video-game (Tetris). Training involved ten 50-minute sessions. All of the stimuli were displayed on a large projection screen (60x30deg).

Both action video-game training and attentional tracking training yielded improved performance in all psychophysical tasks, with the attentional tracking training usually producing the largest improvements. For example, perceptual training reduced visual search reaction times by 47% for the attentional tracking group and 40% for the action video-game group. Overall, training effects were larger in the far periphery and improvements did not occur in the fovea.

These results demonstrate that 8h of perceptual training can yield substantial visual improvements and support the idea that peripheral perception might be under-utilized by visually impaired youth. Moreover, similar improvements following attentional tracking and action video-game training suggest that documented effects of action video-game training in typically sighted adults might be due to the sustained rapid deployment of attention to multiple dynamic targets.

63.324 Perceptual Learning Is Similar Across the Central Visual Fields

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Visual perceptual learning of stimuli presented in the central visual fields, near the fovea to 20° eccentricities, occurs with many novel visual tasks. It was unclear, however, if the magnitude and rate of perceptual learning are similar across the central visual fields or if visual learning decreases with increasing eccentricity, like visual acuity and color vision. The robustness of perceptual learning across the central visual fields may affect the magnitude of computer-aided visual recovery after visual brain injury. Therefore we determined if eccentricity was a factor that influenced perceptual learning.

Subjects aged 21 to 29 years were trained to detect the presence or absence of a single line oriented differently (odd element) from an array of lines that otherwise had the same -30°orientation (Neary, Anand & Hotson, Experimental Brain Research 2005:162:23-34). The odd element was presented for 120 ms in 1 of 4 visual field quadrants 3°, 9° or 18° from fixation. Prior to training, an odd element orientation was selected that resulted in ~ 60-70% correct responses. Pre- and post-training percentage correct responses without feedback were obtained. Each subject trained in a total of 2880 trials with feedback over multiple days.

Perceptual performance improved during training trials with a similar magnitude and similar learning curve slopes at all 3 eccentricities. Pre- and post-training performance improved to a similar magnitude at 3 vs. 9° in 4 of 4 subjects tested and at 9° vs. 18° in 4 of 5 subjects. In a fifth subject there was no post-training improvement in performance at 18°.

The magnitude and rate of perceptual learning is similar across the critical central visual fields in almost all young subjects. Subject performance variability may increase with eccentricity.

63.325 Letter learning: feature detection and integration

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Letters are identified in two stages: feature detection and feature integration. At which stage does the learning of unfamiliar letters occur? To make this distinction, we designed three letter identification tasks, matched in feature detection statistics. One challenged both detection and integration, a second challenged only detection, and a third challenged only integration. While previous learning studies have been unable to distinguish learning detection from learning integration, we used gabor letters, which are uniquely suited to distinguishing the stages. Each "gabor letter" is a 2x2 array of four gabors (grating patches), each of which may be horizontally or vertically oriented. Our alphabet contains all 16 possible combinations. By displaying letters at threshold contrast, we challenged both detection and integration. By presenting single features at threshold contrast, we challenged only detection. By presenting only some of the letters' features at a high contrast, we challenged only integration. The results show that learning unfamiliar letters reflects improvement at both stages. Plotting threshold contrast as a function of number of trials, we find that learning feature detection is very slow (log-log slope of 0.03) and learning feature integration is very fast (log-log slope of 2).

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63.326 House training modifies activity in PPA, RSC, but not FFA

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The cortical mechanisms of object learning are not well understood. A number of studies have examined the fusiform face area (FFA) as a potential expertise area with mixed results (e.g. Gauthier 1999; Op De Beeck et al., 2006), while other studies have found training-induced changes in the lateral occipital gyrus, a generic object processing region (e.g. Grill-Spector 2000; Kourtzi et al., 2005). However, there has been little focus on the effect of learning within areas that, before learning, respond preferentially to the trained object class. Given that training can result in changes to the tuning properties of task-responsive neurons (Schoups et al 2001), the strongest effects of learning might be expected in regions that are reliably responsive to the trained object class prior to training. The current fMRI experiment focuses on houses, an object class that is associated with three main regions of preferential neural activity (e.g. Epstein et al., 2007) : the parahippocampal place area (PPA), the retrosplenial cortex (RSC), and the temporal occipital sulcus (TOS). Houses also elicit strong behavioural perceptual learning (Husk et al., 2007). BOLD responses to house stimuli were measured during a 1-back matching task before and after 5 days of psychophysical house discrimination training. The behavioural improvement in the 1-back matching task correlated significantly with increases in PPA and RSC, but not TOS, activity. No such correlations were observed for activity within FFA or any retinotopically-defined visual areas. These results suggest that object discrimination training modifies activity within existing object-selective cortical networks without recruiting additional regions.

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URL: http://psycserv.mcmaster.ca/vislab/index.html

63.327 Contrast-reversal abolishes perceptual learning

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Identification accuracy of band-limited noise patterns embedded in Gaussian noise increases substantially in a 10AFC task over two training sessions, when the same set of ten patterns is used throughout. Such perceptual learning is stimulus-specific, little improvement transfers to different stimuli with similar spatial attributes. Ostensibly, learning might be invariant for stimulus transformations that leave intact the exemplar identities by preserving the spatial distribution of information in the stimulus. Here, we test the effects of such transformations by measuring the amount of transfer to stimuli reversed in contrast and to stimuli rotated by 180 degrees. Four groups of observers performed the task on two consecutive days. On Day 1, all observers practiced the 10AFC task with a given set of textures. On Day 2 separate groups identified the same textures, different textures, rotated textures, or contrast-reversed textures. In all conditions, stimuli were displayed at one of seven contrasts, in one of three external noise levels, using method of constant stimuli. Results: The effects of contrast reversal and stimulus rotation were the same as replacing the trained stimuli with an unexposed set. The same texture group showed a continuous learning profile across both days, with performance on Day 2 exceeding that measured on Day 1. All other groups' performance dropped sharply on Day 2 relative to performance at the end of Day 1. Although there was some recovery for all three groups, they did not achieve the level of performance of the same texture group on Day 2. This result is particularly surprising for the contrast-reversed stimuli, in which the information distinguishing stimuli is spatially unchanged, unlike the rotated stimuli. Therefore, perceptual learning is sensitive to the presence of stimulus alterations, yet indiscriminate as to the type of stimulus transformation.

63.328 **Stimulus coding rules for perceptual learning**

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Background: We reported previously (Kuai et al., NN2005) that perceptual learning of contrast and motion direction discrimination occurs when multi-stimuli are presented in a fixed sequence (temporal patterning), but not randomly (roving), which points to the need for proper stimulus coding for multi-stimulus learning to occur. In this study we examined the stimulus coding rules for perceptual learning with multi-stimuli. Methods: Subjects practice contrast discrimination of Gabors at multiple reference contrasts and orientation discrimination of illusory lines at multiple reference orientations in various roving and temporal pattering conditions. Results: 1) Stimulus rhythm, especially temporally evenly spaced, is necessary for temporal patterning to take effect during practice. 2) Both the encoding phase, and the slow consolidation phases as least 4 hours after each practice session, of perceptual learning are subject to roving disruption; 3) However, after completion of temporal patterned learning, performance is undisrupted by extended roving training, and instead learning is transferable to the roving condition; 4) Roving is ineffective if each stimulus is presented in a block of five or more consecutive trials; 5) Roving is also ineffective if each stimulus has a distinct identity, either due to large inter-stimulus difference, or inherited identity (i.e., cardinal/oblique orientations), or assigned identity through pre-trial letter cueing. Conclusions: Our results sketched some basic rules for stimulus encoding, consolidation, and retrieval for multi-stimulus perceptual learning. These rules may be needed because the brain needs to "tag" each stimulus, in order to switch attention to the appropriate perceptual template. Stimulus temporal patterning assists in tagging stimuli and switching attention through its rhythmic stimulus sequence. However, once the identities are learned, stimulus information can be efficiently retrieved to guide visual discrimination regardless of the stimulus temporal context.

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Wednesday, May 14, 8:30 am - 12:30 pm Poster Session, Royal Palm Ballroom 6-8

Faces: Adaptation and Context
Perception and Action: Locomotion and Navigation
Visual Working Memory 2

Faces: Adaptation and Context

63.401 **Familiarity for faces and novelty for natural scenes in preference: does similarity matter?**

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Memory is obviously critical for visual preference, but how precisely is yet unclear. Two seemingly inconsistent principles, Novelty and Familiarity, have been proposed. We reported(VSS'07) a surprising segregation of these principles across object categories: familiarity preference monotonously increased in faces(FC) whereas novelty preference increased in natural scenes(NS), over repeated 2AFC preference judgment between a new and an old stimulus. Geometric figures(GF) did not show any bias. While the segregation may indicate intrinsic biological differences among object categories, it may also be due to differences in similarity/variability within category between FC and NS.

To examine it, we ran two experiments. First, we reused the same FC and NS stimuli but presented them upside down in the same 2AFC preference task, to see if the critical factor is orientation-specific and holistic. The results faithfully duplicated the pattern of the original results, i.e. Familiarity in FC and novelty in NS. Second, we directly manipulated variability within object category; i.e. to introduce more variability within FC by including cartoons, and natural face-like patterns, etc., and more similarity within NS. As a result, the familiarity preference disappeared in FC. In NS, however, the same increasing bias towards novelty preference persisted. In addition, we ran two sets of GF; one with high similarity within, and the other with low similarity. We found an increasing bias towards familiarity preference in the high similarity set, but no such bias in the low.

The overall pattern of results is consistent with a notion that increasing similarity in local features shifts preference from novel to familiar stimuli, in close relation to the averageness hypothesis of attractiveness and the efficient coding theory of perception. The persistence of novelty preference in NC with more similarity is an exception that requires more investigation.

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63.402 **The influence of processing style on face perception**

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A wealth of evidence suggests that face processing typically involves global (holistic) analysis but that, under some circumstances (e.g., when viewing inverted or fragmented faces), a feature-based analysis is undertaken (e.g., Farah et al., 1995). This approach may also be used when viewers process incongruent (McGurk) audiovisual stimuli; under these circumstances, viewers tend to focus disproportionately on the mouth (Paré et al., 2003). The purpose of the present experiments was to see if individual differences in processing style predict performance on tasks in which feature-based analysis of faces is likely to occur. Processing style was assessed with the Group Embedded Figures Test (GEFT, Witkin et al., 1971); high scores on this test indicate a local processing bias, while low scores indicate a global processing bias (Ellis, 1996). In the first experiment, participants completed the GEFT and a face matching task in which they were required to match a target face to one of two choice faces. The choice faces were always in the same orientation as the target, but could be shown from the same or a different viewpoint. Local processors tended to be more accurate than global processors at matching inverted (but not upright) faces; they were also more accurate at matching a target face to a choice face differing in viewing angle by 90 degrees. In the full sample, GEFT scores were positively correlated (r = .36, p = .046) with accuracy scores for matching inverted faces differing in viewing angle by 90 degrees. In the second experiment, we examined the relationship between processing style and the strength of the McGurk effect. In some conditions, local processors showed a larger McGurk effect than global processors. Together, these results lend support to the idea that individual differences in processing style affect performance with certain types of face stimuli.

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63.403 **Sex, Handedness and Sexual Orientation as Predictors of Face Perception Ability**

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Behavioural studies consistently demonstrate a female advantage for face processing. Evoked potentials have also shown gender effects with men displaying more right-lateralized activation for faces while women appear functionally bilateral (Proverbio, 2006). Together, these results suggest gender differences in face processing at a cortical level. Similar hemispheric asymmetry in men is documented for cognitive tasks such as mental rotation. However, handedness mediates this trend. Imaging research demonstrates increased left-hemisphere activation for mental rotation in left-handed (LH) men, indicating less hemispheric asymmetry than right handed (RH) men (Shimoda, 2007). Structural differences attributable to handedness are also evident in the corpus callosum. Research has shown that RH homosexual men display structural differences in the corpus callosum similar to those of LH heterosexual men (Witelson, 2007). Furthermore, homosexuality is positively correlated with non-right-handedness in both men and women (Lalumière, 2000). RH homosexual men show female-typical performance patterns on many sexually dimorphic cognitive tasks (Rahman, 2003). This suggests less functional asymmetry in homosexual men regardless of handedness. Findings regarding handedness and sexual orientation in women, however, are less consistent. We explored the implications of these trends for face processing by comparing performances of LH and RH heterosexuals to RH homosexual men and women on a battery of face perception tasks (old-new recognition, configural, featural and composite face processing). Results demonstrate a dissociation in performance for heterosexual men and women as a function of handedness— RH women were better than RH men whereas LH men outperform LH women. Moreover, homosexual men outperform RH heterosexual men and were therefore comparable to heterosexual LH men and RH women. These results show that sex, handedness and sexual orientation play a role in face perception ability. Further, LH men and homosexual men's similar performance may reflect underlying structural similarities involved in face processing.

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63.404 **Dual Perceptual Adaptation in Human Faces: Gender and Age**

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Purpose: Adaptation to female faces makes a gender-neutral test face appear male, and vice versa. While it may not be clear which features define "maleness" or "femaleness" in faces (Webster et al., 2004) or biological motion (Jordan, Fallah & Stoner, 2006), the assumption is that adaptation shifts the viewer's judgment along a single perceptual dimension. Perceptual adaptation effects have been extended beyond gender to many other dimensions depicted by faces, e.g. identity, race, viewpoint, expression, attractiveness etc. However, it remains unknown whether perceptual adaptation can occur for more than a single dimension.

Method and Results: The first study tested whether gender adaptation is observed to children's faces. On each block of trials, participants were adapted to either boy or girl faces for a period before judging a morphed test face as predominantly a boy or a girl. Participants were more likely to report gender neutral stimuli as a girl after adaptation to the faces of boys and vice versa. This clearly replicates studies showing gender adaptation for adult faces. Like adults, the faces of boys and girls appear to be represented along a single gender dimension.

The second study tested the relationship between the representation of young (boys/girls) and mature (men/women) males and females. The adapter and test stimuli comprised all possible pairs of gender/age combinations. Adaptation was observed simultaneously across both gender and age. The relationship between age and gender adaptation effects, and its implications for neuronal representation will be discussed.

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URL: www.yorku.ca/hjordan

63.405 **Adapting to age**

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Adaptation can strongly influence many natural attributes of faces such as their gender, identity or ethnicity. In this study we examined how adaptation affects the perceived age of a face. Stimuli were frontal view images of male and female faces with average features and neutral expressions created with Singular Inversions FaceGen Modeller software. The images were manipulated to simulate aging in a continuum from approximately 20 to 65 years. Participants classified images as young or old using a staircase task to find the boundary between participants' young and old categories. These boundaries were strongly biased by prior exposure to old or young faces. Thus perceived age, like other facial attributes, is highly susceptible to adaptation and may therefore be routinely regulated by the average age characteristics an observer is exposed to. Like many other facial categories, age-related variations include changes in both the shape and the pigmentation and texture of the face, the latter of which have also been found to provide important cues in face recognition (e.g. Russell et al, 2006). In further experiments we compare the form and selectivity of adaptation effects for pigmentation and shape changes in faces to assess whether these dimensions are jointly coded in the mechanisms underlying face adaptation.

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63.406 **Adaptation Reveals Multichannel-Coded Cells Tuned to Body Orientation in Humans**

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Neurophysiological research has revealed superior temporal sulcus (STS) cells in macaques that respond selectively to different directions of seen body orientation in the absence of head or face based cues (Perrett et al, 1992). Here we use adaptation to investigate, for the first time, the functional organization of social direction perception from seen body orientation, with masked heads, in humans. In Experiment 1 we found that adaptation to left (or right) facing bodies increased participants tendency to perceive subsequently viewed left (or right) facing bodies as facing directly towards them – evidence for direction selective coding of seen body orientation in humans. In Experiment 2 we sought to investigate whether the visual representation of body orientation is coded by an opponent-coding system, recently implicated in facial identity perception (Jiang, Blanz, & O'Toole, 2006; Leopold, Bondar, & Giese, 2006; Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes et al., 2005) or a multichannel system, which has been shown underlie the visual representation of seen gaze (Calder, Jenkins, Cassel & Clifford, in press). We tested predictions that arise from the underlying assumptions of these two models and found that, consistent with multichannel coding, simultaneous adaptation to left and right facing bodies resulted in an increased tendency to perceive subsequently seen left and right body orientations as direct. Conversely, but also consistent with a multichannel system, adapting to direct facing bodies increased accuracy in perception of subsequently seen left and right body directions. In each case an opponent-coding model would predict no effect of adaptation. Together, our findings provide the first evidence for selective neural representations of different body directions within the context of multichannel coding. These findings extend pervious adaptation research showing separable coding of seen gaze (Jenkins, Beaver & Calder, 2006) and head direction (Fang & He, 2005).

63.407 **Brief adaptation increases sensitivity of face recognition**

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Some models of adaptation propose that adaptation may serve to enhance discriminative sensitivity in the visual system. Increased sensitivity has been well established for retinal adaptation. However, empirical data for higher-levels remain inconclusive, with some studies appearing to confirm enhancement for the discrimination of orientation, contrast, and direction of motion, and others failing to find such improvements. In this study we assessed the impact of variable periods of adaptation on face recognition.

We measured discrimination contrast thresholds for faces in a five-alternative forced-choice paradigm with or without prior adaptation to a face, for periods ranging from 10ms to 6400ms. Following adaptation and a noise mask lasting 50ms, subjects saw a low-contrast test face lasting 150ms. Contrast of the test image was varied with the Quest procedure to estimate 82% thresholds.

For adaptation periods greater than 500ms, contrast thresholds for both faces identical to and different from the adapting face were elevated and continued to increase with longer adaptation durations. However, for durations less than 500ms, adaptation reduced thresholds for the same face, indicating a facilitation effect that was maximal at 200ms, but continued to elevate thresholds for different faces. Similar effects were obtained with adapting faces that differed in size from the test faces, excluding adaptation to low-level image properties as the source of the results. To exclude a response-bias account of the facilitation result we repeated the same experiment with a two-interval two-alternative detection task using the same stimulus set, with similar findings at short adapting durations.

We conclude that brief periods of adaptation may serve to enhance recognition in high-level object processing.

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63.408 **Face space has a center-surround organization: evidence from a novel contrast-based face-adaptation technique**

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'Face-space' is a concept of the multidimensional representation of faces in the neural system. Faces of similar appearance are considered closer to each other than faces that are dissimilar; however, it is not clear how representations interact across this space. In this study we used a novel adaptation paradigm in which we examined how a 200ms preview of one face affected contrast thresholds for recognition of the same face or of other faces of the same or different ethnicity as the previewed face.

We obtained images of two Caucasian and two Asian female faces. We used an ideal observer analysis and measured pair-wise discrimination thresholds to verify that, in this stimulus set, faces were more similar to those of the same ethnic group than to those of the other. In the adaptation experiment, 7 subjects viewed either a blank screen or one of the four faces for 200ms, followed by a 150ms test face, which was a low-contrast version of one of the same four faces. Subjects indicated which of the four faces they believed the test face to have been. Test-face contrast was varied with the Quest procedure to estimate 82% contrast thresholds.

We found that a 200ms preview of a face facilitated its recognition but impaired recognition of other faces. Thresholds were more elevated for other faces of the same ethnic group than for other faces of a different ethnic group. This is consistent with a center-surround organization in which the neural representations of faces that are closer in face-space to the priming stimulus are suppressed more than those more distant. This suggests that center-surround relationships that serve to sharpen neural tuning and perceptual discrimination are also found in high-level face representations.

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63.409 **Illumination effects on the inverse relationship between face typicality and recognition**

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The inverse relationship between the rated typicality of a face and its recognizability is thought to reflect the properties of the similarity space for human representations of faces. Because most typicality studies use identical images to assess typicality and to test recognition, it is unclear whether the typicality-recognizability relationship reflects similarity in an image representation space or a face representation space. We examined the stability of typicality ratings under different illumination conditions and assessed the typicality-recognizability relationship over changes in these conditions. In Experiment 1, participants rated the typicality of two images of each of 108 faces, with one image taken under controlled, and the other taken under uncontrolled illumination. In Experiment 2, a separate set of participants performed a recognition test, in which the learn-test transfer direction between controlled and uncontrolled illumination images was varied. Performance was better when participants learned controlled illumination images and were tested with uncontrolled illumination images than for the opposite direction of transfer. We found a moderately strong correlation between typicality ratings for different images of the same person. The typicality-recognizability relationship held across varying illumination conditions, but was weaker than that found in previous studies using the same image. It was also weaker than the relationship we found in a control study when illumination conditions remained constant but different images of a face were used. Notably, in all cases, the typicality-recognizability relationship was due primarily to the high false alarm rates associated with more typical faces. These results suggest that part, but not all, of the relationship between face typicality and recognition accuracy reflects properties of the image space rather than the 'face space'.

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Perception and Action: Locomotion and Navigation

63.410 **The effect of walking on perceived visual speed depends on visual speed**

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Perceived visual speed has been reported to be reduced during walking compared to standing still. This so-called 'subtraction effect' has been attributed to an automatic subtraction of part of the walking speed from the visual speed (Durgin et al., 2005). We investigated how general this subtraction effect is, by varying both visual speed and walking speed in a series of experiments. Observers judged the visual speed of a simulated ground plane (presented through a HMD) in a 2IFC task. In one interval, they walked in place on a treadmill, in the other they stood still. In different experiments, the interval with the visual standard speed, the order of the intervals, and the walking speed were varied. In all experiments, observers consistently reported the perceived visual speed for the lowest standard speed to be lower during walking than during standing still. However, most observers also perceived the highest standard speed as faster during walking than during standing still, which is clearly incompatible with the subtraction effect. We tested the apparent interaction between visual speed and walking in another experiment by presenting the exact same visual speed in the two intervals and asking the observers again to judge which of the two appeared to be faster. As in the previous experiments, the visual speed was reported to be faster during standing for slow visual speeds; this gradually changed into the opposite for faster visual speeds. Taken together, the results question the generality of the subtraction effect and raise doubts regarding the hypothesized functional role of this effect.

Durgin, F.H., Gigone, K., & Scott, R. (2005). JEP:HPP 31, 339-353.

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63.411 **Imagined self-motion differs from perceived self-motion**

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Self-motion perception refers to the ability to perceive the speed and direction of movement through space. Past measures of self-motion perception have failed to directly assess the dynamic, instantaneous properties of perceived self-motion in real-world coordinates. Here we developed a novel continuous pointing method to measure perceived self-motion during translational movements. This experiment took place in a large, fully tracked, free-walking space. Participants viewed a target and then, with eyes closed, attempted to point continuously towards the target as they moved past it along a straight, forward trajectory. Pointing behaviour was tracked using a high-precision optical tracking system which monitored a hand-held pointing device. By using arm angle, we continuously measured participants' perceived location and, hence, perceived self-velocity during the entire trajectory. We compared the natural characteristics of continuous pointing in a control condition (sighted walking) with that during conditions in which particular sensory/motor cues were reduced, including: blind walking, passive transport, and imagined walking in the complete absence of physical movement. Results demonstrate that under all reduced cue conditions involving actual movement, perceived self-velocity and displacement were relatively accurate. Specifically, the pattern of pointing in the blind walking condition did not differ from that of the passive transport condition. This indicates that, for simple, linear trajectories with a raised-cosine velocity profile, inertial cues alone can be used to perceive self-motion. Perhaps most interestingly, the "signature" pattern of pointing observed during true self-motion (notably an increase in arm azimuth velocity upon target approach) was absent during imagined pointing. Consequently, continuous pointing reveals a characteristic arm trajectory that is unique to actual self-motion. This appears to be an automatic, obligatory process that is not reproduced during a purely cognitive representation of self-motion in the absence of movement. This method has direct implications for several research areas, including spatial cognition and navigation.

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63.412 **The influence of relevant action on spatial updating during imagined locomotion**

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We investigated the importance of biomechanical information in spatial updating by demonstrating that actions biomechanically related to walking improve performance of imagined walking in a spatial updating task. Spatial updating without vision during both real walking and imagined walking requires imagined updating of the spatial relationships that change concurrently with movement. The imagined walking task, in addition, requires an imagined biomechanical component that corresponds to the rate of imagined spatial updating. Our previous work indicated that absolute time to walk or imagine walking to targets is not equivalent; imagined walking times were consistently faster than real walking times (Kunz et al., VSS 2007). These results suggest that performance of imagined walking may be biased by incomplete perceptual-motor information. In order to test this idea, we asked participants to perform actions, concurrently with the imagined walking task, that were either biomechanically consistent or inconsistent with the act of walking. Participants viewed a target located on the ground-plane at an egocentric distance of 4, 6 or 8 meters and were instructed to form a mental image of the target and surrounding environment. They were instructed to imagine walking to the target while either stepping in place or moving their arms in a circular motion. All participants also performed real walking to the targets without vision. Real and imagined walking times were equivalent only when participants stepped in place while imagining walking, and not during the arm movement unrelated to walking. This finding suggests that stepping in place may facilitate imagined walking performance by providing information about the rate of spatial updating in imagined locomotion. Biomechanical information supplements the mental simulation of a spatial updating task during walking but may also be important in other imagined actions in which rhythm, timing or pace is critical to accurate performance.

Acknowledgement: This work was supported by NSF grant 0121084

63.413 **Little evidence of perceptual depth compression when indicating extents by imagined walking**

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There is a well-known perceptual foreshortening in the depth dimension, even for relatively near distances (e.g., 3-10 m). However, when observers view two markers on the ground and attempt to walk the distance between them with their eyes closed, there is little evidence of foreshortening (Loomis et al., 1992). The present study explored this apparent discrepancy by using imagined walking of exocentric intervals. In an outdoor setting, observers binocularly viewed frontal and depth intervals of 137 cm, presented 3-10 m away; they then attempted to physically pace out the intervals with eyes closed, or imagine performing the same task. Walked distance (real walking only) and walking time (both real and imagined walking) were measured. For comparison, participants also performed a visual matching task in which they attempted to create a depth interval that matched a frontal interval. Results from this matching task showed that depth intervals were made about 40% longer than the corresponding frontal intervals, indicating that these observers showed large depth foreshortening. On the other hand, although walking time was significantly underestimated in imagined walking compared to real walking, both response modes were much more resistant to perceptual depth compression. These results suggest that a similar spatial representation underlies real and imagined walking, which is largely isotropic and dissociable from the anisotropic spatial representation underlying visual perception of exocentric intervals. However, the underestimation of walking time in imagined walking indicates some functional differences between real and imagined walking, conceivably attributable to the lack of self-motion signals during imagined walking.

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63.414 **Adaptation of blind-walking does not influence verbal distance estimates**

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Prior research has shown that verbal estimates of a target's distance may be dissociable from estimates of the target's distance assessed by walking to it with vision blocked (blind-walking). This study examined whether blind-walking responses can be modified by false feedback about walking accuracy, and whether verbal distance estimates would also be modified by this feedback. During pre-adaptation measures, subjects viewed targets placed at various distances between 20 and 70 feet, shut their eyes, verbally estimated the distance to the target, and walked to the remembered target location. Following this, subjects were shown a target 45 feet away and blind-walked toward it on five trials during which they were given false distance feedback. Short adaptation condition: Twelve subjects were instructed that they had reached the target when they had walked 35 feet (or, if they stopped walking before 35 feet, were instructed to keep walking until they had walked 35 feet). Long adaptation condition: Twelve other subjects were instructed that they had reached the target when they had walked 55 feet (or, if they stopped walking before 55 feet, were instructed to keep walking until they had walked 55 feet). Post-adaptation verbal and blind-walking measures were then obtained in the same manner as the pre-adaptation measures. Results demonstrated that blind-walking was significantly longer following long adaptation than following short adaptation. In comparison, verbal estimates were uninfluenced by the adaptation procedure.

63.415 **Perceived Distance Influences Simulated Walking Time**

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Prior research has found imagined and executed actions often exhibit similar temporal characteristics, suggesting a common mechanism for both simulated and physical actions. However, discrepancies in the timing between simulated and executed actions emerge under encumberment. When wearing a heavy backpack imagined walking time increases, but actual walking times are unchanged (Decety et al., 1989). Similarly, when reaching with a weighted pencil imagined reaching times increase while actual reaching times remain unchanged (Ceretelli et al., 2000). These increases in the timing of imagined actions have been generally attributed to compensation for effort during simulation. We propose a more specific alternative explanation, perceived distance influences imagined actions.

In the present work, we manipulated perceived distance to a target and measured imagined and actual walking times to the target. Previous research has shown perceived distance is affected by effort (Proffitt et al., 2003), intention (Witt et al., 2005), and environmental context (Witt et al., in press). Perceived distance was manipulated by placing a target on a hill, thus increasing effort and through the use of a barrier and segmented cones which created an illusion of increased distance. The actual target distance remained constant.

The results showed the following:

1) Imagined walking times were higher when distances were perceived to be greater.

2) Positive correlations between imagined walking time and perceived distance were obtained.

3) Actual walking times did not change with manipulations of perceived distance.

Our results indicate that perceived distance serves as input information for imagined actions. This specific explanation can account for changes in simulated walking times under encumberment and when manipulations of perceived distance occur.

63.416 **Active Vision for Exploratory Localization**

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The identification of objects is a major function of vision, but provision of information about one's localization within a larger spatial environment is important as well (what is there vs. where am I). This task is of an inherently sensorimotor nature, i.e. results from a combination of sensory features and motor actions, where the latter comprise exploratory movements to different positions in the environment. To study the localization process we have designed an artificial agent which operates in virtual spatial environements. Its representation is realized in a hybrid architecture which integrates a bottom-up processing of sensorimotor features with a top-down reasoning that is based on the principle of maximum information gain. The system operates on two sensorimotor levels, a macro-level, which controls the movements of the agent in space, and a micro-level which controls its eye movements. As a result, the virtual mobile agent is able to orient itself within an environment using only a minimum number of exploratory actions. We evaluate its performance with a test suite consisting of different spatial environments and discuss the relation between the representation used by the agent and the properties of place cells in the hippocampus.

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63.417 **Testing Models of Path Integration in a Triangle Completion Task**

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Path integration---the constant updating of position and orientation in an environment-- is commonly tested using a triangle completion task. To complete the task successfully, the participant must integrate the distance traveled on the first two legs with the turn angle to produce an accurate homebound trajectory. Large, systematic errors are observed in triangle completion, which could be due to (i) error in perceiving and remembering ("encoding") distances and angles traveled, and (ii) error in integrating these estimates to determine the homebound path. The aim of this study is to test different models of path integration, such as a geometric coordinate frame (Mittelstadt & Mittelstadt, 1973), an egocentric framework (Benhamou et al., 1990), or continuous updating (Gallistel, 1990). One model (Fujita et al., 1993) focuses solely on encoding as a potential source of error. The present study independently measures participants' encoding errors in distance and angle reproduction tasks, and uses them to predict errors in a triangle completion task. Participants completed the tasks in a virtual hedge maze, which provides both visual and idiothetic information. This approach dissociates angle from distance, which are confounded in triangle completion. By using Monte Carlo methods to sample the observed distribution of encoding errors, different models of integration were tested by using them to predict the homebound path, and comparing the predictions to observed triangle completion behavior. Errors in the homebound trajectory are not due solely to encoding error, but also due to integration error, including potential non-linear combinations of error.

63.418 **Neural Dynamics of Visually-Based Object Segmentation and Navigation in Complex Environments**

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Visually guided navigation through a cluttered natural scene is a challenging problem that animals and humans accomplish with ease. A dynamical neural model proposes how primates use motion information to segment objects and determine heading. These competences reflect complementary properties of MT- / MSTv and MT+ / MSTd pathways. The model clarifies the functions of magnocellular cells in primate retina, V1, MT and MST that relate to heading and describes how feedforward, feedback and lateral brain circuits are used to perform motion estimation calculations. The model retina responds to transients in the input stream, producing moving boundary representations. Model V1 generates a local speed and direction estimate that is noisy due to the neural aperture problem. Model MT+ computes a global motion estimate supporting accurate heading estimation in MSTd. Modulatory attentional feedback from MSTd reduces motion ambiguities in MT+. The model quantitatively simulates properties of human data during heading estimation tasks. Simulated rotations less than 1 degree per second do not affect accuracy, whereas faster simulated rotations do (Royden et al. 1994, Vis Res 34). MT- segments objects using differential motion. Feedback from MSTv to MT- helps resolve the aperture problem and drives global motion capture: When an object moves differently from the background, MT- segments the object and computes accurate estimates of object motion. The resolution of the aperture problem in the model MT- displays the same time-course as primate MT (Pack and Born 2001, Nature 409). Model representations activate processes of visually guided steering and navigation. The model is tested both through simulations of the cellular dynamics of cortical cells and on complex natural image sequences. This distinguishes our model from other models which either include cellular dynamics or focus on real world applications.

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63.419 **Adaptation to conflicting visual and physical self-motion information during walking**

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We investigated the ability of the visual-motor system to adapt to discrepancies between visual and physical information about self-motion, and whether adaptation depends on the presence of rich optic flow. Subjects walked to visible targets 6 m away in an virtual environment presented with a head-mounted display. During adaptation trials, visual space was rotated relative to physical space such that subjects' visual heading specified by optic flow deviated from their physical heading by 10°, which caused subjects to walk along curved paths to the goal. Subjects were unaware of these conflicts. In separate blocks, we tested two simulated environments, one with a textured ground plane that provided optic flow throughout the 45° field of view, and another with a homogeneous ground plane. Over the course of 20 adaptation trials, subjects adapted to partially compensate for the conflicts, resulting in straighter paths. When the conflicts were removed post-adaptation, subjects showed aftereffects in the opposite direction. The amount of adaptation was similar for textured and homogeneous ground conditions (20-25%), with the textured environment producing slightly faster adaptation and larger aftereffects. We conclude that the visual-motor system can rapidly re-calibrate the mapping from physical to visual heading, and that this adaptation does not strongly depend on full-field optic flow.

63.420 **Can people learn to anticipate obstacle motion when necessary to avoid collision?**

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Avoiding moving obstacles is critical to our ability to safely guide locomotion through a complex environment. In many circumstances (e.g. rapid movement), it is advantageous to anticipate which environmental objects are likely become obstacles. Fajen & Warren (2003) proposed a dynamical model of on-line steering control that requires no higher-level path planning or anticipation. Although participants can learn to anticipate a target's motion with repeated exposure to one trajectory, this is not the case for two trajectories, which yield behavior similar to the model's predictions (Owens & Warren, VSS 2006). Participants also fail to anticipate the trajectories of one or two moving obstacles, even when they are cued by color and shape (Owens & Warren, VSS 2007). The current study investigates whether additional constraints can induce participants to anticipate obstacle trajectories and preemptively avoid collision. Participants walk in the VENLab, a 12m x 12m virtual environment with a head-mounted display (60 deg H x 50 deg V) and a sonic/inertial tracking system (latency 70 ms). As in the previous study, participants walk to a stationary goal 6m away. A potential obstacle initially approaches on a path parallel to the participant's, at a speed equal to her current walking speed. When the participant crosses a fixed threshold in space, the obstacle veers rapidly onto a constant secondary trajectory. The terminus of this second trajectory is a point immediately beyond the threshold where the participant would be were she walking directly from the starting position to the goal. If the participant does not learn to deviate before the obstacle veers, a collision will occur. In a control condition, the obstacle is initially stationary at the veering point. We predict that the increased demand of collision avoidance will cause participants to learn to anticipate moving obstacles that pose a potential threat.

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63.421 **Learning a spatial layout: The role of landmark placement and gaze-time**

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Typically in a large-scale environment, there are a number of visual cues that can play an important role for localization and path selection. We investigated how individuals distributed their gaze when acquiring knowledge about a new space and how these gaze patterns lead to a knowledge representation that supported spatial localization within this space.

We trained and tested subjects in a reality indoor environment. Visual landmarks, in the form of unique "pictures" were placed at a uniform distance within the environment. We recorded the total amount of time spent looking at each landmark while the participant explored and learned the environment. After a training period, participants were tested with tailored environments in which we removed half of the visual cues. Participants were given a single view and instructed to indicate where in the environment the view was generated. In one condition we removed the visual landmarks that participants gazed at for the least amount of time during exploration. In a second condition we removed the visual landmarks that had the highest gaze time. Participants were also tested with all the landmarks present. We compared the accuracy of responses in the two conditions to look at the effect on performance.

We found that there was no difference in accuracy when participants were viewing all of the visual landmarks versus only the high-gaze-time landmarks ($t(6)= 0.8$, $p>.05$). However, there was a significant difference in performance between the low-gaze-time landmarks and when all of the landmarks were present ($t(6)=0.04$, $p<0.05$). However, the distribution of the high- versus low-gaze-time landmarks was not distributed equitably. The high-gaze-time landmarks were typically found at the end of hallways, while the low-gaze-time landmarks were found within the corridors. These results, suggest that human observers are strategic in choosing which landmarks to encode about an environment.

63.422 **The circumvention of barriers: Extending the steering dynamics model**

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The steering dynamics model (Fajen & Warren, 2003, 2007) successfully simulates steering and obstacle avoidance during visually-guided locomotion. The instantaneous direction of travel (heading) is the resultant of attractive and repulsive forces acting on the agent, and locomotor paths emerge on-line without explicit planning. However, the model currently treats all obstacles as points. Gérin-Lajoie & Warren (2007) found that modeling a barrier as a set of point obstacles fails to capture human circumvention behavior. Here we propose four barrier models and test them against human data.

The candidate models represent barriers as: (1) a set of point obstacles whose repulsion is a weighted distribution along the barrier length; (2) a solid obstacle whose repulsion is based on its visual angle; (3) a point obstacle at the barrier's center plus two competing aim points at either end; (4) an aim point at one end, selected to minimize the total amount of turning on the future path.

Participants walk in an immersive virtual environment to a goal post (initial distance 10 m) and are instructed to take their preferred route around a barrier. To collect basic data on barrier avoidance in two experiments, we manipulate barrier length (2, 3, 4, 5 m), initial distance (4, 6, 8 m), lateral position (0.3, 0.6, 0.9 m), and orientation (95, 115, 135, 155, 175 deg). We fit each model to the human data and compare simulated and observed paths. The results provide a test of the adequacy of the four candidates and their underlying concepts. A successful model of extended barriers would allow us to generalize the steering dynamics model to locomotor behavior in everyday cluttered environments.

References

Fajen BR, Warren WH (2003) JEP:HPP. 29:343-62.
Fajen, BR, Warren, WH (2007) EBR, 180:303-319.
Gérin-Lajoie M, Warren WH (2007) 6th VSS Meeting, Sarasota, Florida.

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63.423 **Environmental Modulations of Visually-Induced Steering Errors Resulting from Non-Rigid Transparent Optical Flow**

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Non-rigid optical flow causes systematic errors in judgments of heading (Royden & Hildreth, 1996; Warren & Saunders, 1995; Dyre, Richman, & Fournier, 2000), localization of the focus of expansion (FOE; Duffy & Wurtz, 1993), and steering control (Dyre & Lew, 2005). Such flow occurs when an observer moves through a fixed environment where an object (e.g., another vehicle) or a field of objects (e.g., snow or dust) moves independently. The direction and magnitude of error varies depending on the angular distance between the FOEs corresponding to the environment and the moving object(s): small angles move the apparent FOEs closer together (attraction errors) and larger angles move the apparent FOEs further apart (repulsion errors). The angle at which errors change from attraction to repulsion we call the cross-over angle. We examined how a variety of environmental manipulations modulate the overall magnitude and cross-over angle of steering control errors. Displays simulated forward translation over a textured plane with an independently-moving field of dots simulating blowing snow; the angle between the FOEs defined by the ground and dots varied. Participants controlled their yaw such that they appeared to move along a straight path over the ground. We found that: a) static direction cues in the form of lane markings of a straight roadway reduced steering error magnitude and shifted the cross-over angle, b) increasing local shearing motion by adding vertical poles fixed to the ground shifted the cross-over angle but had no effect on overall error magnitude, c) changing the optical speed of the moving dots shifted the cross-over angle, and d) changing the exponential lag of the steering control system had no effect on the pattern of errors. These results suggest that both motion contrast and induced motion contribute to illusory heading and inappropriate steering control induced by non-rigid transparent optical flow.

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URL: http://www.webpages.uidaho.edu/~bdyre/vss2008a.htm

63.424 **Humans can control heading independent of visual path information**

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One's instantaneous direction of self-translation (heading) and one's future trajectory (path) are two defining features of human locomotion. Using a dynamic optic-flow display in which environmental points were periodically redrawn to minimize the path information, we have previously shown that humans can perceive heading without visual path information (Li, Sweet, & Stone, JOV 2006). Here we explore the use of visual path information in active heading control. The display (110° H x 94° V) simulated an vehicle traveling on a clockwise or counterclockwise circular path (yaw rate: ±4°/s) through a random-dot 3D cloud (depth range: 6-50 m) at 8 m/s under two conditions: "static scene" in which dots were displayed until they left the field of view thus containing both optic flow and path information, and "dynamic scene" in which dot lifetime was limited to 100 ms thus removing path information. Five observers (3 naïve) used a joystick to steer and align their vehicle line of sight with true heading as their simulated vehicle yaw orientation was perturbed by the sum of 7 harmonically-unrelated (0.1 to 2.19 Hz) sinusoids. The joystick displacement generated a command proportional to the rate of change of the simulated yaw vehicle angle. Time series (90 s) of heading error and joystick displacement were Fourier analyzed and averaged across 6 trials. For all observers, overall error was similar in both conditions (mean absolute heading error ± RMS across observers: 4.2±5.9° and 4.0±6.3°, for static and dynamic scenes, respectively). However, model-based analysis of the frequency response (Li, Sweet, & Stone, IEEE 2006) shows a significant decrease in lead time constant (ratio of velocity to position gain) for static scenes. We conclude that humans can accurately control their heading from optic flow independent of path, but path information reduces low-frequency (<0.3 Hz) drift, when available.

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63.425 **Implied FOE from form influences human heading perception**

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The present study examines the influence of structured form information on human heading perception. Random-dot kinematograms (100 light-increment dots) were used to generate expanding optic flow (70.1°H x 70.1°V) with a focus of expansion (FOE) at -15°, 0° and 15° from the display center. Form signals were introduced into the stimulus by assigning each dot in the display a partner dot to form a dipole of a particular local orientation. Dipoles were configured to produce a radial "Glass" pattern implying a "form" FOE at -20°, -10°, 0°, 10° and 20° from the display center. The stimulus thus affords that for certain configurations form and motion information each indicates a different FOE. Observers were asked to fixate on a cross in the center of the display and clicked a mouse button to start a trial. The stimulus was displayed for 1.5 sec and observers were required to indicate their perceived heading direction along a horizontal line in the display center using a mouse-controlled probe. For 10 observers (8 naïve), for flow patterns with a motion FOE at the display center (0°), the judged heading is shifted towards the implied form FOE from the Glass pattern with a bias equivalent to a weighting of approximately 0.3. For flow patterns with a motion FOE at 15° to the left or right of the display center, a systematic effect was evident only when motion and form FOE were in same direction. No such effect was observed with anti-Glass patterns, possibly due to a weaker association between opposite-polarity dots forming dipoles. Form information plays an important role in human heading perception from optic flow. The findings are consistent with a computational procedure that weights and averages form and motion estimates of heading.

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63.426 Visual control of steering toward a goal uses heading but not path information

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Instantaneous direction of self-translation (heading) and trajectory (path) are two central features for the control of locomotion. We have shown that humans can perceive heading in the absence of path information (Li, Sweet, & Stone, JOV 2006). Here we investigate whether humans use a heading- or path-based control strategy when steering a vehicle toward a goal. We simulated locomotion over a ground plane at 2 m/s with observers' line of sight fixed with respect to the vehicle and randomly offset by ±8° to render screen-centering strategies useless. Observers used a joystick to change the curvature of the vehicle's traveling path to steer toward an environmental target under two display conditions (sparse flow: the ground was composed of random dots; dense-flow: the ground was textured). In the dense-flow condition, we examined both open- and closed-loop performance (open-loop: the target disappeared as observers initiated steering; closed-loop: the target was visible throughout the trial) while in the sparse condition, we only examined the former. For 7 observers (5 naïve), in all conditions, the maximum path curvature was several times larger than that expected if observers used a path-based strategy to point their expected path at the target and then hold curvature constant (mean curvature ratio±SE: 15.1±4.7, 9.1±1.7, & 17.3±8.2, for sparse open-loop, dense open-loop and closed-loop, respectively). Instead, observers over-steered initially and then let path curvature decrease toward zero over time with the final heading error larger for sparse-flow than for either open- or closed-loop dense-flow (mean±SE: 5.0±1.1°, 1.2±0.3°, & 1.7±0.4°, respectively). This behavior is consistent with observers steering their heading (estimated from optic flow) towards the goal. The fact that final heading error is indistinguishable in the open- and closed-loop conditions argues against a Tau-equalization strategy. Humans rely primarily on heading when steering toward a goal and not on estimated future path or time-to-contact information.

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63.427 Visual guidance of locomotion in infants, young adults, and the elderly

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Possibilities for action depend on the fit between physical properties of the body and physical features of the environment. However, across the lifespan, both body and environmental properties are in constant flux. To guide actions adaptively, motor decisions must take these changes into account. In four experiments, we investigated how infants, young adults, and elderly adults navigated through doorways of varying width.

In Experiment 1, elderly adults (65+ years) decided whether they could walk through doorway apertures varying from 0 to 74 cm in .2 cm increments. Participants slightly overestimated their abilities, occasionally erring by attempting to squeeze through doorways a few centimeters smaller than their dynamic body width. Elderly adults' navigation strategies were idiosyncratic, and dependent on their own body and balance characteristics. In Experiment 2, we observed college-aged adults walking through doorways to compare their motor decisions with those of the elderly adults. Like the elderly, young adults occasionally attempted doorways that were slightly too small, indicating no decrement in perceptual control of action due to aging.

Experiment 3 assessed motor decisions at the other end of the lifespan. In contrast to adults, 16-month-old walking infants grossly overestimated their abilities by attempting to squeeze through impossibly small doorways. However, we wondered whether infants' errors might reflect their willingness to risk entrapment, rather than failure to perceive changing possibilities for action. In Experiment 4, we tested this possibility by removing the side wall from the doorway, creating an opening bounded by a wall on one side and a risky drop-off on the other. When the penalty for errors was falling off the walkway, infants responded cautiously by refusing to walk through impossibly small openings. Like the elderly adults, infants exhibited creative and idiosyncratic strategies for navigating through openings, reflecting sensitivity to the different environmental constraints.

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Visual Working Memory 2

63.428 Memory, Eye Position and Computed Saliency

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Saliency based image computations have been useful in understanding the mechanisms of guiding overt and covert attentional shifts and predicting eye position in natural and artificial scenes. With this foundation we investigated the relationship between memory, eye position and saliency. Particular we tested the hypothesis that in natural scenes an object's computed saliency will positively correlate with subjects' memory of the object independent of eye location. To this end we recorded eye movements from fourteen naive subjects while they were shown 18 images (subtending 55^ox33^o of visual angle) from scenes of shopping environments for two second followed by a random mask. Subjects were then asked to recall whether subsequently presented image patches contained items that were present in the scene. We found that the amount of computed saliency of object patches in natural scenes has no significant correlation with subjects' recall rates; however, eye position and fixation time on an object are strong factors in facilitating recall($p <.05$). We also find that saliency can predict eye location three standard deviations above chance. These results indicate that saliency's contribution to memory is mostly through overt(eye movements) and not covert attention.

63.429 The Effects of Interference on Visual Memory of 2D Shape

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Change detection requires comparing the representation of a previously presented stimulus to the representation of a new stimulus. During the interval over which information about the previously presented stimulus is stored, processing of additional information may corrupt the stored representation. The effects of this interference on change detection performance has been shown to depend on allocating attention to the additional information, but is largely independent of the type (visual vs. auditory) of information to which attention is allocated (Makovski, Shim, & Jiang, 2006). In the current experiments, subjects detect changes between the shapes of two smooth, closed, 2D contours presented sequentially, while sometimes also performing a shape-part-counting task between presentations of the change detection displays. On one-third of the trials, the part-counting task was done on a shape similar in structure to the shapes in the change-detection task. On another one-third of the trials, the part-counting task was done on a shape with very different structure - a shape composed of a set of straight lines all meeting at a single point. On the remaining trials, the part-counting task was omitted. Interference due to the part-counting task was measured as the decrease in change detection performance on trials with the part-counting task relative to trials without the part-counting task. Interference effects were dependent on the similarity of the shapes used in the two tasks; similar shapes interfere more than dissimilar shapes. The difference in interference may be reduced or eliminated if the subjects know ahead of time whether there will be an additional, interfering task, and if there is, what type of stimuli will be presented.

63.430 Action and Semantic Attributes in Object Identification

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Previous research has shown that action and semantic attributes are processed in physiologically distinct streams (Milner, A.D. & Goodale, M.A., 2006). For example, visually guided movements, such as the action of a hammer hammering a nail, are processed predominantly in the dorsal stream, while colour is processed in the ventral stream. Furthermore, these two streams, ventral and dorsal, have been associated with the upper and lower visual fields respectively (Milner, A.D. & Goodale, M.A., 2006).

The present investigation sought to evaluate the impact of attribute type and visual field on identification of novel objects. It is expected that matching the processing stream with its complementary visual field and attribute type (dorsal stream? lower visual field? action; ventral stream? upper visual field? semantic) will produce decidedly faster reaction times in identifying these novel objects as compared to mismatched presentations. Twenty-one university students learned names and attributes associated with six novel objects. Three objects were paired with action attributes (pull, twist, slide) and three were paired with semantic attributes (nice, weak, rare). A computer recall task was performed once participants were able to recall all six objects error free during randomized presentation. Data was collected from this computer recall task where the six novel objects were presented in pseudo-randomized order in the upper or lower visual fields. Recall errors and the time required to identify the object were recorded. This study investigated interactions between visual field, processing stream, and their associated attributes. Previous research has examined each of these variables separately, and interactions may prove useful in further understanding neurological disorders such as apraxia.

63.431 **Two Memory Components Explain Sequential Dependencies in a Search Task**

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PURPOSE. To identify the characteristics of memory processes responsible for sequential dependencies in the Priming of Pop Out (PoP) paradigm.

METHODS. Stimuli were 3 bright and dark grayscale diamonds with a notch on the left or right side, displayed on a uniform gray background. Observers identified the odd target (dark/bright among bright/dark distracters) and responded by indicating the side of the notch. Color and notch were chosen randomly and independently on each trial. Reaction times were collected from individual observers running in blocks of 500 trials, totaling more than 10000 trials per observer.

RESULTS. Reaction times from each block of trials were de-trended with a 2nd order polynomial and z-scored. Lag 1-40 cross-correlations between the color/response series and the reaction time series were calculated to obtain 1st order Wiener kernels identifying the memory for color/response. The kernels were then averaged across blocks. For both color and response, kernels were well described by the sum of 2 exponentials comprising a fast and a slow component. The fast component is limited to 1 trial back and can be facilitatory or inhibitory. The slow component relaxes completely in about 20 trials and is always facilitatory. Calculation of second-order cross-kernels between color and response revealed a remarkable linearity, indicating independence of memory for color and response.

CONCLUSION: Memory in PoP is comprised of 2 components: a fast, explicit, one-trial-back component that can be facilitatory or inhibitory and varies considerably in gain across observers; a second, implicit, slow component that is always facilitatory and less variable across observers. Memories for color and response are independent and as such do not support the hypothesis of episodic representation in PoP. There are strong similarities in form with the kernels obtained with reward tasks in monkey, suggesting the possibility of common mechanisms for attention and reward processing.

63.432 **Multiplying the capacity of visual working memory**

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Recently there has been considerable interest and debate surrounding the capacity of visual working memory. Estimates of working memory have declined steadily from the “magic number” seven, to four, and even recently to very nearly one item. Though the number of items able to be stored in visual working memory is arguably few, there has been no controversy regarding the belief that visual working memory consists of a single store.

The present study, however, was inspired by a growing number of findings indicating that the brain can maintain multiple states simultaneously and switch between these states. For example, Dobbins and colleagues (2004) revealed that repetition priming is contingent upon how the observer intends to respond: whereas repetition priming for an object exists under one set of instructions, it is eliminated when adopting a second set of instructions, but returns when the observer switches back to the original set of instructions.

Does the same hold true for the capacity of visual working memory? To answer this question, we required observers to remember two working memory arrays: one array contained shapes and the other contained colors. The observers’ task was to detect a change in the probed display. Importantly, they did not know which array would be probed until the test array appeared. The data show that performance on the probed array was not affected by the number of items in the non-probed array, i.e., the capacity of working memory was able to be multiplied when observers presumably maintained a separate ‘page’ for each display. This outcome requires a reconsideration of the capacity of visual working memory as not a fixed value of a single store; rather, visual working memory can be expanded by the maintenance of multiple stores.

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63.433 **Working memory capacity is modality-specific: Evidence of separate stores for auditory and visuospatial stimuli**

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While working memory (WM) is regarded as a capacity-limited process, theories differ on whether that capacity is set by modality-specific stores (Baddeley, 1986) or a single, unimodal store (Cowan, 1995). In support of the unimodal theory, several studies have observed dual-task interference between visual and verbal WM tasks (Morey & Cowan, 2004; Saults & Cowan, 2007). However, these studies used a visuospatial WM display that may be encoded as a set of propositional relations (e.g., blue on the left) and thus may rely on a verbal code. Here we re-examined dual-task costs in WM with a different spatial WM task that minimizes this potential confound. Participants were required to memorize the spatial positions of 1-5 dots. By always presenting stimuli along a line, the shape formed by the configuration of the dots was uninformative. Spatial memory was assessed by having participants judge whether a single-probe stimulus was presented in a location that matched one of the memory stimuli. In Experiment 1, participants performed the spatial WM task during the retention interval of a verbal WM task that required maintenance of 2-10 consonants. In contrast to previous studies, we found that the capacities for each of the two tasks were comparable in the single- and dual-task conditions. Additional experiments revealed no dual-task costs when an articulatory suppression task was added (Experiment 2), or with other auditory WM tasks (distinct, non-vocal sounds in Experiment 3 and bird songs in Experiment 4). To remove any possible contributions from sensory memory in these WM tasks, Experiment 5 extended the retention interval from 2s to 9s and Experiment 6 masked the sensory representations. Neither study demonstrated dual-task costs. Together, these results strongly suggest that the WM stores for auditory and visuospatial stimuli are independent, and support the existence of modality-specific WM systems.

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63.434 **Effects of training on the organization of spatial and feature visual responses in the lateral prefrontal cortex**

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The prefrontal cortex is known to be important in the short term maintenance of information. While some studies have found a domain-specific organization, with dorsolateral prefrontal neurons representing spatial information and ventrolateral prefrontal neurons representing feature information, other studies using different behavioral tasks arrived at contradictory conclusions. For this reason, we sought to determine how training affects prefrontal neuronal responses. We performed neurophysiological recordings from monkeys before and after training on a working memory task that required the integration of spatial and feature information. We evaluated spatial selectivity of neuronal responses to visual stimuli appearing on a 10-degree, 3x3 grid, and feature selectivity to eight geometric shapes. Prior to training, we recorded from 441 neurons in the dorsal prefrontal cortex (areas 8 and 46) and 542 neurons in the ventral prefrontal cortex (areas 12 and 45) of three monkeys, only required to fixate. Overall, more neurons responded to the visual stimuli in the dorsolateral PFC (42%) than in ventrolateral PFC (9%). In dorsolateral prefrontal cortex more neurons were selective for stimulus locations than features; ventrolateral neurons were more selective for features. Neurons that were selective for both locations and features were found in both regions. After training, we recorded from 127 dorsolateral neurons and 149 ventrolateral neurons. We again found more neurons to be responsive to visual stimuli in dorsolateral (55%) then ventrolateral (13%) PFC. Dorsolateral PFC was still dominated by spatially selective neurons and had significantly fewer feature selective neurons, while ventrolateral contained more feature selective neurons. The percentage of neurons selective for both locations and features was actually lower after training. Our results suggest that contrary to earlier studies, prefrontal neurons represent the locations and features of visual stimuli regardless of training. Training on a working memory task actually enhanced domain-specific organization resulting in higher regional selectivity.

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63.435 **The complexity of a category affects working memory capacity in a search task**

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How are perceptual and cognitive resources allocated when we are faced with realistic tasks involving complicated objects? Dual-task experiments have attempted to address such questions by asking subjects to perform a demanding task while holding one or more objects in memory. However, since the memorized objects are unrelated to the primary task, such approaches do not reveal the underlying resource requirements of the primary task. In the current study, a more natural search task was devised in which perceptual and cognitive complexity was varied and search performance was used to assess memory load.

Subjects had to find 3 objects in a field of 9 hidden objects that belonged to a common category. Category definitions were based on features (e.g. color, shape and texture). The 5 levels of category complexity ranged from the simple (e.g. objects must share one feature) to the complex (e.g. objects must share two features and differ on one feature). During search, objects were revealed for 1 second intervals by a mouse click. Revisits were permitted. Stimuli shown on each trial were chosen randomly with the provision that the performance of an ideal searcher (no memory loss) would be the same across category complexity.

The number of revisits to previously viewed objects increased linearly with category complexity. Category complexity, not the number of features defining the category, determined performance. These results show that category complexity interacts with memory capacity: the greater the complexity of the category definition, the less memory is available to store the contents of the visual array. These results argue against strictly modular approaches to resource allocation during natural task performance, and in favor of a unitary pool that must be managed by shifts in overt or covert attention.

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63.436 **Relating visual working memory capacity and visual attention in schizophrenia-spectrum individuals**

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Numerous studies have found deficits in visual attention and working memory capacity in schizophrenia patients (SZ) in comparison to healthy controls (HC; e.g., Nuechterlein & Dawson, 1984; Park & Holzman, 1992). For example, Gold et al. (2003) found that SZ have reduced VWM capacity, particularly when presented with larger set size arrays. Moreover, in healthy controls, we have recently shown that an individual's memory capacity strongly predicts his or her selective attention ability (Vogel et al, 2005). Here, we used a battery of visual memory and attention tasks to characterize the distribution of individual differences in performance in schizophrenia-spectrum individuals. One goal of the study was to examine whether the predictive relationship between working memory capacity and attention tasks is preserved within the SZ population. Specifically, we recorded behavioral and electrophysiological data while subjects performed a change detection task, as well as several attention tasks (e.g., attentional filtering; multiple object tracking; and task switching). Our preliminary results indicate that we have replicated Gold et al.'s findings that SZ subjects have lower memory capacity than HC. Additionally, our data thus far suggests that the direct relationship observed between attention and working memory capacity in HC does not persist in SZ subjects. That is, low capacity HC tend to have deficits in attentional filtering, whereas SZ tended to have normal filtering ability despite low memory capacity. Together, these results suggest that examining the relationship between various cognitive processes can provide some predictive ability for functional outcome in SZ. Thus, neurocognitive markers identified with adequate sensitivity and specificity may allow for predictive validity for the later development of schizophrenia.

63.437 **Role of Encoding Duration on Visual-Short Term Memory Capacity**

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Visual short-term memory (VSTM), which has a capacity of approximately four objects, is a key bottleneck in our visual perceptual abilities. However, it remains unclear which processes govern the limited capacity of VSTM. Memory is traditionally described in terms of the processes of encoding, maintenance/storage, and retrieval. It has been proposed that capacity limits are not the result of encoding limitations, but rather reflect a fixed number of "stores" (Vogel, Woodman, & Luck 2001). In the present study we have investigated the influence of encoding on VSTM performance. Subjects were asked to perform a visual short-term memory task in which colored squares were presented for either 100 or 500 ms. Performance improved across a range of set sizes with longer stimulus presentations. Furthermore, K scores reached a plateau at 5 rather than 4 objects when stimulus durations were increased to 500 ms. In order to limit possible effects of verbalizing, we investigated the role of encoding duration in a second paradigm in which subjects were asked to detect a 20 degree change in orientation of a luminance-defined gabor which was presented for either 200 or 1000 ms. In this paradigm, performance again improved for longer encoding durations. These results confirm the view that maintenance provides a major limit to VSTM capacity, but also demonstrate that encoding can have a strong impact on VSTM capacity. These results serve as an important caveat for researchers studying VSTM mechanisms.

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63.438 **Object Similarity in Visual Working Memory: A Face-Specific Memory Effect**

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While the effect of stimulus similarity has been well-studied for auditory working memory, the impact of object similarity on visual working memory is not well known. Across eight experiments, we compared accuracy in a change detection task with displays of four objects. The display could consist of four objects from a single category (one-category condition) or two objects from two separate categories (two-category condition). The initial experiment used complex faces and houses, and results showed better change detection accuracy for two faces and two houses together versus either four faces or four houses alone. Experiments 2-6 tested additional categories (butterflies, bodies, and watches) to examine how generalizable this effect is. Results demonstrated that accuracy was better in the two-category condition only when faces were part of the set. Otherwise, when faces were not part of the set, accuracy in the two-category condition was never greater than in the one-category condition. Experiments 7-8 used inverted faces to examine the face-specific memory effect, and an advantage for inverted faces was not found. Together, these results suggest that upright faces are unique to visual memory (Curby & Gauthier, 2007). However, faces remain subject to hard limits of memory capacity, as remembering four faces was never better than remembering four other objects. For all other object categories that were tested, similarity does not affect visual memory processes.

63.439 **Facing fear: The effect of emotional expressions on visual short-term memory for faces**

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Visual short-term memory (VSTM) is capacity-limited, with most people able to keep no more than 3 - 4 simple items in VSTM at any given time (Luck & Vogel, 1997). Notably, as the complexity of stored items increases, capacity seems to decrease suggesting that this range may represent the upper limit of VSTM capacity (Alvarez & Cavanagh, 2005). Is there anything that can offset the trade-off between stimulus complexity and VSTM capacity? Recent studies using face stimuli – which are visually complex – suggest that our extensive experience with faces translates into a VSTM advantage for upright but not inverted faces (Curby & Gauthier, 2007). Here, we connect this line of research to a large body of research showing that emotion can benefit memory. Although such memory-emotion studies have typically pertained to long-term memory, we investigate whether faces signaling emotion have a VSTM advantage over those that are more neutral, and if so whether this effect depends on encoding time (as might be suggested based on work by Maljkovic & Martini, 2005). We measured VSTM capacity for faces with either neutral or fearful expressions under long (4000 ms) or short (1000 ms) encoding durations. To control for basic perceptual differences between the fearful and neutral faces while decreasing the salience of emotional expression, we also tested the same faces in an inverted orientation. Results revealed that VSTM for emotional faces was larger than that for neutral faces, but that this VSTM advantage was limited to upright faces and was equivalent across long and short encoding conditions. In order to clarify the nature of this main finding, we report additional studies probing the impact of more limited encoding durations on this VSTM advantage.

63.440 **Microsaccade directions are not correlated with cued locations in a spatial working memory task**

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Although we know the eye moves imperceptibly during fixation, there is still debate concerning a functional role for microsaccades. We investigated this oculomotor activity in a spatial working memory task that had produced results used to argue for covert attention shifts as a rehearsal mechanism for locations of stimuli. Participants were briefly cued to one of many locations surrounding a central fixation cross, and were instructed to remember it pending onset of a probe stimulus seconds later. 2AFC responses were made indicating whether the probe was in the same location as the cue, or shifted inward toward fixation. Discrimination of large displacements was at ceiling, whereas small displacements were at floor. With the goal of affecting attention during the retention interval, another 2AFC task was imposed while participants waited for probes: Shape discrimination in one condition took place on 2/3 of trials, and color discrimination in another condition on every trial within selected blocks. These "choice" stimuli interacted with memory responses in a way not reported previously. We replicated some findings from the recent literature, such as inhibition of microsaccades after stimulus onsets, and a following "rebound" phase in which they occur at greater than baseline rates. However, we did not replicate behavioral results that would indicate the presence of covert attention shifts in the task, nor did we find directional bias of microsaccades toward cued locations during rebound phases. Moreover, the distribution of our microsaccade trajectories is anisotropic, with most of them oriented in the horizontal plane. Individual differences and strategy effects are brought to light in explaining results and suggesting future directions for inquiry. If microsaccades can signal the presence of some covert attention shifts, as it has been suggested recently, they cannot do so for all of them, or for shifts in all directions.

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